Achieving forest biodiversity outcomes across scales, jurisdictions and sectors with cycles of adaptive management integrated through criteria and indicators

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ABSTRACT

The national forest strategy provided a model for Canada's international support for sustainable development, which later resulted in the development of a national biodiversity strategy. Adaptive management is a preferred approach for implementing such policies where incomplete knowledge and the highly variable dynamics associated with natural ecosystems are challenges. While the concept of adaptive management is embedded in various policies, complete implementation is only beginning in Canada. Case studies on adaptive management frameworks focusing on conservation and sustainable management of forest biodiversity compare how information has been integrated across spatial scales, jurisdictions and sectors of activity. To monitor progress in sustainable forest management, the Canadian Council of Forest Ministers established a framework of criteria and indicators in 1995. The potential for criteria and indicators reporting to drive cross-scale adaptive management of Canada's biological resources is discussed.

Key words: forest biodiversity, conservation, sustainable use, criteria and indicators, adaptive management, monitoring

RÉSUMÉ

L'appui du Canada au développement durable à l'échelle internationale a mené à l'élaboration de la stratégie nationale sur la diversité biologique et à la stratégie nationale sur la forêt. L'aménagement adaptatif est la voie d'application privilégiée de telles politiques quand le manque de connaissances sur les écosystèmes naturels et leur dynamisme en constante évolution posent en soi un défi. Bien que le concept de l'aménagement adaptatif soit enchâssé dans diverses politiques, sa mise en œuvre intégrale ne fait que commencer au Canada. Des études de cas comparent la manière dont l'information, présentée selon une multitude d'échelles spatiales, de juridictions et de secteurs d'activité, a été intégrée dans un cadre d'aménagement adaptatif axé sur la conservation de la biodiversité forestière et l'aménagement durable. Afin de suivre les progrès de l'aménagement forestier durable, le Conseil canadien des ministres des forêts a défini en 1995 un cadre de critères et d'indicateurs. On discute de la possibilité d'utiliser ce cadre comme cadre de gestion à l'aménagement adaptatif à différentes échelles.

Mots clés : biodiversité forestière, conservation, utilisation durable, critères et indicateurs, aménagement adaptatif, suivi

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Introduction

The conservation of biodiversity was identified as essential for human well-being in the Millennium Ecosystem Assessment (MEA 2005). This assessment, involving more than 1300 scientists from 95 countries, studied the impact of human activities on the services provided by ecosystems. Biodiversity, the variability within genes, species, ecosystems and their interactions, is the basis of Canada's natural capital and national legacy, providing many direct and indirect benefits. Benefits from biodiversity, estimated as the underpinning for up to 40% of the global economy (Packer and MacDonald 2002), range from essential life support services such as water and air purification and carbon cycling, to pollination and also include artistic inspiration and spiritual values and products such as fibre, fuel and medicine.

Forests, considered as the single most important repository of global biodiversity (UNEP 2005, Kapos and Iremonger 1998), provide habitats for about two-thirds of the species in Canada (Mosquin *et al.* 1995). Maintaining biodiversity allows for a continued flow of goods and services from forest ecosystems to communities. Both the value of sustaining forest-based natural capital and its replacement value, now and in the future, are estimated to be high (Olewiler 2004). However, all of the proposed systems for valuing the many goods and services have some problems.

Strategies to conserve forest biodiversity may be either static or dynamic, ranging from the creation of protected areas to the adoption of natural disturbance regimes in areas managed for intensive or multiple uses. While networks of protected areas form the backbone of any conservation strategy, the maintenance of biodiversity is dependant on management actions at the landscape level (Margules and Pressey 2000, Gaston *et al.* 2002). Objectives for biodiversity are now included in sustainable forest management policies in most Canadian jurisdictions (Neave *et al.* 2002) and are considered to be as important as production objectives (Work *et al.* 2003).

Successful implementation of many existing policies is limited, however, by the lack of monitoring data and the absence of mechanisms for gathering and aggregating multiple-scale data. Canada's ability to accurately assess or provide a complete report on stewardship of its biological resources is further constrained by the lack of a national biodiversity monitoring program or standardized monitoring protocols. This paper examines how partnership and cross-scale integration of adaptive management frameworks could improve the ability to respond to national commitments for conservation and sustainable management of forest biodiversity and the benefits accruing to human well-being.

International Commitments

In ratifying the Convention on Biological Diversity (CBD), Canada committed to 1) the conservation of biological diversity, 2) the sustainable use of its components, and 3) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. In support of the Forest Principles (UN 1992), the non-legally binding authoritative statement for a global consensus on the management, conservation and sustainable development of all types of forests, Canada is also working towards biodiversity goals associated with the proposals for action developed through the United Nations Forum on Forests (UNFF). In addition, as one of 12 signatory countries to the Santiago Declaration on criteria and indicators for sustainable forest management (C&I), Canada endorsed the Montréal Process framework for monitoring, assessing and reporting progress on conservation and sustainable management of temperate and boreal forests (Montréal Process Working Group 1998).

In 2002, at the World Summit on Sustainable Development, the global community renewed their commitment to biodiversity by recognizing the linkages between poverty, the environment and the use of natural resources and agreeing to work towards integrated cross-sectoral solutions. In addition, the Hague Ministerial Declaration of the Sixth Conference of the Parties (COP) to the CBD to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national levels […]" was also endorsed at this Summit. This commitment is commonly referred to as the 2010 target.

National Responses

Existing for more than ten years, the Canadian Biodiversity Strategy (CBS) presents a vision of Canada as "a society that lives and develops as a part of nature, valuing all life, taking no more than nature can replenish and leaving to future generations a nurturing and dynamic world, rich in its diversity of life" (Canadian Biodiversity Strategy 1995). The importance of maintaining and restoring biodiversity is also recognized in the National Forest Strategies (1992–1998, 1998–2003, 2003–2008), developed by a nation-wide coalition of governments, non-governmental organizations, industries and academia. The vision of the current national forest strategy (NFS) is to "maintain and enhance the long-term health of Canada's forest for the benefit of all living things and for the social, cultural, environmental and economic well-being of all Canadians now and in the future" (National Forest Strategy Coalition 2003). This voluntary action plan articulates Canadian's vision for their forest heritage and challenges them to achieve consequential improvements in sustainable forest management policies and practices (including biodiversity conservation) and to strengthen the competitiveness of Canada's forest sector. Strategic targets and priority activities for the forest sector are identified and renewed every five years. Both the CBS and the NFS emphasize the importance of cooperation to create the conditions necessary for advancing ecological management.

The 1992 NFS called for a framework of C&I to define and measure progress towards sustainable forest management. The Canadian Council of Forest Ministers' (CCFM) framework of C&I in Canada (CCFM 2003) is compatible with that of the Montréal Process, adopted by the countries that signed the Santiago Declaration (Montréal Process Working Group 1998) and representing 60% of the world's forests. Canada assessed the capacity to report in 1997 (CCFM 1997) and reported on the CCFM indicators in 2000 (CCFM 2000), with another report due in 2006. Conservation of biological diversity is the first criterion in both of these frameworks. The CCFM subdivides this criterion into three elements of diversity (ecosystem, species, genetic) and eight indicators (CCFM 2003). The indicators are reported using available data, of which the quantity, quality and type vary by jurisdiction. Lack of available data prevents complete analysis of the status of forest biodiversity and scientifically based conclusions on cause and effect relation-

ships (Failing and Gregory 2003). In addition, the absence of a national baseline for forest biodiversity and a means to track status change over time makes it difficult to determine if biodiversity is maintained across forest landscapes or to evaluate the level of implementation and effectiveness of policies and practices put in place to meet this goal.

