Integrating biodiversity and forestry practices in western Canada

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In western Canada, some forestry companies are attempting to incorporate conservation of biodiversity as a new management priority. Here we provide a review of management strategies currently implemented through a survey of companies in this region. Representatives from fourteen companies were asked to complete 30 questions designed to assess six broad issues, all of which are important for integrating biodiversity protection with timber production. Differences in provincial legislation were a major factor contributing to the prioritization of biodiversity objectives. All companies stressed that a variety of stand age classes and compositions was important for maintaining biodiversity. Green tree retention was a common approach proposed by all companies. Definitions of green tree retention varied significantly among companies, ranging from residual material left following standard clearcutting to merchantable trees selected specifically to foster wildlife and biodiversity. Most companies have proposed some monitoring aimed at biodiversity, although most plans target habitat structural features rather than directly monitoring species.

Key words: biodiversity, sustainability, monitoring, green tree retention, coarse filter, fine filter, rare and threatened species, forest industry

Dans l'Ouest canadien, certaines compagnies forestières tentent d'incorporer la conservation de la biodiversité en tant que nouvelle priorité de l'aménagement. Nous élaborons dans ce texte une revue des stratégies d'aménagement présentement implantées suite à un sondage des compagnies de cette région. Les représentants de quatorze entreprises ont eu à répondre à trente questions conçues pour évaluer six directions générales, toutes jouant un rôle important dans l'intégration de la protection de la biodiversité au sein de la production de bois. Les différences au niveau des législations provinciales ont constitué le plus important facteur de priorité des objectifs de biodiversité. Toutes les compagnies ont souligné que la variété parmi les classes d'âge et la composition des peuplements étaient importantes au maintien de la biodiversité. La rétention de bandes vertes était une approche commune proposée par toutes les compagnies. La définition de la rétention des bandes vertes variait de façon importante parmi les compagnies, allant de matériel résiduel laissé debout selon les normes de coupe à blanc, à des arbres marchands choisis spécifiquement pour favoriser la faune et la biodiversité. La plupart des compagnies ont proposé une certaine surveillance de ce qu'est la biodiversité, même si la plupart des plans visent les éléments structuraux de l'habitat plutôt que les espèces directement sous surveillance.

Mots-clés: biodiversité, durabilité, surveillance, rétention de bandes vertes, filtre grossier, filtre fin, espèces rares et menacées, industrie forestière

Introduction

The Canadian forest industry seeks to adopt conservation of biodiversity as a new management priority on extensively managed public land. This new priority is to coexist with the traditional priority of timber production. However, many questions remain about how biodiversity is defined and assessed and how best to manage for the maintenance of species and ecosystem processes over the long-term. Furthermore, trade-offs between fibre production and biodiversity protection have been scarcely studied. Nonetheless, actions intended to conserve biodiversity clearly are penetrating forest management plans and this new paradigm has enormous potential to alter the constitution of future forest landscapes. The question of the day is: will changes in forest management matter ecologically? According to a recent review of tactics adopted in Fennsocandia, there is surprisingly little rigorous evidence that these altered management regimes will preserve biodiversity in the way that we desire (Larsson and Danell 2001). In fact, most of the tactics being applied fall into the realm of untested hypotheses (Spence *et al.* 1999), even though many biologists and forest scientists believe that the altered approach is better than what formerly prevailed. Before the question can be thoroughly assessed Canada-wide, it is essential to review what forest companies are actually doing on forested landscapes.

Forestry in Canada is characterized by extensive regional variability in forest type, topography and history, regulatory differences among provinces, and corporate predilection or ability to consider biodiversity in planning. Furthermore, the issue is muddied by multiple definitions of biodiversity and the large range across taxa in the scale appropriate for assessing impact. Thus, it is not surprising to find considerable variation in the emphasis that Canadian forestry companies currently place on biodiversity in managed forests. Two aspects of the definitional problem seem central to us in evaluating progress in this area. First, it is important to recognize that effective biodiversity conservation should flow from maintaining a representation of species associated with all pre-harvest forest types and age classes over the landscape, and not from arguments about increasing species richness. Second, the concept of biodiversity refers to *all* species, not only those that are targeted by specific management activity, projected in large-scale habitat suitability models and proposed for tracking in most current management plans.

Effective management that is sensitive to the needs of biodiversity will aim to retain all species on forested landscapes. The most sensitive species may require specific fine-filter

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provisions or need to be "life-boated" in parks and reserves (Lindenmayer *et al*. 2000). However, loss of species as a result of industrial activity, no matter how insignificant the species may appear to some, is unacceptable in biodiversity-sensitive management (Simberloff 1999, Spence *et al.* 1999). A significant problem is that the regulatory framework can significantly constrain corporate ability to develop effective management regimes. Present regulatory guidelines range from legislative mandates providing management guidelines (BC Forest Practices Code, Biodiversity Guidelines) to policy statements that provide a vision for forest management but do not specify targets. In evaluating corporate responses to this goal, it is important to recognize that regulatory constraint probably homogenizes approaches, especially within provinces.

