Chapter 23

Sustainable forest management as license to think and to try something different

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"The intensity of a conviction that a hypothesis is true has no bearing over whether it is true or not."

Peter Medawar (1979)

Introduction

The overriding message of this book is that sustainable forest management (SFM) is a broad, multi-component process best expressed as an ongoing framework for development rather than a state to be achieved and forever proclaimed. The necessarily flexible aspects of this approach to forest management are evident in the multiple meanings of "sustainability". Most can generally agree that forest sustainability now embraces more than sustained timber yield, and has come to include the stewardship of non-timber values, equity of benefits derived from forests, equality in decision making and forest planning, and the protection of all forest values for future generations. In the philosophy of SFM, these recently emerged principles are to be balanced with the long established principles of industrial efficiency and positive economic return for investors associated with the harvest of timber and the manufacture of wood, pulp, and paper products. However, even taken together, these principles do not specify recipes for action by managers. It is clear that appropriate ways of implementing SFM depend on the context and the options available. As our understanding of context improves and research identifies new

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options, the balance of principles considered appropriate in a given situation will change, and new, improved prescriptions will result. Nobody involved in the SFM enterprise can be spared the tasks of thinking, adapting, and contributing to the search for the desired balance.

In the most general sense, SFM has been thought of as identifying the optimal balance of trade-offs between social values and economic needs considered in the context of the ecological limitations of forest ecosystems. However, as pointed out in Chap. 2, reconciling competing values and implementing "wise use" of forest resources reveal the fallacy of a strict conceptual compartmentalization of SFM into social, economic, and ecological factors. Such a division with the intention of examining each facet in the context of "separate but equal" consideration ignores the links among these and other issues. The challenges we face in developing an enduring framework for SFM include recognition of the full range of individual, cultural, and regional values, reconciliation of these values into meaningful and pragmatic land-use decisions, and realization that these values will change over time.

Throughout this book the contributing authors have expanded the concept of sustained yield, which has long guided reasoned use of the timber resource, into wider ecological and socio-economic contexts. The resulting broader perspective on wood supply grows from "what can we take" to also encompass "what should we leave" (or, perhaps, "what should we take, how should we take it, and how should we use it to maintain all elements of the regional forest socio-ecological system"). Two themes are consistently present in each chapter. The first theme addresses how to identify the most important non-timber values from socio-economic and ecological standpoints. The second theme deals with how best to balance the demand for wood supply with non-timber values and how to reconcile conflicts as our values change through time. Unfortunately, a single straightforward answer to how we should manage boreal forests over the long term cannot be provided by such an endeavor. However, what is developed in the forgoing chapters is a more focused and mature view of the options available. Collectively, the authors show that what should be done ultimately depends on what we value and how these values are prioritized by those responsible for decisions about land and forest use. In this chapter we attempt to weave together a larger view of SFM from various threads of these two themes, and we discuss the implications as they pertain to conservation of biodiversity, one of the central integrating components of modern SFM.

Integrating values

Viewing social, economic, and ecological values as three separate entities in an attempt to define SFM sidesteps the need to come to terms with tradeoffs rather than just proceeding with those ventures where there is agreement. Nonetheless, a classification of social, ecological, and technical concerns does help us compile a list of competing opportunities and constraints that must be resolved. Commonalities within the three underlying perspectives provide a starting point for the integration of competing values.

The first section of this book sketches out the modern socio-economic aspects of sustainability by considering cultural values of First Nations communities (Chap. 3) and rural communities (Chap. 5), the role of public participation (Chap. 4), forest economics (Chap. 6), and the role of government and other institutions (Chap. 7). Rooted within each of these perspectives are the perceived and real conflicts among individuals, cultures, industry, and institutions. Although the fundamental cause of conflicts may differ with each case, each chapter stresses the importance of distributing significant roles in the decision making process as a means of reconciling the specific conflicts experienced by each stakeholder. The resolution of complex conflicts depends on an effective hearing for all sides in the absence of centrally preconceived solutions.

For example, Aboriginal rights have been given short shrift historically, in part, through violations of existing treaties with First Nations groups and by the differential acknowledgement of rights by provincial and federal governments (Chap. 3). As a result, Aboriginal cultural values and traditional ecological knowledge (TEK) have been too frequently misinterpreted, if considered at all. One possible way to blend these values into SFM is to increase aboriginal self-determination in the form of co-management agreements between groups like the Little Red River Cree and the Tall Cree First Nations and the forest products industry as demands for timber increase. Such agreements may allow Aboriginals more opportunity to advocate their cultural values, become involved in the planning and management of industrial operations, and receive financial benefits.

However, the benefits of incorporating TEK into SFM will be limited if such knowledge is not evaluated critically or adequately placed in the context of long-term sustainable management. There is much that can and should be gained from Aboriginal knowledge, but this must be considered in concert with other ecological and economic considerations. First Nations show strong interest in managing their forest resource according to their own self-determined programs, selling fibre to mills directly, or entering into joint ventures for mill ownership and management. The objectives are better control over the management of traditional territories, and better capture of the benefits that flow from industrial development. Nonetheless, reaching these goals depends on the ability of First Nations to mesh with broader social and modern economic realities. Furthermore, where there are conflicts between TEK and technical understanding of the environment, these surely must be understood and reconciled over the long run.