Assessments of Progress

The Commissioner of the Environment and Sustainable Development (CESD) of the Office of the Auditor General of Canada (OAG) periodically assesses progress in the implementation of the CBS. Both the 1998 and 2000 audits (OAG 1998, 2000) raised concerns regarding the need for improvement in the federal government's lack of ability to report on the overall state of biodiversity. The CESD's 2005 follow-up audit report (OAG 2005) severely criticized the federal government for its inefficiency in implementing the CBS and points to the lack of an implementation plan and monitoring framework for the strategy and for the impacts of its goals on the landscape as a major shortfall, particularly since these needs were clearly identified in the two previous audits.

Canada's Forest Biodiversity – A decade of progress in sustainable management (Neave *et al.* 2002), reported that while Canada is building a framework and embracing an approach to address conservation and sustainable use of forest biodiversity, success so far has been the result of sustained collaboration among governments, industry, non-government organizations, land owners, land managers and interested citizens. The independent panel assessment of the 1998–2003 NFS is another example where progress in sustainable forest management across the country was noted but pointed to the protection of forest biodiversity as a key area that must be addressed to meet evolving economic, environmental and social values and needs.

The Ecosystem Approach and Sustainable Forest Management

The COPII (Decision II/8) of the CBD recommended that the three objectives of the convention be implemented using an ecosystem approach (Convention on Biological Diversity 1995). The adoption of an ecosystem approach (Convention on Biological Diversity 2000) implies acknowledgement that humans are an integral component of the ecosystem and focuses on the essential processes, functions and interactions among organisms and their environment. Implementation of the ecosystem approach also implies recognition of the need for synergy between sustainable forest practices and conservation activities in order to maintain biodiversity. The ecosystem approach equally advocates a migration from management based on single species and area protection towards ecosystem protection and integrated land use planning. At COPVII (Decision VII/11), national forest and biodiversity programs were linked with the recognition of sustainable forest management as a means of applying the ecosystem approach to forests (Convention on Biological Diversity 2004). This link, described and analyzed by several authors (e.g., Haüsler and Scherer-Lorenzen 2001, Løyche Wilkie *et al.* 2003) further demonstrates that implementation of biodiversity policies encompasses all aspects of sustainable development.

Inherent in the Decision VII/11 is the recommendation that, "the ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning." Managing forest biodiversity requires that this uncertainty and variability associated with ecosystem processes and their dynamics at various spatial scales be considered as part of management outcomes. The higher the natural variability in an ecosystem, the more difficult it is to identify abnormal variation. Because the results of management actions are often non-linear and detectable only after an initial time-lag, adaptive management is often suggested as a cost-effective framework to deal with complex dynamic systems. Feedback from adaptive management allows information to flow from operational activities to management and policy making, systematically reducing uncertainty (Johnson 1999, Murray and Marmorek 2004). Taylor *et al.* (1997) and Duinker and Trevisan (2003) report that there is little actual implementation in Canada, particularly in terms of monitoring and assessment. However, the concept is often embedded in legislation or certification requirements, and uptake of adaptive management principles is increasing.

The Adaptive Management Cycle

Surfacing in the 1970s, the concept of adaptive management (Holling 1978) integrates design, management, and monitoring to systematically test assumptions in order to adapt and learn (Salafsky *et al.* 2001) and utilize the newly acquired knowledge in modifying policies and practices to achieve management goals (Lindenmayer and Franklin 2002). Management policies are deliberately designed, in a structured process of "learning by doing," to test and increase understanding of the effects of management activities on the system being managed (Taylor *et al.* 1997, Walters 1997).

Typically, the two primary adaptive management strategies are distinguished by the extent of learning they offer, the resources they require to be successfully carried out, and the degree to which management goals are incorporated into the design. Passive adaptive management is characterized by the implementation of a single policy or hypothesis formulated on the basis of available data and knowledge as an appropriate means to reach management goals. This "best" management scenario is often selected from a set of scenarios tested through computer simulation models. Although the passive approach is the most frequently adopted by forest management agencies professing to be using an adaptive management framework, it has been criticized for limited ability to induce learning and reduce uncertainty (Baker 2000). With active adaptive management, several policies or hypotheses are concurrently tested and monitored through management design (Murray and Marmorek 2004). Each of the policies is implemented simultaneously using an experimental approach with random settings and controls to test which of the policy options achieves the desired outcomes (Baker 2000). For example, testing of several alternative silvicultural treatments to identify the best management option might be a test application in forest management (MacDonald *et al.* 2003).

Both passive and active adaptive management can be described as a cycle composed of the following typical steps: problem definition and design, implementation, monitoring, assessment, reporting and adjustment (Salafsky *et al.* 2001, Duinker and Trevisan 2003, Bunnell and Dunsworth 2004, Rempel *et al.* 2004).

Problem Definition and Design

The cycle is initiated by defining: the management context (e.g., spatial and temporal scale, stakeholders' values); what will be achieved (e.g., mission, vision, goals, objectives); and how progress will be measured (e.g., indicators and targets) (Nyberg 1999, Duinker and Trevisan 2003, Noss 2004). Goals are established by policy-makers and forest managers based on adequate knowledge of the past, current, and potential future conditions of the forest (Noss 1999). Creating a model of the system and forecasting the effects of forest management operations and practices on forest biodiversity are important components of this initial step. Modelling also allows for the design of one (passive adaptive management) or more (active adaptive management) hypotheses that are most relevant to management decisions. The effectiveness of policies or hypotheses, tested through the implementation of a carefully designed management strategy, is measured through the monitoring program.

Implementation and Monitoring

Monitoring strategies normally focus effort and resources on indicators that will provide information useful for managers to assess whether or not their predictions or assumptions were accurate (Taylor *et al.* 1997). Three types of monitoring schemes have been described: implementation, effectiveness, and validation (Lindenmayer and Franklin 2002). Implementation (also referred to as performance) monitoring is used to determine whether the types and levels of activities stipulated under a policy are actually conducted. Effectiveness monitoring determines the impact of management goals and objectives on the landscape. Validation monitoring uses hypothesis testing to investigate the relationship between an action and an effect (Mulder *et al.* 1999, Lindenmayer and Franklin 2002). The management goals will dictate the type of monitoring most appropriate.

The development of indicators to measure the progress towards the goals and objectives and to maximize learning from the system under management is the cornerstone of the monitoring strategy. Both coarse (e.g., forest cover, fragmentation) and fine (e.g., species, gene) filter approaches are required to detect changes in the system (Carignan and Villard 2002). The selection of a set of indicators, although area/scale-specific (Kneeshaw *et al.* 2000), can be grouped into broader categories (guilds, communities, associations, other functional groups) to allow reporting at the appropriate scale. Meffe and Carroll (1994) suggest that indicators should focus on processes rather than species. Many indicators have been proposed for monitoring forests (Prabhu *et al.* 1999). While policy and management objectives will guide the selection, indicators that can be aggregated across scales will make the most effective use of monitoring resources. The U.S. National Research Council Committee to Evaluate Indicators for Monitoring Aquatic and Terrestrial Environments (2000) recommended three categories of national level indicators to capture the status of the dynamics of an ecosystem and changes in its functioning: the biological capital of an ecosystem (land cover and land use); its ecological capital (native species diversity, soil condition); and the ecological processes (production capacity, net primary productivity, carbon storage). For a forest management unit, Newton and Kapos (2002) suggested eight general groups of biodiversity indicators that can easily be aggregated across scales: 1) forest area by type, and successional stage relative to land area; 2) protected forest area by type, successional stage and protection category relative to total forest area; 3) degree of fragmentation of forest types; 4) rate of conversion of forest cover (by type) to other uses; 5) area and percentage of forests affected by anthropogenic and natural disturbance; 6) complexity and heterogeneity of forest structure; 7) numbers of forest-associated species; and 8) conservation status of forest-dependent species.