In this paper, we describe the early stages of the western Canadian move toward biodiversity-sensitive forestry in the context of new management plans and preliminary efforts at monitoring that are being laid out in the field. We have endeavoured to provide a "state of affairs" status report on woodland management for biodiversity protection and to compare how it has affected overall management across fourteen companies operating in British Columbia, Alberta, and Saskatchewan. We highlight the different perspectives and management approaches that exist among companies and underscore issues that require further investigation in order to more fully integrate biodiversity with timber harvesting and forest regeneration objectives.

Survey methods

Of the fifteen companies contacted in western Canada, only one company declined to participate in the survey. These companies collectively manage approximately 54% or 15 million ha of the commercial forest land in these three provinces (Saskatchewan Environment and Resource Management 1995, Brown and Green 2001, Schneider 2001). Thirty questions along with a brief set of instructional guidelines were sent to a representative of each company, usually the Woodlands Manager or in some cases an employee associated with developing woodlands management policy, before the survey was conducted.

Because of the broad definition of biodiversity and the varieties of interpretation, survey questions allowed a range of responses from brief statements to longer explanations and opinions. However, in a cover letter given to all participants, we asked survey participants to base their responses on a definition of biodiversity that included species associated with the so-called "non-timber" values of the forest such as (but not limited to) soil fertility, water quality, and wildlife habitat. Participants were asked to include (but again were not limited to) wildlife species, insects and other arthropods, plant species associated with the tree crop, rare or endangered species, and species that may play a functional role in the long-term sustainability of forest resources in this definition. Finally, we recognized the importance of genetic diversity of the tree crop to long-term sustainability of both timber resources and non-timber values and asked survey participants to consider this in their responses. The survey was designed to assess six different broad issues, all of which are important for integrating biodiversity protection with timber production objectives. These issues are described in general terms below. The full questionnaire is provided as Appendix 1.

The first section dealt with how biodiversity is prioritized within the company, with respect to timber management objectives. Survey participants were asked how land-holdings were prioritized for timber harvest and biodiversity, what proportion of land is set aside for biodiversity over the length of a rotation, and what is the present average and range of cut-block and reserve sizes. The purpose of these questions was to determine whether biodiversity is a concern during development of a management plan, or whether it is *de facto* implemented following timber management objectives. Furthermore, to the extent possible, we sought to describe the relative proportion of land-holdings allocated to each objective.

The second section was used to evaluate the importance of coarse-filter approaches (activities designed to maintain habitat features following harvest) to maintaining biodiversity and explore the role of green tree retention as a management tool. Participants were asked to estimate the proportion of retention areas that was potentially merchantable volume in order to determine whether companies incurred real cost in loss of merchantable volume, or alternatively, whether these areas would not be harvested anyway.

In the third section, participants were asked how the effectiveness of coarse-filter strategies was being monitored. If biodiversity was being monitored directly we asked them to summarize the efforts that were currently in place or planned, what variables were being measured (e.g., forest condition, habitat structure, indicator species), and how frequently monitoring was being conducted. Participants were also asked to explain the criteria by which success of strategies was evaluated. Also, within this section, participants were asked for information regarding fine-filter approaches to biodiversity such as managing threatened and rare species and the use of indicator species.

The fourth section provided estimates of how much direct corporate support for biodiversity had been in place or allocated for biodiversity objectives. The funds budgeted for monitoring efforts, research and development, and the number of positions created within the company were used as an indication of resources committed to biodiversity objectives.

The fifth section requested participants to describe changes in management within time frames of the last 5 and 10 years as well as to speculate on the major changes likely to occur in the next 10 years.

In the last section, participants were asked to identify the major knowledge gaps that limited their ability to build biodiversity objectives into their management planning. We also asked about other factors that might be most needed to integrate biodiversity with timber harvesting.

After industrial foresters had an opportunity to review and consider the questionnaire, surveys were conducted either by telephone or in person by the senior author. All interviews were recorded on audio tape and then transcribed. When participants could not be contacted directly, written responses to the survey were accepted. Survey responses were classified according to major themes and then tallied.

Results

Prioritizing timber and biodiversity objectives

At the broadest landscape level, prioritization of the harvestable landbase for timber harvesting and biodiversity objectives was largely predetermined by provincial regulations for forestry activities on Crown land. All companies interviewed noted that preliminary exclusion of certain regions and areas by the government occurs before any forest plan or forest management agreement (FMA) was approved.

Within the areas dealt with in the forest plans, prioritization of harvesting and biodiversity objectives varied regionally. In British Columbia, all companies stressed that specific targets for areas set aside for either late seral stages or biodiversity were defined by the Forest Practices Code and Biodiversity Guidebook (British Columbia Forest Service and British Columbia Environment 1995). One British Columbia company characterized its relationship with the provincial government as "half and half" in regard to prioritizing biodiversity objectives. It pointed out that the government designated old growth and mature areas to recruit into old growth, while the company designated placement of wildlife, reserve, and riparian patches.