In a similar way, increased community capacity or adaptability of rural communities requires investments by government, industry, and the communities themselves in projects that promote community leadership, education, and social services, all of which increase autonomy. Ultimately, "the public" includes all groups of people that are defined by shared interests and political connections, many of which may actually transcend geographic or cultural boundaries. The increasing demands to participate directly in decision making about use of the forest resource by various groups affected by these decisions has required regulatory institutions and government to devolve responsibilities and to include these other perspectives in planning. Likewise, the creation of public advisory groups by government agencies, industry groups, and forest products companies is a concession to the public's perception that they have been left out of the decision-making process. The road to SFM as envisioned in this book will involve *more* parties being involved in *more* decisions about forest management.

From an economic standpoint, efficient markets demand more autonomy at the regional and provincial scale through increased flexibility to pursue alternative forest tenure systems to offset risks associated with investing in forests over the long term. However, markets do not acknowledge most non-timber values except through third-party processes such as certification of wood harvested from sustainably managed forests (Lippke and Bishop 1999). Criteria and indicators of sustainability may be proposed by a wide range of proponents, but their effectiveness and importance will ultimately be judged and enforced by consumer demand.

The responsibility of balancing autonomy and influence among stakeholders has fallen mainly on the shoulders of government institutions. Shifting the focus and impact of activities on the ground relies either on direct "command-and-control" (i.e., regulatory) approaches or indirect market-based strategies that promote non-timber values. Redesigning tenure agreements and reforming markets to provide incentives to protect non-timber values are an important new role for government. The recent creation of institutions (e.g., public advisory boards for certification, co-management boards) through which stakeholders can participate in the policy articulation process and in guiding local forest management further underscores the importance of stakeholder input into both forest policy decisions and forest planning. Clearly, much needed progress in this area will require creative thinking and thorough exploration of alternative scenarios.

When the need for independent input among individual stakeholders is evaluated in light of market forces and government regulation, two fundamental aspects of socio-economic trade-offs become apparent. First, increased autonomy allows stakeholders to be heard during decision making and planning, and reflects stakeholder desire to influence actions that affect their interests and values. In other words, stakeholders want a voice that carries weight in the decision process. This underscores a second fundamental aspect of socio-economic trade-offs: simply put, increased influence requires increased responsibility and accountability. As individual stakeholders become more involved in forest planning and management, these same stakeholders become responsible for full understanding of the issues and impacts that surround SFM and attempts (some inevitably unsuccessful) at implementing it. This requires that all parties be well educated in the broad framework for socio-economic trade-offs described in this book and that they understand the unique local trade-offs that often are the main motivation for involvement of particular stakeholders in the process. As with most exercises in democracy, effective decision making in SFM will likely benefit from a series of checks and balances. An elected official or panel should be accountable for the final decisions, but an independent auditing body that disseminates information to promote educated and informed perspectives should oversee results. Properly executed, SFM should inspire wide community participation in a focused and well-informed decision-making process that becomes an ongoing aspect of how society manages decisions about use of a public forest resource.

Effective input into the process also extends stakeholder responsibilities further to include accurate understanding of the ecological and social factors that may ultimately limit any agreement between stakeholders. Ecological interactions, as discussed below, are often dynamic and complex and can affect forest processes over a variety of spatial and temporal scales. As such, the large-scale and long-term ecological effects of socio-economic decisions can remain poorly understood, even hidden from us (e.g., consider knowledge of the global impacts of broad-spectrum insecticides) until disaster strikes or new understanding comes to light (Van den Bosch 1978). In some instances ecological issues may be complex or wide-sweeping enough that individual stakeholders will be unable to bear these responsibilities and will have to cede independence to larger institutions. This is essentially the role of government in SFM.

Whether we like it or not, ecological constraints set firm limits to the scope of forest-based activities that can be sustained. Integration of socio-economic and ecological factors is an additional responsibility faced by all stakeholders. Not only are all stakeholders required to have an accurate understanding of present knowledge but they will need the ability to incorporate new and relevant information into their evolving views, as effective SFM must be a dynamic, knowledge-based and principle-based process. In essence, independent input of individual stakeholders provides a license or mandate for them to "think" beyond their own narrow interests. The complex compromises and trade-offs required for SFM cannot be encoded adequately in a set of operating rules or management prescriptions that cater to narrow interests or are insensitive to regularly encountered contingencies.

Dynamics of knowledge and values

The boreal forests of the world do not require management in the absence of human activity, so forest management is really the management of people and their activities in the forest. Therefore, when resolution of socio-economic trade-offs is expanded to include specific aspects of non-timber values, it is more readily apparent that solutions must ultimately work within the ecological limits of the forest ecosystems. However, our knowledge of ecological processes will always be a work in progress, particularly as the world's climate changes (see Chap. 20) and our views of disturbance ecology (see Chaps. 8 and 9) evolve. When applying the SFM "license to think", we must be aware of the dynamic nature of the problems we face. Appreciation for the dynamic nature of knowledge is a key aspect of the new SFM approaches to how we "do" forest management. At present, two evolving sets of ideas are critical for managing public forest units. First, understanding disturbance regimes and designing forest management strategies that "emulate" critical aspects of natural disturbance has been the focus of the emulation of natural disturbance paradigm (Hunter 1993). Second, incorporating new knowledge into existing forest management practices or "learning by doing" can be facilitated enormously by embracing adaptive management (Walters and Holling 1990; see Chap. 21). The thornier issues of managing whole forested landscapes and our societal relationship to forests in general require even broader thinking. The largest pressure facing the continued viability and health of Canadian forests in the long run is not the activities that take place within the present forest, but rather the human activities of ruralization and urbanization that are bound to absorb, reduce, and bound the forest. Land base conversions inevitably associated with human population growth will demand consideration under the evolving scope of SFM.