The importance of designing monitoring schemes (e.g., sampling strategies, sample sizes and stratification, assessment protocols and identification of relevant drivers of change) based on best available science, can not be overlooked. Engaging scientists to participate in the process encourages the introduction and effective use of new techniques such as molecular genetics, bioinformatics, and remote sensing. Exploring potential informal methods for data gathering can also improve effectiveness. Rempel *et al.* (2004) suggest that a key means of engaging scientists is through involvement in the identification of indicators that can be linked to forest or other inventories associated with operational planning. Indicators developed in this way, rather than through the creation of separate scientific inventories, will continue to be relevant and evolve along with current scientific trends. Scientific rigour is also required for the determination of thresholds, and the baseline information used to guide the establishment of targets.

Assessment, Reporting and Adjustment

The assessment process in effectiveness monitoring involves compilation and analysis of the monitoring data on ecosystem responses and comparison with the forecasted response. The focus is on understanding the discrepancy between monitoring responses and expected results. This process is greatly facilitated when supported by additional input from a validation monitoring scheme integrated within the management framework. The results of the analyses are presented to the original stakeholders and other interested parties through reporting activities and communication products. New information about the functioning of the system, gained through monitoring, can be applied to the adjustment of policies and management actions where required. Using this information to update models and forecasting tools also reduces the management uncertainty associated with the system. The formulation of new hypotheses or modifications to existing policies introduces the beginning of another cycle.

Applications of Adaptive Management

Five types of challenges associated with the implementation of adaptive management have been identified: technical, economic, ecological, institutional, and political (MacDonald *et al.* 1997, Baker 2000). A survey of 15 Canadian forest industries on the use of adaptive management (Moreau *et al.* 2002) highlighted the following technical difficulties: lack of an appropriate model or sufficient expertise; precision of available forecasting tools to respond to needs of forest managers; limited protocols to systematically evaluate achievement of specific management objectives; and availability (both in quality and quantity) of adequate information. Economics dictates the level of staffing, data collection, data manage-

ment, and data analyses that can be allocated over the time span required to obtain reliable results. Institutional and organizational issues limiting adaptive management include a reluctance to admit uncertainty for policy outcomes, a lack of expertise and time to learn adaptive management approaches, the rigour required to implement an adaptive management project, and the necessity for long-term commitments for human and financial resources (Walters 1997). Finally, policy-makers appear unwilling to accept the potential perception of failure if a particular policy is not successful (Lee 1993).

Despite these challenges, attempts to use adaptive management principles are occurring across production landscapes in Canada. Table 1 summarizes a few case studies of adaptive management focussing on forest biodiversity across a range of scales. Common elements of these case studies include: initial involvement of stakeholders or partners to build consensus around common values, goals and objectives as part of the problem definition stage; the use of tools to forecast management responses and build scenarios to enhance the consultative and predictive processes; the development of multi-stakeholder collaborative partnerships for monitoring and reporting purposes; the introduction of adaptive management principles into forest management and biodiversity conservation plans; and the use of the CCFM C&I framework for monitoring and reporting.

The Millar Western Forest Products Ltd. initiative to implement a passive adaptive management framework within their operations near Whitecourt, Alberta, led to the development of the Biodiversity Assessment Project (BAP) as a component of the company's decision support system (Van Damme *et al.* 2003). A distinctive part of the BAP approach is the adaptive planning stage, whereby a suite of dynamic models is used to simulate future forest conditions, providing an analytical tool for the assessment of alternative management strategies prior to their implementation (Doyon 2003). Although it was originally developed for the Whitecourt forest management unit, other groups such as the Western Newfoundland Model Forest are now using the same framework to assess impacts on forests (Doyon 2003, WNWF 2003).

The Stand Level Adaptive Management (SLAM) project is located in aspen-dominated mixedwood stands in northern Ontario (MacDonald *et al.* 2003, MacDonald and Rice 2004). The project developed and implemented an active adaptive management framework designed to enhance knowledge and reduce uncertainty related to the sustainable management of the Boreal mixedwood forest and to monitor changes in ecological indicators (ULERN 2004). The partners, Domtar Inc., Abitibi-Consolidated Inc, the Ontario Ministry of Natural Resources, Natural Resources Canada, the Forest Engineering Research Institute of Canada (FERIC), and the Lake Abitibi Model Forest, decided on a less formal but cost-effective approach to adaptive management by: 1) designing workshops that were less structured than advocated by Holling (1978); 2) limiting the scope of the study; 3) applying only treatments that were practical, operationally relevant, and economically feasible; 4) accommodating operational constraints; 5) using treatment plots small enough to permit regular monitoring of ecological indicators; 6) using relatively simple conceptual models versus more elaborated quantitative models; 7) monitoring a limited number of silvicultural, economic, and ecological indicators; 8) pre-determining which activities would be cut if funding decreased; 9) focusing on rapidly providing answers to management questions rather than spending too much time on design; 10) developing an alternative, scaled-down monitoring program; 11) relaxing rigour of sampling design; and 12) ensuring a key role for resource management partners (MacDonald and Rice 2004). The success for this initiative is measured by the degree to which results are incorporated into new provincial silvicultural guidelines and forest management plans (MacDonald *et al.* 2003).

Monitoring and reporting at the regional level (i.e., landscape with multiple land uses) has been achieved through the development of multi-stakeholder collaborations and partnerships. For the past 15 years, building partnerships has been a primary focus of the Canadian Model Forest Network, regrouping 11 forest-based landscapes ranging in size from 181 000 hectares to 2.75 million hectares. The network has generated a vast amount of information that can contribute to the implementation of adaptive management at the landscape scale. For example, the Foothills Model Forest (FHMF) in Western Alberta, the largest of the Canadian model forests, includes several provincial protected areas, one national park, forest management areas and urban settlements. Stakeholders of the FHMF, including members of the public, have identified shared local goals for sustainable forest management. Progress is monitored using Local Level Indicators (LLI) linked to the CCFM C&I framework. Reporting is based on data assembled from the different resource management partners (Alberta Government, industry, and Parks Canada) with coordination and analysis carried out through the FHMF. The first LLI report was produced in 2003 with the intent to report on status and trends on each of the indicators over time. When the initial data baseline is established, it will be used by individual partners to adjust their activities in response to trends identified through the aggregated monitoring results.

At the provincial level, adaptive management principles are increasingly being integrated into forest management and biodiversity conservation planning. The British Columbia Ministry of Forests and Range put in place the Adaptive Management Initiative (BC Forest Service 2005) to develop guides and tools for forest managers to integrate adaptive management into their operations. The Commission for the Study of Public Forest Management in Quebec (Commission d'étude sur la gestion de la forêt publique québécoise 2004) recommended the adoption of an adaptive ecosystem-based approach to management. The Ontario Ministry of Natural Resources has identified adaptive management as a key guiding element within provincial forest policies, such as Ontario's Policy Framework for Sustainable Forests and the Crown Forest Sustainability Act. The Forest Management Planning Manual, which provides the direction for preparing a forest management plan, prescribes the adoption of a passive adaptive management framework, including the requirement for forest managers to put in place a monitoring program (Duinker and Trevisan 2003). Ontario's Biodiversity Strategy further recognizes the importance of adaptive management of biodiversity recommending that: "... mitigation of the diverse threats to biodiversity requires an integrated, adaptive approach to caring for Ontario's natural assets [...]" (Government of Ontario 2005). A priority for the

Table 1. Case studies of applications of adaptive management principles across scales.