In Alberta and Saskatchewan, a somewhat wider range of emphasis on biodiversity objectives was apparent. For two companies, requirements or allowances for biodiversity objectives were considered solely the responsibility of provincial government and were therefore not internally prioritized with timber harvesting objectives. Another company reported that it has changed its forest management practices to address biodiversity conservation with particular directives focused on managing caribou (*Rangifer tarandus*). Four other companies reported that they conducted some form of ecological classification or ecosite inventory that was linked to timber supply models to estimate the representation of given features, cover types, and age distributions under differing management strategies. Management strategies were judged acceptable if these simulations maintained a "historic" or "natural" range of variability of age classes and stand compositions. One company simulated natural disturbance patterns through modified fire models such as LANDIS. In another case, management strategies were reported to be based on modified habitat models that incorporate habitat requirements and the response of specific vertebrate taxa; however, the specific taxa and specific measures of habitat had yet to be chosen and the relationship to forest management was undefined.

When companies were asked whether a constant proportion of land was devoted to particular biodiversity objectives (e.g., late seral stages), all indicated that maintaining of a variety of age classes and compositions was a major theme for their approach. Companies from British Columbia reported the highest percentage of land left in late seral stages, with percentages following the recommendations of the provincial Biodiversity Guidebook. British Columbia companies reported that 3–60% of the landbase is to be maintained in late seral stages depending on regional biogeoclimatic zones and priorities for biodiversity mandated by provincial government. Companies based in Alberta and Saskatchewan maintained smaller areas in late seral stages ranging from 1–5% of the total landbase. However, one company reported having adopted a multiple rotation approach with a significantly higher proportion of the merchantable forest landbase retained in late seral stages (5–20% depending on ecological land classification and forest type). For one company, the proportion of age classes was allowed to drop to 50% of the pre-harvest age class distributions predicted by timber supply models during the course of a rotation. However, age class proportions were required to be 100% of the projected targets at the end of a rotation period. This provision was meant to allow flexibility in achieving predicted age class targets.

Survey participants considered the distribution of cutblock sizes and areas of standing residual to be as important as the overall proportion of land maintained devoted strictly to biodiversity. As expected, companies from British Columbia reported that the range in cutblock size was defined in the Biodiversity Guidebook. The largest variability in cutblock size was found in companies based in Alberta and Saskatchewan, particularly those operating in areas that emphasized caribou management (Table 1). Two participants suggested that the large range in cutblock sizes was a result of companies moving away from predefined cutblock sizes in a two-pass harvesting system to harvesting activities based on attempts to emulate the sizes that characterize natural disturbance patterns such as wildfire. The representative of one of these companies reported that cutblocks of 25 ha were placed adjacent to one another to form larger aggregate cutblocks exceeding 100 ha. Foresters from other companies predicted that cutblock sizes in the future are likely to increase, becoming as large as 1300 ha depending on the availability of merchantable trees.

Coarse-filter approaches to biodiversity

Coarse-filter approaches to maintaining biodiversity dominated the landscape strategies employed by all companies. All but one company reported that green tree retention was their most important approach for maintaining biodiversity in stands (Table 2). The single exception reported that green tree retention was important in large areas of similar-aged timber, but stated that they de-emphasized the role of green tree retention in areas where harvestable areas are intermixed with non-merchantable areas.

The BC companies we interviewed reported retention levels ranging from 2–12% of the cutblock area with clumped patches that ranged from 1–10 ha. Most of the companies characterized retention trees as merchantable, although one company expressed preference for leaving more wind-firm trees that tended to be non-merchantable. One BC company reported that reserve areas were comprised of non-merchantable timber left as single trees or clumps depending on overall worker safety issues. The range of merchantable volume in retention areas reported by all companies interviewed was 0–50%. In four cases, participants simply reported that reserve areas were composed of merchantable timber and did not specify relative proportions. The two Alberta companies that indicated 50% merchantable volume in reserve areas used a two-pass harvesting system, under which all reserve areas left for the second pass were also considered as green tree retention for biodiversity. Two Alberta companies reported 10–15% of pre-harvest merchantable volume being left as retention in roughly equal proportions of coniferous and deciduous trees. One Alberta company reported leaving 8% of the harvested forest landbase in late seral stages. The same company reported leaving 5% merchantable volume of deciduous species and 1% merchantable volume of coniferous species in harvest blocks. One Saskatchewan-based company reported that retention areas typically comprised 3% of the merchantable volume but could range from 0.5% to 13%, depending on the cutblock. Of the typical 3% retention, one-third was left as individual trees and two-thirds was left in aggregated blocks. Likewise, they also specified that 5% merchantable volume was left in late seral stages, and 1% was left as very late seral stages. Retention areas were generally similar in species composition to surrounding forest, with two exceptions. One company in British Columbia selected areas with older trees as reserves while an Alberta company selectively removed older trees from retention areas.