As stressed in Chaps. 8 and 9, identifying and understanding long-term implications of both large- and small-scale natural disturbance dynamics may affect management decisions at the stand, regional, and landscape level. For example, the interaction between the large-scale mortality caused by wildfire, life-history traits of individual tree species, and age-structure of existing stands drives the establishment and succession of future forests. Specific consideration of seed dispersal and species adaptations to fire can inform us about which management actions may be effective following harvest in reestablishing species that would normally recolonize following fire. As a result, planning considerations such as the size and shape of cutblocks, though they can be manipulated to emulate some spatial patterns of wildfire, are likely less important than is site preparation in reestablishing fire-adapted tree species. Likewise, limitations in seed dispersal of non-serotinous species may be alleviated by broadcast seeding or direct replanting within harvested blocks.

Other large-scale disturbance factors such as insect outbreaks regulate the age structure and composition of forest stands through high mortality targeted at particular species in specific age classes (Mattson and Addy 1975; Elkinton and Liebhold 1990; Mallett and Volney 1990; McClure 1991; Bergeron and Harvey 1997). For example, interactions between outbreaks of spruce budworm (*Choristoneura fumiferana*) and the establishment of balsam fir (*Abies balsamea*) seedlings in eastern Canada illustrate the importance of persistent seedling banks. Failure to generate an adequate seedling cohort before harvesting the overstory, or excessive damage to the seedlings during harvest, results in poor regeneration of balsam fir and a shift away from this particular forest type. Extended outbreaks of spruce budworm may reduce seed production and can also prevent the establishment of a persistent seedling bank, as might excessively truncated rotations. Inadequate seedling bank survivorship may also result in a failure to reestablish balsam fir.

As pointed out in Chap. 9, a comprehensive natural disturbance based approach to forest management cannot focus only on wildfire dynamics, ignoring the role that smaller disturbances play in structuring boreal forests. In fact, small-scale disturbances caused by insects, pathogens, windthrow, or ice-storms may have more significant impact than wildfire in some regions, and may contribute significantly to structural aspects of post-rotation age stands that sustain elements of the biota (Kohm and Franklin 1997; Lee et al. 1997). As with large-scale disturbances, specific forest management strategies may be able to emulate particular aspects of small-scale disturbances, such as the creation of small openings in the canopy associated with mortality caused by insects and pathogens, but these strategies may only be effective at reproducing limited aspects of a natural disturbance under specific forest conditions. Once again, context matters and SFM offers no shortcuts around the classic familiarity that each forest manager must develop with his/her land base. Only by observing the legacy of past disturbances, and how trees and other organisms have responded to them in a particular landscape, can managers grasp the relative importance of different events and contingencies, and how they might be appropriately employed, emulated, or learned from in managing for particular forest values.

In acknowledging the role of disturbance processes, we must also acknowledge that disturbance regimes themselves are subject to change. We must manage on a stage where tomorrow need not be like yesterday. For example, return rates of catastrophic fires in the boreal have decreased in the last 300 years since the Little Ice Age. Which "natural fire regime" should be chosen as a basis for harvest planning? The natural range of variability (NRV), although still invoked by many as a guidepost, generally provides only gratuitous advice because it permits extreme approaches well outside of the range that is socially or economically acceptable (see below). Neither is the future stable; increased global warming is predicted to increase fire frequency in western Canada, but may decrease fire frequency in eastern Canada. As our objectives change from assessment and characterization of current disturbance regimes to prediction of future changes in these processes, the dynamic and multi-scaled nature of these processes require our thinking to become multi-dimensional as well.

Designing forest management strategies that emulate natural disturbance processes is the fundamental goal of the natural disturbance model (NDM) of ecosystem management (Hunter 1990). This paradigm for resource management attempts to maintain forest conditions in accord with the NRV that characterized unmanaged areas before human influences were widespread. Working within the NRV is assumed to minimize adverse effects of forest management on species that have been selected for their adaptations to boreal conditions, including the characteristic boreal climate, habitat types, and disturbance regimes (Chap. 1). Indirectly, the NDM defines the "ecological stakeholders" in boreal forest management (Box 23.1). Management under this model, or any other approach to SFM, seeks to avoid any species extirpations that might be caused by our management activities. This sort of thinking has helped us move away from the timber-oriented approach to sustained-yield forestry, but it is critical that it be seen as no more than a step in the right direction.

The underlying assumption of the most restrictive and immature forms of NDM (i.e., that departures from natural disturbance regimes are inherently undesirable, and its corollary that natural disturbances or their anthropogenic analogues are desirable events) makes it impossible to fully implement the NDM in practice (Spence et al 1999*a*). Simply put, it has become clear through recent work that this approach is neither economically feasible nor socially acceptable. Furthermore, because of the complexity of integrating the ecological requirements of the biota with our imperfect

Box 23.1. Treating species as "ecological stakeholders".