Scale / Type	Example	Adaptive Management Cycle Problem Definition	Design	Monitoring	Assessment/Reporting/Adjustment
Operational / Passive	Millar Western Forest Products (MWFP), Ltd., Forest Management Agreement area near Whitecourt, Alberta	**Values, Goals, and Objectives** - Developed through stakeholder consultations - Based on CCFM C&I framework - Main biodiversity goals: i) Maintain ecosystem and species diversity; ii) Maintain genetic diversity; iii) Protect rare and endangered species.	**Management Plan** - Development assisted by computer simulation - Testing of forest scenarios to resolve conflicting issues—Collaboration of 60 experts - Approved by provincial authorities **Forecasting Responses** -Biodiversity modelling tools (e.g. Biodiversity Assessment Project using habitat-supply models) - Scenario planning and Decision Support System -Both coarse and fine-filter biodiversity statistics and models used to reduce uncertainty	**Type**[1] I, E, some V **Monitoring program** -Permanent Sample Plot Program -27 metrics with 5-year remeasurement interval (e.g. understorey vegetation, tree measurements, downed woody debris). -Survey and assessment of rare plant habitat -Research supporting the development of the Alberta Biodiversity Monitoring Program (ABMP): -Development of protocols (e.g. invertebrates, pests) - Some validation through research programs: i) effect of thinning on wildlife ii) wildlife use of harvested areas iii) aquatic biota iv) coarse woody debris	- Annual performance reports - Stewardship reports every 5 years. - MWFP uses the information acquired through monitoring to adapt their practices to the local ecological characteristics.
Operational/ Active	Stand-Level Adaptive Management (SLAM), Boreal mixedwood stands within the Abitibi-Consolidated Iroquois Falls Forest and the Domtar Spanish Forest.	**Values, Goals and Objectives** - Developed through stakeholder consultations - Identified management questions for existing forest conditions - Determined desirable future forest condition (objectives) - Identified potential management actions to achieve desirable future conditions - Main goals: i) Achieve desirable and economically feasible stand structures ii) Enhance biodiversity and other forest values	**Strategy** - Developed with project partners, resource managers and other experts - Sequence and type of treatments determined **Forecasting Responses** - Conceptual modelling (vs. quantitative modelling) approach used for generating hypotheses about treatment effects - Response indicators identified	**Type** I, E, some V **Monitoring program** -Sylvicultural indicators (e.g. regeneration, overstory, soil) - Ecological indicators: • overstory • vegetation succession • coarse woody debris • microclimate • invertebrates - Annual re-measurement interval for 5 years post-treatment then at 2–3 year intervals for a subsequent 10–20 years.	- First report on monitoring results released in 2004, based on data gathered one year after harvesting. - Intent is to integrate information gained through this project into provincial forest management policies and forest management plans of industry partners through transfer of knowledge tools.

Table 1 (continued)

Regional / combination	Foothills Model Forest (FHMF)	**Values, Goals and Objectives** - Developed through stakeholder consultations - Landscape goals shared with all partners and stakeholders - Main biodiversity goals: i) maintain viable populations of all currently occurring native species; ii) maintain genetic diversity; iii) protect rare ecological sites and special landscape features; iv) maintain natural diversity, pattern and stages of forest ecosystems over time. - Board members review and endorse values and priorities - Based on CCFM C&I framework	**Work Plan** - FHMF has no land or resource management mandate - Work plan developed by consulting partners and stakeholders (including the public) **Forecasting Responses** Development of habitat-supply models	**Type** E , some V **Monitoring program** - Fish - Grizzly Bear - Woodland Caribou - Highway 40 Project - Regionally-specific data collected by agencies with land and resource management responsibilities and compiled to report on Local level indicators.	- Local level indicator reports: Baseline report in 2003 with intent to repeat the monitoring and measuring over time. - Local level indicators can be used for reporting obligations under provincial policy if they are consistent with the guidelines of the Alberta Forest Management Planning Standard. - Each partner is responsible for adjusting their activities based on indicator responses.
Provincial / combination	Alberta's forest land	**Values, Goals and Objectives** - Identified within Forest management plans (FMP) - Provincial Policy/ Strategic Planning (e.g. proposed Forest Management Planning Standard, Alberta Forest Legacy) provides guidance - Based on CCFM C&I - Developed through stakeholder consultations within each Forest Management Agreement (FMA)	**Proposed Forest Management Planning Standard** - Coarse and fine filter approaches to conservation of biodiversity - Establishes performance standards (Values, Objectives, Indicators, Targets) **Forecasting Responses** - Mandatory within each FMA	**Type** I, E, V **Monitoring program** i) Effectiveness reporting: - ABMP (under development) -Based on a 20 km spatial grid pattern throughout Alberta corresponding to the National Forest Inventory grid. A total of 1,656 sampling sites to be established, 350 sampled/yr (5 yr re-measurement interval) ii) Implementation: - Companies are required to monitor implementation of biodiversity objectives - Monitoring programs to be developed by the company iii) Validation - Conducted through various research programs throughout the province	i) Effectiveness reporting: -Provincial and regional reports - 10 stewardship reports over a five-year cycle. These reports provide information on the status and trends of biodiversity to the public. - Biodiversity Index (under development) ii) Implementation reporting requirements under FMPs: the Planning standard identifies required reporting products for each indicator (e.g. Stewardship reports - tables and maps) iii) Validation reporting through scientific publications -Amendments to FMPs as appropriate - Commitment to adjust existing policies based on adaptive management output

Table 1 (continued)

National / combination	Canada's forest land	**Values, Goals and Objectives** a) National Forest Strategy -Vision: Maintain and enhance long term health of Canada's forest - Strategic themes: 1) Ecosystem-based management 2) Sustainable forest communities 3) Rights and participation of aboriginal peoples 4) Forest products benefits 5) Knowledge and innovation for competitiveness and sustainability 6) Urban forest and public engagement 7) Private woodlots 8) Reporting and accountability -Developed by a national coalition of governments, non-governmental organization, industry and academia	**Strategy** a) National Forest Strategy: no defined land or resource management mandate - Voluntary Action Plans -Developed by members of the National Forest Strategy Coalition **Forecasting Responses** - No forecasting tools	a) National Forest Strategy **Type** I, some E **Monitoring program** - No national biodiversity monitoring program - CCFM C&I framework provides a platform to compile data - National Forest Inventory - Aggregation of sub-level data sources from 25 metrics, 5-10 yr re-measurement interval - Blue ribbon panel evaluation	a) National Forest Strategy - CCFM C&I reports - NFS midterm and final reports - NFS Performance indicators (under development) - Adjustment based on recommendations of blue ribbon panel.
		b) Canadian Biodiversity Strategy **Vision** A society that lives and develops as part of nature, values the diversity of life, takes no more than can be replenished and leaves to future generations a nurturing and dynamic world, rich in its biodiversity -Developed by Federal/ Provincial / Territorial governments **Goals** 1) Conservation and Sustainable Use 2) Ecological Management 3) Education and Awareness 4) Incentives and Legislation 5) International Cooperation - Provide guidance for provincial/ territorial biodiversity strategies	b) Canadian Biodiversity Strategy - 5 goals are supported by strategic directions - Outcomes framework (under development) **Forecasting Responses** - No forecasting tools	b) Canadian Biodiversity Strategy **Type** I some E **Monitoring Program** - No dedicated program - Data is compiled from diverse initiatives i.e. EMAN, NatureServe, Parks Canada Ecological integrity monitoring, Christmas bird count, CCFM C&I, etc	b) Canadian Biodiversity Strategy -National Reports to CBD (1998, 2001, 2005) -Thematic reports on forest program of work to CBD - Audits by the Commissioner of the Environment and Sustainable Development (CESD) - Adjustment reactive to CESD reports - Adjustment will be facilitated by the outcomes framework under development

[1]Type of monitoring: I = implementation, E = effectiveness, V = validation

implementation of the strategy is to develop criteria and indicators with associated benchmarks for biodiversity and to improve biodiversity inventory, monitoring and assessment programs to support reporting on the state of Ontario's biodiversity every five years starting in 2010.