Table 1. Regional differences in size and range of cutblocks and retention areas

Province	Mean cutblock size (ha)	Range of cutblock size (ha) (upper limit of future cutblocks)
British Columbia	15–20	1–40
	Defined by Forest Practices Code	Defined by Forest Practices Code
British Columbia		
British Columbia	–	–
British Columbia	25	–
	Defined by Forest Practices Code	Defined by Forest Practices Code
British Columbia		
British Columbia	40–80	1–500
Alberta	26	2–500
Alberta	20–30	5–40 (800–1000)
Alberta	40	Up to 60 (1300)
Alberta	25	0.5–360
Alberta	25	200–500
Alberta	40	5–800
Saskatchewan	20	10–100s
Saskatchewan	40–60	5–700

Some companies managed reserve areas further to promote biodiversity. One British Columbia company, for example, indicated that when areas of old growth were not available within an area, mature areas were selected as reserves and then periodically thinned to promote old-growth stand characteristics such as large trees with large branches. This company also used prescribed burning in some areas to limit in-growth and to promote old-growth characteristics. Six other companies indicated that additional considerations for reserve size, stream protection, retention of snags, and stand composition were considered important factors in establishment of reserve areas. Five companies actively managed leave areas by creating habitat for cavity nesting birds and snag-associated fauna or selectively enhancing or reducing conifer species. Of these, one Alberta company promoted conifer species in retention areas by selectively removing aspen. One British Columbia and one Saskatchewan company selectively removed conifer species depending on other management considerations (e.g., hardwoods were often preferentially left in areas subject to windthrow, pines were preferentially removed from areas containing mountain pine beetle).

Ten of 14 companies responded that the areas they left to facilitate biodiversity did not include sensitive areas, and that these additional residual areas increase the total habitat available for biodiversity. In contrast, four of the six companies from British Columbia indicated that requirements for leave areas were overlapped with sensitive areas whenever possible in order to increase the area available to biodiversity and create a network of reserves. Likewise, one Alberta company reported linking leave areas to sensitive areas in an effort to increase the total area of reserves for biodiversity.

Monitoring and fine-filter management

Six companies indicated established or preliminary monitoring programs (Table 3). Of these companies, one BC and one Saskatchewan company indicated that tree regeneration in managed areas, a standard silvicultural variable, was the major component in monitoring programs. Two Alberta companies identified stand structure as the major component of monitoring efforts. Of these, one company conducted preliminary monitoring of habitat structural variables such as cutblock size and shape, coarse woody debris, and vertical stand structure. The other Alberta company indicated that long-term monitoring of variables such as coarse woody debris, vegetation and stand structure was conducted in permanent reference plots established throughout managed and leave areas. This company interpreted the effectiveness of retention areas through habitat supply models developed for seventeen vertebrate species. To date, only one of these habitat supply models has been validated through surveys of animal tracks.

Only two companies, one from BC and one from Alberta, indicated that they currently monitor wildlife species. The BC company reported that it currently monitors threatened and potentially threatened species as well as indicators of wildlife such as dens, middens, and feeding sites. The Alberta company reported monitoring mammals, nocturnal raptors, migratory birds and threatened and endangered species. Eight companies indicated that biodiversity monitoring within both leave areas and managed areas was in the planning stage or a future direction of the company but has yet to be implemented.

Indirect monitoring of biodiversity through indices of habitat suitability was the most common approach in monitoring programs reported by nine of the fourteen companies. Included in habitat suitability were related factors such as the amount of coarse woody debris, distribution of forest age classes, stream classifications and landscape and structural indices. Three companies indicated understory vegetation as an important factor included in monitoring efforts. Four companies planned to directly monitor species through surveys that record presence/absence, species richness, geographical range, and abundance of target species.

Both indirect and direct monitoring plans reported a large range of potential indicator taxa. The widest range of response came from BC companies. Proposed indicator taxa included tree species from standard forest inventories, threatened and endangered species, terrestrial vertebrates, and in two instances monitoring suites of organisms (as many as 270 species) with a variety of life histories and habitat associations. One BC company claimed to monitor all forest values through its integrated forest plan, but only monitored four classes of organisms (fish, terrestrial vertebrates, cyano-lichens, and rare plants). Alberta and Saskatchewan companies also proposed multi-taxa monitoring. In Alberta, the proposed Alberta Forest Biodiversity Monitoring Program may eventually monitor some yet-undefined suite of indicator taxa; however, this has not been an industry-driven initiative. Likewise in Saskatchewan, a monitoring program, currently under provincial review, consists of 45 variables including songbird, mammal, and vegetation diversity. Another Alberta company indicated population sizes of caribou to be the dominant factor included in any monitoring effort.

Criteria for selecting target taxa were justified on ecological, economic, political, and pragmatic grounds. While there was little consensus among companies in criteria for useful ecological indicators, each response had aspects of an overall view that indicators must be easy to sample, able to detect change, and cost-effective. In two instances, indicators were chosen because of their ability to reflect large-scale processes. Vertebrate taxa were chosen as indicators by one BC company because

Table 2. Regional differences in green-tree retention, reserve composition, and reserve management and placement