- An appealing aspect of the natural disturbance model is that it invokes natural selection to define "ecological stakeholders". In emulating the patterns and processes of natural disturbance, forest managers seek to minimize impacts of timber harvesting on the natural selection regime of species that have evolved in concert with the disturbance regimes of the boreal forest. As a consequence, all extant species are seen to have something at stake.
- In the long term, some extant species will naturally become extinct, and new species and new ecological relationships will develop. This is a dynamic process, the results of which cannot be anticipated, much as changing social values continually (but unpredictably) redefine intergenerational equity.
- In the short term, determining which species are ecologically relevant to sustainable forest management includes identifying those species that are negatively impacted by management practices but also identifying the ecological interactions in which they participate, and identifying the conditions that must be maintained to keep those relationships intact.

understanding of the short- and long-term dynamics of critical ecosystem processes, such an extreme view of NDM seems to be, at best, a somewhat naive working hypothesis. The viability of this hypothesis as even a background working model for SFM depends on determining how well the impacts of management practices coincide with the effects of natural disturbances. Many of these aspects can be tested scientifically at the stand level (Spence et al. 1999*b*; Volney et al. 1999*a*, *b*). We must not hesitate to do so and to move forward using what we discover. Should we be slave to natural disturbance patterns that are but temporary manifestations of nature, or should we strive to manage the forest in line with our values while ensuring that all processes and elements that define the ecosystem are retained? Recent research and advances in SFM do not answer this question but they do encourage us to ask it, and should allow our answers to influence management decisions and policies.

Our experimental comparisons cannot be fully valid for NDM evaluation until they are extended to cover landscape scales with unmanaged control areas that are adequately replicated and large enough to define the impacts of large-scale natural disturbances over appropriate time scales. Only a few large undisturbed forested areas remain where such experiments are feasible. But with road networks widely developed and plans for timber harvesting in much of Canada already specified, opportunities to test this model at the landscape level may have been pre-empted before NDM can be fully evaluated scientifically. As fully explored in Chaps. 8 and 9, just because we claim to replace natural disturbance with forest harvesting and silviculture (now planned and conducted on some larger scale to mimic natural shapes and patterns), does not mean that forest management activities are acceptable ecological analogues to replace natural disturbance processes. While some integrated landscape-level experiments testing the NDM have been initiated (e.g., the EMEND project in northwestern Alberta, Box 23.2), it is imperative that more of these operational trials be implemented throughout the boreal forest, along with commitments for their long-term funding, maintenance, monitoring, and analysis.

A questionable assumption of the NDM is that all species are valuable and all can be supported under a natural disturbance management regime, since they have not already gone extinct under historical disturbance conditions. Because it is impossible to know and manage the ecological conditions that permit the maintenance of all species, and further, because the ecological value of new relationships that may evolve cannot be specified in advance, coarse-filter conservation strategies have been proposed (Schwartz 1999). These strategies strive to maintain the necessary conditions (especially habitat types) for persistence of all species and for the evolution of forest ecosystems to be unrestricted by forest management.

Across Canada, the forest products industry presently relies largely on coarse-filter strategies such as variable green-tree retention and landscape-level planning to maintain biodiversity and any critical ecological interactions that could be negatively affected by forest harvesting (Work et al. 2003). In a survey of the forest products industry in western Canada, 14 companies were asked to specify the practical and tangible changes they have made to incorporate biodiversity as an objective along with the traditional goals of fibre production (Box 23.3). While all companies specified the importance of retaining

Box 23.2. The EMEND experiment: a partnership putting the natural disturbance model (NDM) to the test.

- The EMEND (Ecosystem Management Emulating Natural Disturbance) experiment is a large-scale comparison of alternative cutting practices with two approaches to burning (whole stand and slash burning), which tests the effectiveness of stand-level approaches to implementing NDM.
- The main objectives are to determine which forest harvesting and regeneration practices are ecologically sustainable in terms of maintaining biological communities, spatial patterns of forest structure, and ecological processes.
- EMEND capitalizes on a statistically rigorous factorial experimental design where comparisons of harvest intensity and forest cover type are evaluated in one hundred 10-ha experimental compartments. Forest cover comparisons were made among: (1) deciduous-dominated, (2) deciduous-dominated with a developing understory of white spruce, (3) mixed deciduous–conifer, and (4) conifer-dominated stands. Harvest comparisons were made among six levels of residual canopy: 0–2%, 10%, 20%, 50%, 75%, and uncut controls.
- Biodiversity concerns are a major consideration of the EMEND experiment. Responses of insect, fungal, vascular plant, non-vascular plant, bat, and bird communities are examined in this project.
- This project is a joint effort of Canadian Forest Products and Daishowa–Marubeni International to develop management plans that will meet the criteria of sustainability. These companies are committed to using a variety of cutting prescriptions to guide successional tracks of regenerating forests to maintain the variation crucial for conservation of biodiversity.

Spence 1999; Spence et al. 1999*b*; see also
http://www.biology.ualberta.ca/old_site/emend/index.htm

green trees on the landscape following harvest, there is little consensus about the appropriate range of wood volume that should be left and what the best way is to leave retention trees following harvest. But perhaps this lack of consensus should be viewed as encouraging, for the best strategy to maintaining biotic diversity and ecological complexity will likely embrace a diverse range of management approaches.