The province of Alberta, through its Alberta Forest Legacy and proposed Forest Management Planning Standard, both committed to adaptive management, took a decisive step towards its adoption at a provincial-scale with the development of the Alberta Biodiversity Monitoring Program (ABMP) (Stadt *et al.* in press). Table 1 shows how the results from this effectiveness monitoring program will provide objective information to policy experts, managers, scientists, and the general public (ABMP Management Board 2005). The program was initiated by a broad range of partners from government, industry, non-government organizations and academia. For example, both Millar Western Forest Products Ltd. and Foothills Model Forest have been actively involved in the development of the ABMP through sharing of expertise and collaborative research projects.

Multi-scale Linkages through C&I: Progress and Challenges

Biodiversity, in the CBD context, with co-objectives of conservation, sustainable use and benefit-sharing, implemented through an ecosystem approach, may be proposed as a surrogate for sustainable development. Translating this broad concept with a multitude of wide-ranging stakeholders into practical activities, monitoring responses, and assessing progress relative to specific targets however, continues to be a challenge (Green *et al.* 2005).

The CBD decision VII/11 recognizes sustainable forest management as a means of applying the ecosystem approach to forests and the United Nations Forum on Forests resolution 4/3 urges countries to use C&I to monitor national policy frameworks and improve informed decision-making. Furthermore, the joint task force to improve and streamline forest-related reporting, comprising the 14 major forest-related international organizations, institutions and convention secretariats making up the Collaborative Partnership on Forests, has agreed on an information framework built around the seven themes, common to the nine on-going international C&I processes. Further contributing to improved reporting, these same themes, which include biological diversity, are being used as a basis for the standardization of definitions and data collection for the Food and Agricultural Organization's Global Forest Resources Assessment (GFRA). Efforts are now underway to identify how the GFRA, through its seven thematic areas can provide information for reporting on the 2010 target (FAO n.d.). At the national level, Forest Ministers attending the October 2005 joint meeting of the Canadian Councils of Wildlife, Fisheries and Aquaculture, Forests and Endangered Species Ministers, made a commitment to develop an outcomes oriented framework to report on the 2010 target.

The CCFM C&I national policy framework connects international, provincial/territorial, regional and local processes and community initiatives for sustainable forest management and at least one forest certification scheme. This linkage, illustrated in Fig. 1, highlights the potential for the C&I framework as an enabling mechanism to integrate cross-scale adaptive management of Canada's biological resources. Cycles of adaptive management provide the feedback mechanism to orient policies and steer management actions, compensating for incomplete knowledge about the functioning of the system. Adaptive management requires continually revised sources of best available information to adjust and feed new cycles across spatial scales and political jurisdictions. Using the C&I framework as a common mechanism for information transfer across scales ensures complementarity of information and eliminates duplication in monitoring and reporting. This flow of information permits integration of biodiversity and forest legislation with planning, management, monitoring, reporting and certification activities. Information on biodiversity status and trends, communicated through C&I reporting, allows appropriate adjustments to be made in the policy chain. Whereas adjustments to management activities are direct (i.e., scale specific), policy adjustments can either be direct or indirect through a trickle-down effect.

In addition to cross-scale and cross-jurisdictional harmonization, some countries have expanded the C&I framework as a mechanism to integrate monitoring and reporting across sectors. In Australia, the Montreal Process C&I framework provides the basis for meeting regional, national and international reporting requirements for Regional Forest Agreement monitoring, the State of the Forest, and the State of the Environment reports. In the U.S.A., it has provided the groundwork for the development of parallel resource indicator monitoring programs such as the Sustainable Roundtables on rangelands, minerals and energy. In Canada, while there are some sectoral national indicator processes, such as the National Agri-health and Analysis Reporting Program, Parks Canada Agency Ecological Integrity Monitoring, the Indicators for Coastal and Marine Management, and the National Environmental Indicators, each process has its own framework. Adoption of a common or complementary framework, with common monitoring grids and protocols, is an initial step toward integration of these sustainable development initiatives across sectors.

The commitment, inherent to sustainable forest management, to manage forests for a multitude of benefits has led to the incorporation of new attributes such as biodiversity, into forest inventories. The renewal of Canada's National Forest Inventory (NFI) to provide a forest measurement and monitoring system for the CCFM C&I framework (Gillis *et al.* 2005) facilitates the capacity for cross-scale integration. The only extensive network of monitoring plots, covering 1% of the land base across the country, the NFI provides a useful skeletal national framework for collecting and aggregating information on biodiversity. Aggregation of multi-scale, multi-source and non-standardized data sets is, however, a complex task and will only occur by design. In order to nationally aggregate information collected at various scales, and make it meaningful to policy-makers and the public, protocols for data collection should be harmonized (Puumalainen *et al.* 2002). The NFI photo-based and ground level plots, enhanced through remote sensing, provide complete coverage of forested areas on 25 attributes, many of which contribute data or can be used to derive information on biodiversity. The plot-based observational units on the national grid have common data standards and procedures