Province	Perceive green tree retention as important tool	% of retention areas by area[1] or volume[2]	Retention areas merchantable or non-merchantable	Species composition of reserve	Dominant species in reserve	Management activities within reserves	Reserves separate from sensitive areas
British Columbia	Yes	2%[1]	Non-merchantable	Similar to Pre-harvest	*P. menziesii, T. plicata, P. englemannii, A. balsamea*	Protection of streams and wildlife associated habitats	Yes
British Columbia	Yes	10–14%[1]	Both Merchantable and Non-merchantable	Remove *Pinus* species	*P. contorta*, interior *P. menziesii, Picea* spp.	No	Overlapped when possible
British Columbia	Yes	10–14%[1]	Both Merchantable and Non-merchantable	Similar to Pre-harvest	Interior *P. menziesii, P. contorta*	No	Yes
British Columbia	Yes	3–12%[1]	Merchantable	Similar to Pre-harvest, leave older trees	*T. heterophylla, A. balsamea, Picea* spp.	No	Overlapped when possible
British Columbia	Yes	Up to 20%[1]	Merchantable	Similar to Pre-harvest	–	Introduce cavities and snags	Overlapped when possible
British Columbia	Yes	–	Merchantable	Similar to Pre-harvest, in some instances make them more diverse than surrounding areas	*P. menziesii, P. ponderosa, Larix, Picea, Abies, Populus, Betula*	Thin in mature stands to achieve old-growth structure, Prescribed burning to remove in growth	Yes, Overlapped under certain conditions
Alberta	Yes	8%[2]	1–5% Merchantable	Similar to Pre-harvest	*P. tremuloides, P. glauca*	Leave variability in Stands	Yes
Alberta	Yes	15%[2]	Merchantable	All reserves	–	Promote conifer overstories through selective removal of aspen	Yes
Alberta	Yes	15%[2]	Merchantable	Similar to Pre-harvest	*P. tremuloides, P. glauca, P. balsamifera, Pinus spp.*	No	Yes, linked to sensitive areas to increase network area
Alberta	Conditionally	50%[2]	Merchantable	Similar to Pre-harvest, remove older trees first	Conifer-dominated	No	Yes
Alberta	Yes	Undecided	Merchantable	Unknown	–	Leave large patches to prevent blowdown	No
Alberta	Yes	50%[2]	Merchantable	Similar to Pre-harvest	–	–	Yes
Saskatchewan	Yes	Dependent on species composition	Merchantable	Similar to Pre-harvest, leave at least 2 species	*P. tremuloides, P. balsamifera, Betula* spp, Understory *Picea* spp.	No	Yes
Saskatchewan	Yes	3% (can range[2] from 0.5–13%)	Merchantable	Selective for Hardwoods	*P. tremuloides, P. glauca, P. mariana*	No	Yes

[1]Retention areas estimated as percent of total area.
[2]Retention areas estimated as percent of total volume.

Table 3. Regional differences in establishment, intensity, and frequency of biodiversity monitoring

Province	Monitoring in leave areas	Monitoring in all areas	What variables areassessed	What species are indicators	What criteria were used to determine indicators	Frequency of monitoring efforts
British Columbia	Developing	Developing, implemented by 2001	Habitat suitability	Fish, identified wildlife, rare plants, and cyano-lichens	Reflect stand-level to 1:20000 map scales	Volume-based tenure does not promote long-term monitorin
British Columbia	Developing	Developing	Distribution of forest age-classes, defined list of terrestrial vertebrates	Plan on vertebrate that are terrestrial for part of their life cycle.	Knowledge of vertebrates is the best, on the basis of science advisors	Monitoring occurs indirectly through other management activities
British Columbia	Developing	Developing	Habitat suitability, stream and fish habitat classification, vegetation	270 species and habitat variables	Not yet decided	Not yet defined
British Columbia	No	No	Anticipate species presence, range, and abundance	Not Applicable	Taxa that provide measure of ecosystem health	10–20 year interval
British Columbia	Developing	Tree Regeneration	Coarse woody debris, understory vegetation species	Future monitoring specific for blue and red listed	Ease of sampling, cost effectiveness, and ability to detect change	–
British Columbia	Yes	Developing	Species richness, abundance, community composition, species turnover, snags, CWD, dens, feeding signs	Goshawks, Pileated Woodpecker, Martin	Keystone species, endangered and threatened status, ease of monitoring	Potentially every 3–4 years but still to be decided
Alberta	Developing, planning to participate in AFBM	Developing, implemented by 2002	Presence/absence species richness, landscape and habitat structure indices		Cost effectiveness, ease of sampling, ability to detect change	Planning on annual monitoring efforts
Alberta	Developing	Developing	Habitat suitability	Potential species that reflect landscape like neotropical birds	Reflect landscape scale changes	–
Alberta	Developing	Developing	Not yet defined	Not yet defined	Not yet defined	Not yet defined
Alberta	No	No	Not applicable	–	–	–
Alberta	Yes	Yes	Classical tree measurements, habitat structure, coarse woody debris, vegetation.	Lynx	No answer	–
Alberta	Developing	Yes	Structure retention (merchantable and unmerchantable), patches, single trees, etc.	Mammals, nocturnal raptors and migratory birds as indicators of stand and landscape diversity. Plus threatened and endangered species (caribou, bull trout)	Professional opinion based on best knowledge. Subject to change as additional knowledge is acquired.	Every three years
Saskatchewan	Tree Regeneration	Tree Regeneration	Specifics come from provincial monitoring program	Monitor trees, use government to monitor moose	See provincial monitoring program	Planning on annual monitoring effort
Saskatchewan	No	Not currently, waiting for direction from government	Not yet defined, any variable will be in comparison to fire origin stands	Planning to monitor 45 variables that included songbird and mammal diversity, and vegetation (under provincial review)	Effective and meaningful	3–5 year interval

they are well known ecologically. One Alberta company reported that indicator taxa were chosen solely on their status as threatened or endangered.