In extreme cases, companies practicing traditional two-pass harvesting viewed the reserves left following the first pass as an adequate approach to coarse-filter protection of biological diversity. Another variant of the old status-quo perspective (apparently still much alive and not yet discredited) includes the view that leaving non-merchantable material is adequate for maintaining biodiversity. In contrast, the majority of companies reported leaving a higher proportion of merchantable trees on the landscape. Specific retention levels differed regionally as specified by provincial regulations such as the *Forest Practices Code Biodiversity Guidebook* in British Columbia, but also in response to regional differences in forest type, elevation, and disturbance frequency (BCMOF and BCMELP 1995). Sustainable forest management research is needed in

Box 23.3. Movement of western Canadian forestry practices toward ecological sustainability.

- Actions intended to conserve biodiversity clearly are penetrating forest management plans, and this has enormous potential to alter the constitution of future forest landscapes. Biodiversity is here used as an integrative measure of ecosystem integrity, with long-term productivity and resilience as corollary benefits. However, many questions remain about how biodiversity is defined and assessed and how best to manage species and ecosystem processes over the long term. Furthermore, tradeoffs between fibre production and biodiversity protection have been scarcely studied. Here we provide a summary of management strategies currently implemented by companies in western Canada. Representatives from 14 forest products companies were asked to complete a survey assessing several broad issues, which are important for integrating biodiversity protection with timber production.
- Prioritizing biodiversity objectives was largely determined by differences in provincial legislation. Governmental rules and guidelines such as the *Forest Practices Code Biodiversity Guidebook* in B.C. at least provided standardized targets for distribution of age classes, size of cutblocks, and amounts of green-tree retention left following harvest. In some cases, biodiversity was considered to be entirely a governmental responsibility.
- Green-tree retention and maintaining a variety of stand age classes were stressed by all companies interviewed as important approaches to maintaining biodiversity. British Columbia companies reported retention levels ranging from 2 to 20% of the cutblock area. Alberta and Saskatchewan companies reported retention levels ranging from 0 to 15% of merchantable volume. In B.C., 4 of 6 companies overlapped retention requirements with sensitive areas to create a network of reserves. All Alberta and Saskatchewan companies reported that the area left for retention was in addition to other leave requirements.
- Cutblock size was largest and most variable among Alberta and Saskatchewan companies. Future cutblock sizes in these areas were projected to increase substantially.
- Six of 14 companies reported established monitoring programs for biodiversity, although only 4 of these went beyond measuring standard silvicultural variables. Of these 4, 2 reported monitoring structural features such as cutblock size and shape, coarse woody debris, and vertical stand structure. The other 2 companies reported monitoring several vertebrate and vascular plant species as well as threatened and endangered species in addition to structural features.
- Eight companies indicated some form of biodiversity monitoring plan was being developed but had yet been implemented. Proposed monitoring plans focused on indirect monitoring through indices of habitat suitability such as amount of coarse woody debris, distribution of forest age classes, stream classifications, and landscape and structural indices. Four of these companies also indicated future plans to monitor presence/absence or species richness of target taxa, although these were highly variable among companies. In most cases target taxa had yet to be defined.

While few, if any, conclusions can be made at this point on the effectiveness of any of these strategies, it is clear that conservation of biodiversity in western Canada will likely focus on indirect management of habitat features or a coarse-filter approach to biodiversity, rather than direct management and monitoring of species. Likewise, the forest products industry will likely depend on government and academic research partnerships to develop these strategies.

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this area, and the discussion surrounding green-tree retention should be expanded to include buffer management and the more advanced concept of riparian connectivity. Natural patterns do not establish anything similar to our formula-driven buffer strips, and there is no science to promote this retention management scenario (Burton 1998). Ultimately, the present approach to buffer management could be counter-productive to long-term aquatic environmental health as it prevents or slows down the rate of renewal for riparian forests.

While green-tree retention is becoming an increasingly common strategy of forestry companies, there have been few tests of the effectiveness of this strategy (Spence 2001; Vanha-Majamaa and Jalonen 2001). As a practical extension of the NDM, coarse- filter approaches to maintaining biodiversity require evaluation to ensure their effectiveness. Without proper evaluation and monitoring, coarse-filter approaches can become a self-fulfilling fallacy that presents the illusion of sustainability ("a green lie") while critical ecosystem functions steadily degrade. As with the determination of disturbance regimes, identifying metrics and variables that adequately characterize the effectiveness of coarse- filter retention in maintaining biodiversity is also an ongoing process. Landscape indices may be useful in identifying large-scale spatial patterns in the abundance, size, and connectivity of habitat patches, but are deficient by themselves. For these metrics to merit implementation, they require validation that biodiversity and ecosystem processes are maintained at the stand level (Larsson and Danell 2001). Likewise, the effectiveness of proposed stand-level metrics of stand structure and coarse woody debris as indicators of ecosystem integrity must also be demonstrated if coarse-filter strategies are to be considered a viable alternative for biodiversity protection.