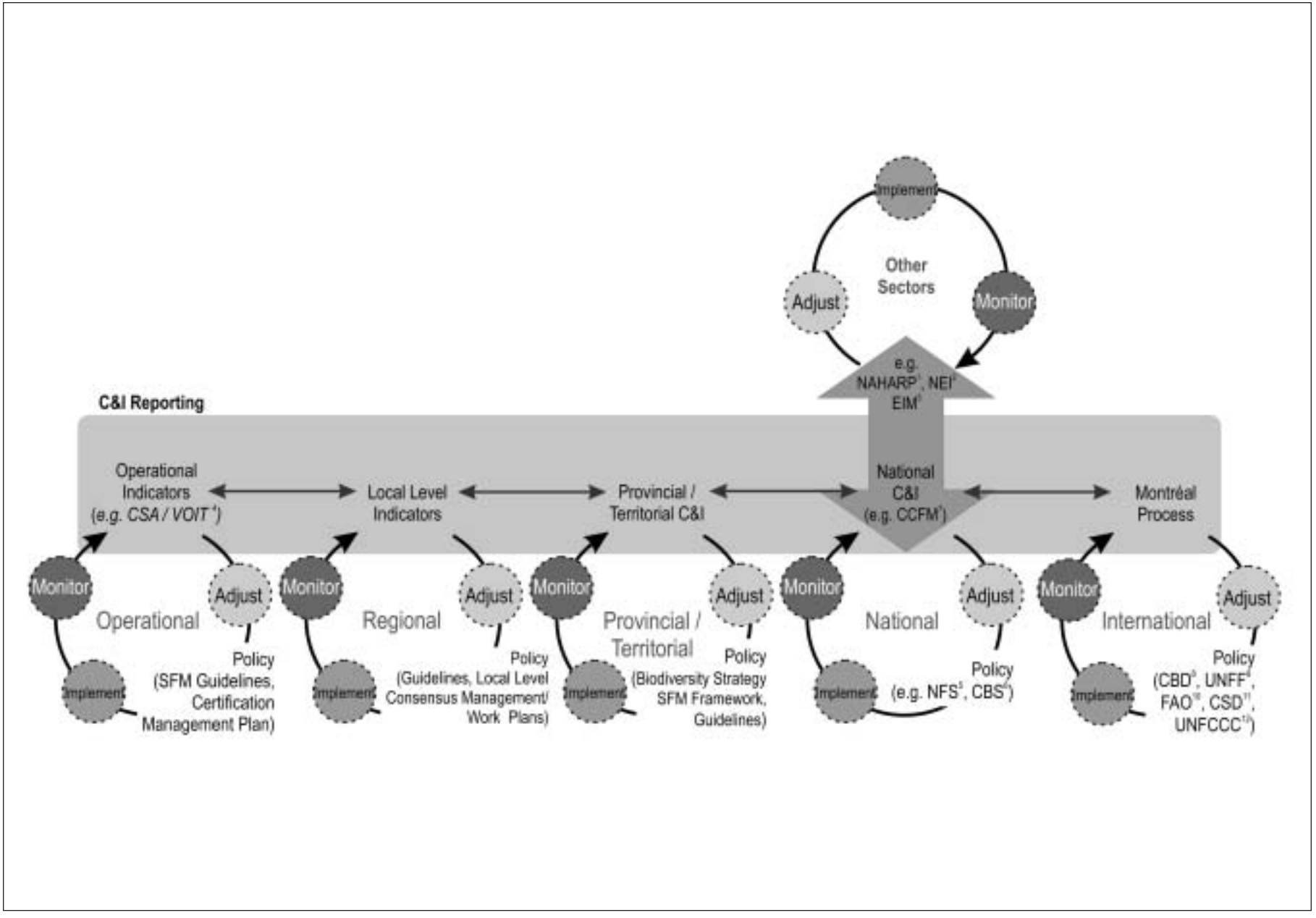

Fig. 1. Criteria and indicators (C&I) of sustainable forest management (SFM): an enabling tool to integrate cycles of adaptive management across spatial sales, jurisdictions and sectors.

from which interagency partnerships and monitoring programs, such as Parks Canada Ecological Integrity Monitoring Program and Alberta Biodiversity Monitoring Program, have already developed. Linking observational data from these monitoring programs with the vast amount of currently inaccessible information from biological collections and making it readily available would greatly expand baseline information for assessing the status of sustainable management of Canada's forest biodiversity. Newton and Kapos (2002) suggested that communicating meaningful information on the results of management actions to a wide variety of stakeholders is facilitated when there is a core set of indicators, common across scales.

The case studies outlined in Table 1, selected among a growing number of examples, demonstrate how adaptive management is currently being applied at various scales and identifies some gaps. Commitments towards the implementation of adaptive management principles for the conservation and sustainable use of forest biodiversity are part of the National Forest Strategy (Strategic themes 5 and 8) and the Canadian Biodiversity Strategy (Goal 1d). An adaptive approach to the management of forest resources is often incorporated into provincial/territorial legislation and forest management policies. Although policy drivers exist, the mechanisms to make forest biodiversity data available for the assessment, reporting and adjustment phases at the landscape to national scales are not yet well established. National reports on sustainable forest management and biodiversity, currently generated from available — often incomplete — data sets and information, are of limited use to decision-makers on the success or impact from policy implementation (Failing and Gregory 2003). Efficiency of data collection and availability of biodiversity information for decision-makers could be greatly improved through standardization of design to allow aggregation of monitoring data from existing government, industry, community programs and academic studies at national, provincial/territorial, regional or local levels.

Rempel *et al.* (2004) emphasize that while an effective monitoring framework is essential to achieving adaptive management, the importance of using the framework to learn adaptively is equally important. In order for learning to occur, a formal mechanism for responding to new knowledge must be in place. The Values, Objectives, Indicators and Targets framework (VOIT) associated with the Canadian Standards Association (CSA) sustainable forest management standard, (CSA-Z809-02) (Canadian Standards Association 2003) provides a good example of how the CCFM C&I framework, applied at the forest management area, can be used as a learning tool. The standard provides elements relevant for the management-level scale for each criterion of the CCFM framework. Organizations applying for CSA certification must develop the values, objectives, indicators and targets associated with each element and propose a monitoring and measuring scheme. While proposed targets are often associated with provincial/territorial or national legislation, many go beyond existing legislation requirements (Abitibi-Consolidated 2004, Hinton Wood Products 2005). The monitoring associated with this process generates valuable information that could also be captured for analyzing the status of Canada's forest biodiversity. At the national level, the CCFM framework is primarily used for reporting with little focus on its potential for mutual learning and sharing of experiences. Integrating C& I into the daily operations of governments or other organizations would also enhance opportunities for learning at the national and landscape scales. The development of national goals or targets would allow the potential of the CCFM C&I as a tool, not only for reporting, but also for planning and assessment, and as a driver of adaptive management, to be fully realized.

The establishment of targets linked to policies and forest management plans is appearing in some provincial C&I reports, extending the adaptive management concept beyond the management unit level. International and national level frameworks (e.g., Montréal Process, CCFM C&I, CBS) generally lack goals or targets, thus compromising the assessment and adjustment stages and the associated learning that accompanies these activities. The development of the outcomes-oriented framework for tracking progress on the 2010 target to significantly reduce the current rate of biodiversity loss, recently supported by federal, provincial and territorial Ministers, will require the establishment of national targets. In place for more than ten years and applicable across all spatial scales, the CCFM C&I framework provides a focal point for integration with other sectors and across landscapes and positions the forest sector well to respond to this commitment. National level targets, essential to determine if the status of biodiversity is improving or getting worse or to demonstrate the effectiveness of policy actions (The Royal Society 2003) and the associated monitoring capacity, however, remain as gaps.

Having a National Forest Strategy that has served as a template for many other countries, being one of the first industrialized countries to sign the CBD, and an initiator of international discussion on criteria and indicators, Canada has a track record as a world leader in conservation and sustainable management of forests. Based on the utility and relevance of the CCFM C&I as an integrative framework for implementing international biodiversity and sustainable development commitments, this paper points to C&I as a synergistic mechanism for implementing National Biodiversity Strategies and Action Plans and National Forest Strategies as yet another example where Canada can continue to provide leadership in sustainable development. The paper also identifies existing gaps and suggests cost-effective opportunities for addressing them. Adaptive management is suggested as an appropriate way to deal with the variability and uncertainty associated with management of ecosystems, particularly in the context of global change (Peterson *et al.* 1997, Kellomäki and Leinonen 2005). The selected case studies presented here also show that criteria and indicators of sustainable forest management, superimposed on a national monitoring grid such as the NFI, can serve as the integrative road map to apply adaptive management and link it across spatial scales. This road map for the forest sector lends itself to integration across sectors and landscapes. Full implementation could provide a model for ecosystem-based decision-making, improving Canadians' awareness, governance of and participation in the shaping of future policies to manage, extend and share the benefits derived from biological resources.

Acknowledgements

The authors thank Mark Gillis, Bonnie James, John Stadt and Sylvain Savard for their helpful comments on the manuscript and Sandra Abi-Aad for assistance with graphics.

References

Abitibi-Consolidated. 2004. Mackenzie Woodlands Sustainable Forest Management Plan – Appendix B VOIT description. Abitibi-Consolidated. Forest Certification. Mackenzie Region Division. Accessed January 17th 2006, at http://www.abitibiconsolidated.com/aciwebsitev3.nsf/site/en/images/pdf/MACK_APP_B_DEC1.pdf/$file/MACK_APP_B_DEC1.pdf

ABMP Management Board. 2005. The Alberta Biodiversity Monitoring Program: Program Overview and Consultation Backgrounder. Alberta Biodiversity Monitoring Program. Accessed January 17th 2006, at http://www.abmp.arc.ab.ca/Documents/Backgrounders/Biodiversity%20final%20consult%20report%20and%20appendix_AUG_16_KB.pdf

Baker, J.A. 2000. Landscape Ecology and Adaptive Management. *In* A.H. Perera, D.L. Euler and I.D. Thompson (eds.). Ecology of a Managed Terrestrial Landscape: Patterns and Processes of Forest Landscapes in Ontario. pp. 311–322. UBC Press, Ontario.