Of the companies with established monitoring programs, those monitoring stand structure and regeneration do so annually while the two companies conducting multi-taxa inventories plans to do so every three and five years. Of the companies currently developing monitoring programs, the frequency of monitoring activities ranged from every one to 20 years. In one case, no formal inventory was initiated, rather monitoring was conducted through feedback and observations that occurred during other management activities.

All companies reported collaborations with other sources in developing and implementing monitoring efforts. Collaborations were most common with academic institutions (9 of 14 companies), followed by Federal government (5) and Provincial government (5), and lastly, private consultants (2). In two cases, companies classified contributions to research trust funds as collaborations. Likewise, all companies reported that most data collected from biodiversity monitoring efforts will be made available to other parties such as the public or provincial and industrial co-operators either directly or through some data-sharing agreement. However, in one case, location of plants with medicinal value to First Nations peoples was kept confidential to the general public.

It was unclear how results from biodiversity monitoring plans have been or will be incorporated into timber management objectives because most monitoring plans are still being developed. Only one BC and one Alberta company provided specific examples of how information obtained from biodiversity monitoring has altered management practices. The BC company reported that results from biodiversity monitoring are used to educate loggers and other workers what habitat features are valuable for wildlife and should be left following harvest. The Alberta company reported that results of monitoring have caused changes in cutblock size, access and harvest sequence of cutblocks. Three other companies stressed that any results from biodiversity monitoring would be incorporated with timber objectives through an adaptive management approach. One Saskatchewan company de-emphasized the effect of biodiversity monitoring on timber objectives because results of monitoring efforts can only be incorporated into management plans every five-year planning interval.

The influence of rare and endangered species on timber objectives was also highly variable due to differences in governmental involvement in monitoring. BC companies reported that the Ministry of Forests addressed endangered species concerns before operational areas were approved. Beyond the initial land planning by government, three BC companies reported that they are in the process of conducting inventories to determine presence of threatened or endangered species within their areas of operation. A fourth BC company has begun to verify habitat availability models for marbled murrelet (*Brachyramphus brevirostris*) and is planning to incorporate results of these simulations into land planning. In Alberta and Saskatchewan, four companies indicated that presence of rare and endangered species, specifically caribou, influenced timber operations. These companies modified operations and roading layouts to avoid caribou populations. One Alberta and one Saskatchewan company also increased the size of cutblocks to promote caribou populations.

Five companies reported that they monitored for noxious weeds or exotic species. One BC company reported that it controls noxious weeds through spraying herbicides, washing of vehicles and equipment, and requiring contractors' yards be free of noxious weeds. Four additional companies utilized information obtained through governmental monitoring programs to monitor invasive species. However, in all cases the specific examples of how monitoring affected timber objectives were not given.

Resources allocated for biodiversity-related objectives

The amount of money allocated by forestry companies to activities such as basic research, monitoring, and contributions to related trust funds ranged from zero to Can$ 5 million per year. Two reasons account for the wide range in reported financial support: 1) biodiversity-related activities often are subdivided among other activities on company budgets and therefore are difficult to assess; 2) the role of governmental involvement in monitoring and research differs by province.

Seven companies indicated they had at least one full-time position such as wildlife manager, biologist, or woodlands manager on staff to oversee or implement biodiversity-related goals. One Alberta company reported having five ecologists on staff and another three to four biologists on full-time contract. Another Alberta company reported having lost a forest ecologist position, but had planned to replace this position on a forest planning committee.

Measuring success of biodiversity management

All companies reported that it was too early for any meaningful evaluation of management efforts for biodiversity. When asked how management efforts were deemed successful, nine of the fourteen companies responded that success of biodiversity objectives would be determined by meeting coarse-filter targets detailed above. In addition to meeting coarse-filter targets, one BC company responded that management of biodiversity was deemed successful if supply analyses and environmental impact assessments were approved by certification bodies such as the Forest Stewardship Council and the Sustainable Forestry Initiative. One company in Alberta, through its monitoring program, intends to use the persistence of species on its FMAs as an important measure of success.

Changes in biodiversity management

All companies responded that incorporating biodiversity and other non-timber values into management practices has been an important change in management in the last 10 years. BC companies emphasized the development of guidelines such as detailed management plans by companies and the Forest Practices Code by the provincial government as significant events in designing strategies for managing biodiversity. BC companies also emphasized the importance of maintaining and managing old-growth areas as an important change in biodiversity management. Alberta and Saskatchewan companies emphasized a shift away from the previously standard two-pass harvesting system to harvesting patterns that characterize natural disturbance patterns. As a consequence, these companies also emphasized the increase in size and variability of cutblock sizes as an important change in the last 10 years. Six companies responded that the importance of habitat structure in the form of green tree retention, vertical structure, and/or coarse woody debris has been recognized in the last 10 years. Two companies responded that the identification of important indicator species and implementing ecological monitoring have recently become important aspects of biodiversity management.