As with all measurements that are meant to guide wise action, landscape- and stand-level measurements must be revisited to ensure that the impacts of management can be curbed before lasting detrimental effects to biodiversity occur. Thus, effective monitoring becomes the backbone of any workable coarse-filter strategy. An effective schedule for monitoring coarse-filter indicator variables will be specific to the variable of choice. Factors that must be considered include the timeframe of disturbance and succession as well as the dynamics of the species and processes for which the strategy was intended. The systematic evaluation of coarse-filter strategies will also build our skills in designing fine-filter strategies aimed at threatened and endangered species and other specific aspects of biodiversity that we are trying to protect and manage.

Most SFM proponents have now moved on from use of the NDM and coarse-filter strategies as a wide-sweeping insurance policy to protect forest ecosystems against unspecified effects of industrial forestry (Armstrong 1999). Instead, many of the most steadfast former proponents of the NDM now recognize that "natural disturbance" is, at best, a source of inspiration with respect to developing ecologically sensitive forestry practices. The goal of maintaining biotic assemblages and ecosystem processes broadly characteristic of unmanaged forests still pertains, but we now understand that there is likely more than one way to save a cat . . . or bear, orchid, beetle, or fungus. This likely reflects the "many routes to one outcome" connections in ecosystems. There is a serious message here for Canadian proponents of SFM who have perhaps raced to apply ideas that should really just be considered hypotheses. It is up to researchers to critically review the information available to date, and to construct and test hypotheses that help us understand the systems that we wish to manage. From this understanding we can develop credible suggestions for practical application, to be tested in the context of adaptive management, but we must guard against the development of rigid or universal guidelines. It is sobering to realize that many directions set in the past but now in disrepute were reluctantly followed by companies due to pressure to adopt modern management practices and to "protect the environment". As we find our way through this maze we should promote cooperation and encourage researchers and managers to follow alternative paths that cannot be clearly rejected, rather than to criticize those unwilling to follow the hypothesis of the day. We must not confuse the statement of a scientific hypothesis with claims of science-based management, a confusion that the present authors feel has been too common in the early enthusiasm for SFM and NDM in particular.

We need to better understand how the way we cut and regenerate forests affects the biota and the ecological processes to which they contribute over the long term. Achievement of SFM, of course, depends more on outcomes consistent with its fundamental precepts than on the use of a certain set of methodologies. The challenge clearly is to gain the economic benefits from a viable forest industry in a manner that is both socially acceptable and ecologically sensitive, leaving the basic whole-forest components and processes intact. We hope to do this by *understanding* the consequences of our actions through the broad pursuits of the relatively new field of disturbance ecology, rather than by a blind attempt to *mimic* natural disturbances. Natural disturbances can be our legitimate inspiration, but they should not be a straightjacket for forest management.

The present state of SFM

As the impacts of industrial forestry are felt across ecosystem boundaries, affecting input of nutrients and water quality of watersheds (see Chap. 10) and the flux of carbon into the Earth's atmosphere (see Chap. 20), our ability to "do" effective forest management becomes increasingly relevant to reconciling the demand for wood supply with non-timber values because everyone becomes effected. Balancing this trade-off will be facilitated by:

(1) improving on the things we already do;
(2) minimizing our mistakes while learning from them; and
(3) developing new management options as better knowledge of ecosystem processes comes to light.

Improving our approach to forest planning (Chaps. 11 and 12) through greater consideration to natural disturbance dynamics and applying a variety of silvicultural systems (Chap. 13) to achieve a "desired future forest" can be meshed easily with pre-existing forest practices. Incorporation of "new takes" on familiar actions may help push status-quo forestry towards SFM. For, example, a combination of standard silvicultural approaches to even-aged and uneven-aged management has been proposed as a means to create stand compositions and age structures consistent with the effects of fire in black spruce – feathermoss forests in northwestern Quebec (Chap. 11). Redefining management objectives to include consideration of a variety of ecological as well as timber values will require forest inventories to be conducted more frequently than before. Likewise, increasingly complex models of forest dynamics that make accurate predictions across multiple scales will also require more data of higher quality (Chap. 14). Achieving a desired future forest that is rooted in the principles of disturbance ecology and habitat management will clearly involve selective use of a variety of silvicultural systems that reflect the spectrum of management options ranging from nature-emulating practices to intensive fibre production.

In the same way that current planning and silvicultural approaches can be adapted to embrace SFM, the ecological footprint of existing industrial forestry practices such as road construction (Chap. 15) and pulp processing (Chaps. 16–19), can be minimized by applying our "license to think". Reducing the negative effects of large road networks on runoff and sedimentation, and reducing lethal and sub-lethal effects of atmospheric and aquatic discharges of effluent from pulp processing facilities will be achieved by combining existing technologies with new innovations. For example, levels of BOD, dioxins, and furans from pulp processing facilities were reduced when secondary wastewater treatment processes were implemented in response to governmental regulation. As we become increasingly aware of the potential for subtle and long-term effects from other materials such adsorbable organic halides (AOX), suspended particulates, and colour-causing material in wastewater, additional steps in pulp processing such as membrane-based capture of these materials as an alternative (or in addition) to biological and chemical treatment can be implemented to reduce the overall impact of wastewater effluents (Chap. 17).