Bunnell, F.L. and B.G. Dunsworth. 2004. Making adaptive management for biodiversity work- the example of Weyerhaeuser in coastal British Columbia. For. Chron. 80: 37–43

British Columbia (BC) Forest Service. 2005. Ministry of Forest and Range. Province of British Columbia. Accessed January 19th 2006 at http://www.for.gov.bc.ca/hfp/archives/amhome/amhome.htm

Canadian Biodiversity Strategy. 1995. Canadian Biodiversity Strategy: Canada's Response to the Convention on Biological Diversity. Biodiversity Convention Office. Hull, QC. 80 p.

Canadian Council of Forest Ministers (CCFM). 1997. Criteria and Indicators of Sustainable Forest Management in Canada: Technical Report 1997. Natural Resources Canada, Ottawa, ON. 137 p.

Canadian Council of Forest Ministers (CCFM). 2000. Criteria and Indicators of Sustainable Forest Management in Canada: National Status 2000. Natural Resources Canada, Ottawa, ON. 122 p.

Canadian Council of Forest Ministers (CCFM). 2003. Defining Sustainable Forest Management in Canada – Criteria and Indicators 2003. Natural Resources Canada, Ottawa, ON. 20 p.

Canadian Standards Association. 2003. CAN/CSA-Z809-02 Sustainable Forest Management: Requirements and Guidance. Canadian Standards Association, Mississauga, ON. 51 p.

Carignan, V. and M.-A Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. Environmental Monitoring and Assessment 78: 45–61.

Commission d'étude sur la gestion de la forêt publique québécoise. 2004. Rapport de la Commission d'étude sur la gestion de la forêt publique québécoise. 307 p. Accessed 31 January 2006 at http://www.commission-foret.qc.ca/rapportfinal.htm

Committee to Evaluate Indicators for Monitoring Aquatic and Terrestrial Environments. 2000. Ecological Indicators for the Nation. National Academy Press, Washington, D.C. 180 p.

Convention on Biological Diversity (CBD). 1995. Report of the second meeting of the conference of the parties to the Convention on Biological Diversity. UNEP/CBD/COP/2/19 (Decision II/8). Convention on Biological Diversity. Conference of the Parties – background and status. Accessed January 17th 2006 at www.biodiv.org/decisions/default.aspx?m=COP-02&id=7081&lg=0

Convention on Biological Diversity (CBD). 2000. Report of the fifth meeting of the conference of the parties to the Convention on Biological Diversity. Convention on Biological Diversity. Conference of the Parties – background and status. Accessed January 17th 2006 at www.biodiv.org/decisions/default.aspx?m=COP-02&id=7081&lg=0

Convention on Biological Diversity (CBD). 2004. Report of the seventh meeting of the conference of the parties to the Convention on Biological Diversity. UNEP/CBD/COP/7/11(Decision VII/11) Convention of Biological Diversity. Conference of the Parties. Decisions. Accessed January 19th 2006 at http://www.biodiv.org/decisions/default.aspx?m=COP-07&id=7748&lg=0

Doyon, F. 2003. Western Newfoundland Model Forest Biodiversity Assessment Project: Overview. (PPT Presentation). Institut Québécois d'Aménagement de la Forêt Feuillue. Québec. Available at http://www.wnmf.com/main/partners/working/biodiversity/PDF/BAPoverview.PDF

Duinker, P.N. and L.M. Trevisan. 2003. Adaptive Management: Progress and Prospects for Canadian Forests. Chapter 21 *In* V. Adamowicz, P. Burton, C. Messier and D. Smith (eds.). Toward Sustainable Management of the Boreal Forest: Emulating Nature, Minimizing Impact and Supporting Communities. pp. 857–892. NRC Research Press, Ottawa, ON,

Failing, L. and R. Gregory. 2003. Ten common mistakes in designing biodiversity indicators for forest policy. Journal of Environmental Management 68(2): 121–132.

Food and Agricultural Organization (FAO). (n.d.). What is Sustainable Forest Management? FAO. Collaborative Partnership on Forests. Accessed January 17th 2006 at http://www.fao.org/forestry/site/24447/en

Gaston, K.J., R.L. Pressey and C.R. Margules. 2002. Persistence and vulnerability: retaining biodiversity in the landscape and in protected areas. J. Biosci. 27(4-2): 361–384.

Gillis, M.D., A.Y. Omule and T. Brierley. 2005. Monitoring Canada's forests: The National Forest Inventory. For. Chron. 81(2): 214–221.

Government of Ontario. 2005. Protecting what sustains us: Ontario's Biodiversity Strategy. Available at http://www.mnr.gov.on.ca/mnr/pubs/biodiversity/OBS_english.pdf

Green, R.E., A. Balmford, P.R. Crane, G.M. Mace, J.D. Reynolds and R.K. Turner. 2005. A Framework for Improved Monitoring of Biodiversity: Responses to the World Summit on Sustainable Development. Conserv. Biol. 19 (1): 56–65.

Haüsler, A. and M. Scherer-Lorenzen. 2001. Sustainable forest management in Germany: The ecosystem approach of the biodiversity convention reconsidered. German Federal Agency for Nature Conservation, Bonn, Germany. 65 p.

Hinton Wood Products. 2005. Sustainable Forest Management Plan. Hinton, AB. 165 p.

Holling, C.S. 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, New York, NY. 377 p.

Johnson, B.L. 1999. The role of adaptive management as an operational approach for resource management agencies. Conserv. Ecol. 3(2): 8. Accessed January 17th 2006 at http://www.consecol.org/vol3/iss2/art8/

Kapos, V. and S.F. Iremonger. 1998. Achieving global and regional perspectives on forest biodiversity and conservation. *In* P. Bachmann, M. Kohl and R. Paivinen. Assessing Biodiversity for Improved Forest Planning. EFI Proceedings No.18. pp. 3–14. Kluwer Academic Publishers, Dordrecht, NL.

Kellomäki, S. and S. Leinonen (eds.). 2005. Management of European forests under changing climatic conditions. European Union (SilviStrat). Joensuu, Finland. Accessed March 6th 2006 at www.dow.wau.nl/forestry/pdf-files/ Kellomaki%20et%20al%20%202005.pdf

Kneeshaw, D.D., A. Leduc, P. Drapeau. S. Gauthier, D. Paré, R. Carignan, R. Doucet, L. Bouthillier and C. Messier. 2000. Development of integrated ecological standards of sustainable forest management at an operational scale. For. Chron. 76(3): 481–493.

Lee, K.N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Island Press. Washington, D.C. 243 p.

Lindenmayer, D.B. and J.F. Franklin. 2002. Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach. Island Press, Washington, DC. 351 p.

Loyche Wilkie, M., P. Holmgren and F. Castañeda. 2003. Sustainable forest management and the ecosystem approach: two concepts, one goal. Forest Management Working Paper FM 25. Forest Resource Development Service, Forest Resource Division, Food and

Agriculture Organization of the United Nations, Rome. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/008/j1244e/j1244e00.htm

MacDonald, G.B., R. Arnup and R.K. Jones. 1997. Adaptive forest management in Ontario: A literature review and strategic analysis. Ontario Forest Research Institute, Ontario Ministry of Natural Resources. Sault Ste Marie, ON, For. Res. Info Pap. 139. 38 p.

MacDonald, G.B., J.A. Rice, J. McLaughlin, J. Pearce, L. Venier, K. Nystrom and P. Meek. 2003. Developing sustainable mixedwood practices in a stand-level adaptive management (SLAM) framework: project establishment. Stand-Level Adaptive Management. Forest Research Information Paper no. 157. Accessed January 17th 2006 at http://www.mixedwood.ca/data/report_157.pdf

MacDonald, G.B. and J.A. Rice. 2004. An active management case study in Ontario boreal mixedwood stands. For. Chron. 80(3): 391–400.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. Nature. 405: 243–253.

Meffe, G. K. and C. R. Carroll 1994 . Principles of Conservation biology, Sinauer Sunderland, MA. 600 p.