When asked how biodiversity management will likely change in the next 10 years, all companies emphasized that further knowledge will be used to refine current approaches to monitoring and management. Five companies responded that monitoring programs that are long term and cover a broad spatial scale will be implemented and/or refined. Three companies emphasized the role of adaptive management in successfully managing biodiversity. Two companies responded that coarse-filter strategies to habitat management would become associated with more taxa in the future. One company characterized this direction as "taking finer slices of the coarse-filter approach" by including more spatially explicit habitat variables. Three companies stressed the role of developing spatially explicit models that incorporate climate change as a future direction for coarse-filter strategies. One company predicted collaborative efforts with other companies and governmental agencies would become increasingly important in the future.

When asked what knowledge was most needed to incorporate biodiversity into future forest management, accurate data for model development and evaluation of coarse-filter-strategies was the most common factor cited. Seven companies emphasized the importance of identifying indicator species and their habitat requirements for future management. One company stressed the need for information on soil organisms. Another company valued consistent monitoring methodology. Two of these companies also pointed out that any data gathered through monitoring efforts should address ecosystem and landscape processes. Five companies emphasized the importance of improved modeling tools that include landscape processes and/or incorporate climate change into long-term projections. Three companies stressed the identification of accurate coarse-filter indicators and the evaluation of landscape metrics in maintaining biodiversity. Finally, two companies responded that increased public awareness of current forest management would increase the willingness of the public to accept changes in forest management and suggested that these changes would facilitate biodiversity management.

Other factors suggested to improve the incorporation of biodiversity into future management included increased funding, stronger commitment and collaboration with government policy makers and academic researchers, development of decision support systems, and increased communication between researchers and forest managers. Four companies emphasized increased collaborations with governmental and academic researchers as a factor that would improve the integration of biodiversity with timber objectives. One company advocated creating a National Centre for Excellence group specifically for biodiversity. Another company advocated more applied projects such as the Model Forest Program. Additional factors reported included a single-page technology transfer paper directed at land managers to inform them of current research and management techniques and detailed ecological maps of FMAs. One BC company expressed a need for policy changes in the form of area- rather than volume-based land tenures.

Discussion

Because practical strategies for managing biodiversity are just beginning to be developed and implemented by the Canadian forest industry as a whole, few conclusions as to the effectiveness of any particular strategy can be made at present. However, preliminary evaluations of management strategies in specific regions have recently been completed (Forest Watch Alberta 2001, Schneider 2001). In a survey of FMA holders in Alberta, detailed forest management plans were used to complete a summary of current forest practices. In general, detailed forest management plans were characterized as: 1) highly variable in content and format, 2) vague regarding specific elements of management strategies and 3) questionable in their ability to achieve ecological meaningful results (Schneider 2001). However, the same factors that prevent consensus among forest managers about how to best balance biodiversity and timber objectives also highlight future directions for improving management for biodiversity.

The role of government was clearly an important factor in establishing targets for biodiversity management, particularly in British Columbia (Fenger 1996). In all but one case, BC companies suggested that habitat inventories and the development of monitoring plans was a response to the Biodiversity Guidelines. While standards in the Biodiversity Guidelines have been criticized as insufficient to maintain habitat for biodiversity (Andison and Marshall 1999), the Forest Practices Code provided specific targets for the distribution of age classes, size of cutblocks, and amounts of green tree retention left following harvest. In a broader context, all forestry companies considered biodiversity concerns to be partly the responsibility of governmental agencies before management plans are approved. In extreme cases, this perception put the "burden of biodiversity" completely onto governmental agencies to develop comprehensive management strategies. One company lamented that the overall timber requirements set by government in the form of maximal annual allowable cut rates (which indirectly reflect the fibre demands of the general public), prevent forest companies from managing for anything but timber. These comments stress the potential for governmental agencies to affect biodiversity management. More frequently, companies stressed the importance of co-operative management efforts between government and industry. In some cases however, these viewpoints were tempered by concerns that "government [promotes] biodiversity [through] a regulatory atmosphere without putting up any contribution towards maintaining [it] as a value."

Regardless of regional differences in legislation, management of biodiversity through activities that mimic natural disturbances has become a key feature in forest management by all companies interviewed. Forest management that emulates patterns of natural disturbance has been widely advocated in recent years (Attiwill 1994, Bergeron and Harvey 1997, Angelstam 1998, Bergeron *et al*. 1999). Of the companies we interviewed, management activities that mimic wildfire were cited as replacing historical methods of harvesting. For BC companies that characterized current age distributions as skewed towards younger classes, this has meant implementing prescribed burning and thinning techniques to promote late seral characteristics. In Alberta and Saskatchewan, some companies are trying to move away from the two-pass harvesting systems by replacing it with dispersed logging. These new practices are meant to ensure the persistence of diverse landscapes with a variety of patch sizes of different age and composition, emulating natural systems of fire origin (Johnson 1992). While this approach is expected to result in a greater proportion of forest in mature and over-mature seral classes than even-aged management approaches (Bergeron *et al* 1999), assessing the frequency and intensity of a "natural" disturbance may be hindered by relatively quick changes in fire cycle resulting from climatic change (Bergeron *et al.*1998, 2001), recent changes in forest land-use (Weir and Johnson 1998) or inherent variability in the frequency of fire events (Johnson *et al*. 1998, Armstrong 1999).