Examples of novel processing techniques such as the use of alternative bleaching techniques (e.g., the use of ozone and pretreatment of wood chips with fungal and enzymatic agents) can decrease the total volume of atmospheric emissions through a reduction in emission rates and a decrease in the energy required in processing pulp. The potential benefits of novel processing strategies may be simulated *a priori* through the use of increasingly sensitive atmospheric emission models. Existing technologies such as scrubbers and filters may be augmented with newly developed technologies like biofilters to reduce methanol emissions (Chap. 18). Leaching of heavy metals, dioxins and furans, and microorganisms from sludge into groundwater can be prevented through simple "reduce, recycle, and reuse" principles aimed at solid waste residues (Chap. 19). These new technologies and approaches to road construction and waste reduction demonstrate how building on existing professions and frameworks, and learning from our past experiences, can minimize the negative impacts of our actions and move the entire forest products sector into line with SFM principles.

Developing new management options as better knowledge of ecosystem processes becomes available is the premise of adaptive management (Chap. 21). The framework of adaptive management consists of a five-step cycle of planning, choosing, implementing, checking, and revising. This framework also prods practitioners to incorporate the themes and commonalities that have been presented throughout this book into practical forest management by trying out new ideas in an operational setting. The planning and choosing phase of the adaptive management framework provides an environment where socio-economic stakeholders can achieve increased autonomy in the decision-making process. It is also in this arena where both socio-economic and ecological trade-offs can be evaluated in the light of the best available knowledge. Implementing a strategic objective through combinations of current and innovative forest practices is how advances in technology can be easily incorporated into the framework. Implementation and evaluation of any management strategy should be tempered with clear understanding of disturbance regimes, ecosystem impacts, and their inherently dynamic nature. Finally, the revision phase of adaptive management allows forest managers to "learn by doing" and to keep up with the changes in socio-economic values and the shifting backdrop of ecological processes. During each phase of adaptive management, a license to think is required.

Just as forestry is a composite of activities, so is forestry only one component of the human impact on landscapes. Minimizing human impacts and sustaining forest values thus requires truly integrated resource management. Many objectives of SFM can be achieved only if forest management is effectively seen as a component of broader landscape management.

Into the woods with SFM

Throughout this book there have been numerous examples of forest product companies and government agencies having achieved significant progress toward SFM, demonstrating that many of the suggested approaches are feasible. These case studies span social, ecological, engineering, and management disciplines (Box 23.4), illustrating progress towards SFM in all dimensions. The time is right for all players in the boreal forest to take SFM into the woods and use it. The pathway before us is illuminated by some simple principles such as protection of non-timber values, the legacies of disturbance ecology, community empowerment, and waste minimization, but we must be open to new creative ideas and other promising directions. To achieve rapid progress towards application of SFM systems, research must be effectively connected to evolving management systems and a strategically malleable policy environment. Sustainable forest management should aim towards continual improvement rather than the disruptive "phase shifts" that have characterized past approaches to forestry. Sustainable forest management is not a milestone to be achieved, but a state of being that should automatically embrace new challenges and respond as a way of doing business.

To smooth the Canadian transition to SFM, we believe that both structural and philosophical changes are desirable to allow the industry to move and adapt to new realities. Some of the most important required changes are summarized in Box 23.5.

To a certain degree, progress to sustainable forest management is happening in parallel to the Sustainable Forest Management Network (SFMN) research described in this book. The Network is only one among many progressive players, all of whom are contributing to the SFM transition, with all players feeding off each other and building a collective body of experience and expertise. The Network's own contributions to changing things on the ground in Canada are partially due to the legitimacy conferred by its broad partnership base. There has been a ratcheting effect of efforts by environmentalists, First Nations communities, concerned consumers, politicians, corporate leaders, and scientists, each challenging the others to improve practices and policy. The range of improved practices is characterized by a focus on tradeoffs, and the resulting changes may have different meanings to different groups. For example, provincial government

Box 23.4. Some case studies of progress toward sustainability showcased in previous chapters.

- Little Red River/Tall Cree First Nations: This Aboriginal alliance has taken a proactive role to the management of forests in their traditional territories by developing partnerships, not only with industry, but also with the SFMN. In so doing, they have secured jobs and increased expertise in forest operations and wood products processing though innovative forest management that includes strong community values, non-timber forest products, and a commitment to cultural as well as forest sustainability (see Chap. 3).
- Lac Duparquet Research and Teaching Forest: Developing from a strict ecological research emphasis, this landscape in NW Quebec has become an experiment in the industrial emulation of alternative natural stand development trajectories. Working with the real world issues and demands of industry and the local community has introduced a sense of practicality to an otherwise academic management direction. Results are now being applied to nearby forest management units managed by Tembec Forest Products and Nexfor–Norbord Industries (see Chaps. 11 and 22).
- Boreal Ecology and Economics Synthesis Team (BEEST): This collaborative interdisciplinary research group based at the University of Alberta has effectively used scenario modelling to challenge provincial forest policies on the basis of both ecological and economic criteria, and has proposed more sustainable alternatives (see Chaps. 6 and 14).
- Alberta-Pacific Forest Industries: An early advocate of emulating natural disturbances on a landscape scale, Alberta-Pacific has supported studies of the natural disturbance regime and its effects on landscape pattern and biodiversity. Responsible for a very large public landbase, Alberta-Pacific is working to maximize efficiency in view of demands placed on the forest landbase by other users, notably the energy sector (see Chap. 22).
- Weldwood's Hinton Division, in conjunction with the Foothills Model Forest, is well advanced in its implementation of an adaptive management program that supports continued enhancements to broad-based sustainability as well as CSA certification. An important component of this program is a forest resource advisory group (FRAG) that effectively utilizes both public participation and research to identify and prioritize forest values (see Chap. 21).
- Bas-St.-Laurent Model Forest: This Model Forest, one of 11 across Canada partly sponsored by the Canadian Forest Service, is exploring innovative forest tenure arrangements in which individual entrepreneurship and innovation are being practiced on a public land base, sustaining rural communities while still meeting industry's fibre needs (see Chap. 22).
- Millar Western Forest Products has used a structured program of adaptive management in their biodiversity assessment project (BAP) to explore the impact of harvesting and timber supply scenarios on a broad suite of landscape-level variables considered important to identified wildlife and to biodiversity (see Chap. 21).
- Mystic Management: A partnership of a First Nation and the forest products industry, this organization has pioneered an innovative system of local resource boards for public participation, coupled with respect for non-timber forest resources (furs, wildlife, berries, wild rice). This forest management organization provides fibre for a zero-effluent pulpmill owned and operated by Millar Western (see Chaps. 4, 17, and 22).