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-Being: Biodiversity Synthesis. World Resources Institute. Washington, D.C. 86 p. Accessed January 25th 2006 at http://www.millenniumassessment.org/proxy/document.354.aspx

Montreal Process Working Group. 1998. "Santiago Declaration" – Statement on Criteria and Indicators for the Conservation and sustainable management of temperate and boreal forests. Montreal Process. What is the Montreal Process? Accessed January 5 2006 at http://www.mpci.org/rep-pub/1995/santiago_e.html

Moreau, A., S. Sougavinski and F. Doyon. 2002. Ecosystem-based Forest Management in Canada: Survey of Projects and Current Situation. Unpublished. 41 p.

Mosquin, T., P.G. Whiting and D.E. McAllister. 1995. Canada's Biodiversity: The Variety of Life, Its Status, Economic Benefits, Conservation Costs and Unmet Needs. Canadian Museum of Nature. Ottawa, ON. 293 p.

Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves and H.H. Welsh. 1999. The strategy and design of the Effectiveness Monitoring Program for the Northwest Forest Plan. General Technical Report PNW-GTR-437, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 138 p.

Murray, C. and D.R. Marmorek. 2004. Adaptive Management: A spoonful of rigour helps the uncertainty go down. Proceedings of the 16th Annual Society for Ecological Restoration Conference, Victoria, BC, August 24–26, 2004.

National Forest Strategy Coalition. 2003. National Forest Strategy 2003–2008: A Sustainable Forest – the Canadian Commitment. Canadian Council of Forest Ministers. Ottawa, ON. 26 p.

Neave, D., E. Neave, T. Rotherham and B.J. McAfee. 2002. Canada's Forest Biodiversity: A decade of progress in sustainable management. Natural Resources Canada's Canadian Forest Service. Ottawa, ON. 57 p.

Newton A.C. and V. Kapos. 2002. Biodiversity indicators in national forest inventories. Unasylva 210 – Forest assessment and monitoring. 53: 56–71. Accessed May 30th 2005 at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/005/y4001e/Y4001E09.htm

Noss, R.F. 1999. Assessing and monitoring forest biodiversity: a suggested framework and indicators. Forest Ecology and Management 115: 135–146.

Noss, R.F. 2004. Some suggestions for Keeping National Wildlife Refuges Healthy and Whole. Natural Resources Journal 44: 1093–1111.

Nyberg, B. 1999. An introductory Guide to Adaptive Management for Project Leaders and Participants. B.C. Forest Service, Victoria, B.C. Accessed January 17th 2006 at http://www.for.gov.bc.ca/hfp/publications/00185/Introductory-Guide-AM.pdf

Office of the Auditor General of Canada (OAG). 1998. Chapter 4, Canada's Biodiversity Clock Is Ticking. Office of the Auditor General of Canada. Report of the Commissioner of the Environment and Sustainable Development. Ottawa. Accessed January 17, 2006 at http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c804ce.html

Office of the Auditor General of Canada (OAG). 2000. Chapter 9. Follow-up of Previous Audits: More Action Needed. Office of the Auditor General of Canada. Report of the Commissioner of the Environment and Sustainable Development. Ottawa. Accessed January 17th 2006 at http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c009ce.html

Office of the Auditor General of Canada (OAG). 2005. Chapter 3. Canadian Biodiversity Strategy — A Follow-Up Audit. Office of the Auditor General of Canada. Report of the Commissioner of the Environment and Sustainable Development. Accessed January 17th 2006 at http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c20050903ce.html

Olewiler, N. 2004. The value of Natural Capital in Settled Areas of Canada. Ducks Unlimited and the Nature Conservancy. 36 p.

Packer, M.J. and D.W. MacDonald. 2002. Business and biodiversity: Existing threats ? emerging opportunities. Business & Biodiversity: The Handbook for Corporate Action. Earthwatch Europe, IUCN and WBCSD.60 p.

Peterson, G., G.A. De Leo, J.J. Hellmann, M.A. Janssen, A. Kinzig, J.R. Malcolm, K.L. O'Brien, S.E. Pope, D.S. Rothman, E. Shevliakova and R.R.T. Tinch. 1997. Uncertainty, Climate Change, and Adaptive Management. Conservation Ecology [online] 1(2): 4. Available from the Internet at http://www.consecol.org/vol1/iss2/art4/

Prabhu, R.C. J.P. Colfer and R.G. Dudley. 1999. Guidelines for developing, testing and selecting criteria and indicators for sustainable forest management. Criteria and Indicators toolbox series, Toolbox #1. CIFOR, Jakarta, Indonesia. 85 p.

Puumalainen, J., P. Anglestam, G. Banko, J. Brandt, M. Caldeira, C. Estreguil, S. Folving, J.M. Garcia del Barrio, M. Keller, P. Kennedy, M. Kohl, M. Marchetti, P. Neville, H. Olsson, J. Parviainen, H. Pretzsch, H.P. Ravn, G. Stahl, E. Tomppo, J. Uuttera, A. Watt, B. Winkler, T. Wrbka, 2002. Forest Biodiversity – Assessment Approaches for Europe. European Commission. 128 p.

Rempel, S.R., D.W. Andison, S.J. Hannon. 2004. Guiding Principles for developing an indicator and monitoring framework. For. Chron. 80: 82–90.

Salafsky, N., R. Margoluis and K. Redford. 2001. Adaptive Management: A tool for Conservation Practitioners. The Biodiversity Support Program. 100 p.

Stadt, J.J., J. Schiek and H.A. Stelfox. In press. Alberta Biodiversity Monitoring Program – Monitoring Effectiveness of Sustainable Forest Management Planning. Environmental Monitoring and Assessment. (In press).

Taylor, L., L. Kremsater and R. Ellis. 1997. Adaptive management of forest in British Columbia. Ministry of Forests – Forest Practices Branch, Victoria, B.C. 93 p.

The Royal Society. 2003. Measuring Biodiversity for Conservation. Policy document 11/03. Accessed January 19th 2006 at http://www.royalsociety.org/displaypagedoc.asp?id=6712

United Nations (UN). 1992. Report of the United Nations Conference on Environment and Development (Rio de Janeiro, 3–14 June 1992) – Annex III Non-Legally Bonding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation And Sustainable Development Of All Types Of Forests. Accessed January 5, 2006 at http://www.un.org/documents/ga/conf151/aconf15126-3annex3.htm

United Nations Environment Program (UNEP). 2005. One Planet Many People: Atlas of our Changing Environment. United Nations Environment Programme's Division of Early Warning and Assessment. Nairobi, Kenya. Accessed December 14, 2005 at http://www.na.unep.net/OnePlanetManyPeople/index.php

Upper Lakes Environmental Research Network (ULERN). 2004. Developing Sustainable Mixedwood Practices in a Stand Level Adaptive Management Framework (SLAM). Accessed January 17th 2006 at http://www.ulern.on.ca/slam/SLAMFINAL.pdf

Van Damme, L., J.S. Russell, F. Doyon, P.N. Duinker, T. Gooding, K. Hirsch, R. Rothwell and A. Rudy. 2003. The development and application of a decision support system for sustainable forest management on the Boreal Plain. J. Environ. Eng. Sci. (2): S23–S34.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conserv. Ecol. 1(2):1. Accessed January 17th 2006 at http://www.consecol.org/vol1/iss2/art1/

Western Newfoundland Model Forest (WNWF). 2003. BAP: Components working together to create larger biodiversity assessment structure. Forest Watch (Summer 2003). Accessed January 31 2006 at http://www.wnmf.com/main/whatsnew/publications/2003%20spring%20summer%20forest%20watch.pdf

Work, T.T., J.R. Spence, W.J.A. Volney, L.E. Morgantini and J.L. Innes. 2003. Integrating biodiversity and forestry practices in western Canada. For. Chron. 79(5): 906–916.