Box 23.5. Some guidelines for improved forest sustainability.

- It is essential to define the geographical extent of the management area (an often arbitrary "sustainability unit") over which sustainability is to be expected, monitored, and gauged.
- Activities and processes that minimize their dependence on inputs (e.g., of energy in the form of petroleum products or electricity) from outside the sustainability unit are more sustainable than those that don't.
- Tenure reform is needed to promote land stewardship, perhaps independent of the demand for timber production.
- The temporal scale of reference for forest sustainability is infinite (or at least as far as we can project), not just the operating lifetime of a processing facility, a human lifespan, or a timber rotation.
- Forest sustainability provides forest-based goods and services in a manner that retains the widest possible array of future options for all forest values at some scale; this means that no species, habitats, or ecosystem types can be extirpated and long-lasting system transformations and land-use changes must be minimized.
- Adopt the precautionary principle, including the important step of setting aside significant wilderness/wildland areas for ecological benchmarks, buffers, recreational, and spiritual use, and for future options.
- Implement resource emphasis zoning as needed. Areas set aside from extractive harvesting may be offset by enhancing productivity on other portions of the land base. The degree of compatibility between different forest values must be rigorously evaluated and monitored, with "incompatible" values managed for on different portions of the land base.
- Excess consumption or degradation at one scale or location must be compensated for at a broader scale (and at other locations) if sustainability is to be maintained. To do this we must better understand the resilience of forest ecosystems, and achieve understanding if not consensus among forest stakeholders who will not bear the costs and benefits of development equally.
- Current levels of natural attributes and economic activity are not necessarily optimal for any given forest value, are not necessarily sustainable, and must be negotiable.

and industry initiatives undertaken to protect biodiversity, incorporate public input, or reduce negative impacts of harvesting activities are not necessarily driven by legislation. This is in part a response to campaigns by environmental groups and the threat of boycotts. Such movement also bespeaks a recognition by industry that forest certification assures access to markets and can even confer a premium on pricing. In essence, then, forest products companies are trading a degree of biodiversity protection for market advantage or access.

Sustainable forest management proposals and solution options are evolutionary, not revolutionary; they build upon and expand the concepts of multiple-use and sustained-yield forestry . . . we are not throwing those principles away, only balancing them against other concerns. To a certain extent the SFMN has provided an institutional meeting ground for wide-ranging discussions and tests of ideas about conservation, innovation, and improved management; ideas that are popular and "in the air" but which otherwise might remain untested. In the future, and with cooperation from industry and government partners, the SFMN will undoubtedly become a forum for the re-evaluation of some of the strategies outlined in this book, in keeping with the precepts of adaptive management. Though perhaps underutilized by the Network's partners, the SFMN provides a badly needed framework for national R&D (research and development) incubation in forest management.

In this respect, one of the most important products that the SFMN may provide is an opportunity to challenge our own ideas regarding sustainability and forest management. There is a danger of "fads" setting the agenda everywhere, risking homogenous policies and practices as one untested paradigm replaces another, and reducing our ability to learn. The policies that seem like immutable truth today may appear naive and short-sighted in the future. As such, one of the principles of SFM should be to maintain and engender diversity in forestry practices while keeping a *humble* frame of mind, open to new possibilities.

As is typically Canadian, a reasonable conclusion to draw from the SFM Network experience over the past decade is that our strength lies in our forestry "multiculturalism". In fact, from a national perspective, the last decade has seen a proliferation of adaptive management experiments on the Canadian forest land base. For SFM to unfold successfully and expeditiously we must collect the relevant information residing in this grand national experiment and learn from it. Increasingly broad participation in the Network could support a change in forest management culture. We need dedicated staff, technical expertise, and managerial leadership to draw practical conclusions, show direction, and propose new experiments. And this too, shall be derived from the SFMN as our many students find places in this exciting and nationally important enterprise. No book can be considered as a cookbook for SFM or a final report on Network accomplishments. Rather, the steady pursuit of sustainable forest management will help Canadians evolve useful and enduring relationships with their forest land and ensure that we continue to have forests in which to work, to play, and to live.

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