Perhaps one of the most striking changes in current management in some provinces, particularly Alberta and Saskatchewan, is the attempt to adopt larger cutblock sizes. In some cases cutblock sizes will likely increase by two orders of magnitude. While increases in cutblock size have been suggested as beneficial for wildlife species such as caribou, advocates for ecosystem management strategies have been careful to point out that emulating wildfire is not synonymous with "creating contiguous cutting blocks thousands of hectares" (Bergeron *et al.* 1999). Rather, management based on patterns of natural disturbance has emphasized stand-level factors and coarse-filter strategies such as green tree retention and the maintenance of standing snags as important in maintaining biodiversity. This has been taken so far that meeting coarse-filter targets has been, in itself, perceived as successful biodiversity management.

Green tree retention was almost unanimously perceived as an important tool in maintaining biodiversity. BC companies are currently required to leave 0–18% of the cutblock area as individual wildlife trees or wildlife patches depending on the availability of land for harvest and the amount of land previously harvested (British Columbia Forest Service and British Columbia Environment 1995). The BC companies we interviewed reported retention levels within the ranges specified by the Biodiversity Guidelines. Most of the companies characterized retention trees as merchantable, although one company expressed preference for leaving more wind-firm trees that tended to be non-merchantable. In Alberta, regional ground rules that address structure retention are being negotiated with individual FMA holders. The 1994 Alberta Ground rules, which applied to volume-based licenses, suggested leaving eight trees per hectare with preference for large-diameter dead and selected live trees of unmerchantable species in aggregate patches. Current retention levels reported by three Alberta companies were higher than these guidelines and also were characterized as merchantable rather than unmerchantable. In some cases it was not possible to determine the amount of retention maintained within a cutblock because companies had yet to set specific goals or interpreted green tree retention through a landscape perspective and included timber reserves from two-pass harvesting in their response. Companies in Saskatchewan also characterized retention areas as merchantable and in one instance reported considerable variability in retention levels between cutblocks.

So far, companies have concentrated on creating or maintaining structural features through green tree retention. Maintaining vertical structure and coarse woody debris were cited as important stand-level goals of retention by the forest companies we interviewed. Dispersed retention of individual trees affects vertical structure through the retention of snags and the increase in diameter growth of remaining trees (Franklin and Spies 1991, Halpern *et al*. 1999). Likewise, volume of coarse woody debris can be maintained by dispersed retention, although at much lower levels than found in natural stands (Linder *et al*. 1997). Aggregated patterns of retention minimize edge effects and are typically more wind-firm than dispersed retention trees. Although aggregates of mixed composition are thought to increase structural variability of stands, several companies preferred aggregates of single species composition. In one instance, aggregate blocks of deciduous trees were left more frequently than aggregated blocks of coniferous trees because of the susceptibility of conifer aggregates to windthrow. In another case, species composition of retention aggregates was determined by forest health-related issues such as insect outbreaks.

Maintaining structural features is ultimately meant to provide habitat for native species and the importance of green tree retention for plants (Halpern *et al*. 1999, Vahna-Majamaa and Janolen 2001), lichen (Peck and McCune 1997), saproxylic insects (Siitonen and Martikainen 1994, Kaila *et al*. 1997, Kolström and Lumatjärvi 2000, Siitonen *et al*. 2000), nesting birds (Chambers *et al.* 1999, Schieck *et al*. 2000), and mammals (Lemhkhul *et al*. 1999) has been recently documented. However, only two of companies we interviewed currently monitor whether species actually utilize these areas although four more companies had future plans to do so. As a consequence, the effectiveness of retention strategies and the identification of ecologically meaningful indictors will likely have to be evaluated through other sources such as academic and governmental research.

The forest industry is clearly relying in part on collaborations with academic and governmental research to shape current management practices. This is evident through money contributed to research trust funds as well as in current collaborative efforts. BC companies have to pay stumpage fees to the government, which have been made available for research through Forest Renewal British Columbia. Likewise, Alberta companies also pay stumpage fees that are then reallocated to research through the Forest Resource Improvement Association of Alberta (FRIAA) program. Several Alberta companies contribute to the development of the Alberta Forest Biodiversity Monitoring Program; however, this has yet to be implemented. Three of these companies are partners on the EMEND (Ecosystem Management Emulating Natural Disturbance) project, a landscape-scale experiment that is testing the effectiveness of coarse-filter strategies for maintaining biodiversity. EMEND is a collaborative effort relying on research from six academic institutions and seven government agencies. Likewise, forest companies reported that more collaboration with academic and governmental researchers would improve their ability to implement biodiversity objectives, suggesting that forest companies will continue to depend on academic and governmental sources to develop and implement biodiversity management.

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Appendix 1. Survey of management practices as they pertain to conservation of biodiversity

Biodiversity and Other Management Priorities

1. What decision-process is used in delineating/prioritizing land holdings for timber-harvesting and biodiversity objectives given the requirements of your FMA?

2. During the length of a rotation, is there a constant proportion of land allocated to maintaining biodiversity (i.e., left in late seral stages)? If so what is that proportion?

3. What is the average area of cut blocks and timber reserves (leave areas)? What is the range of these areas?

Indirect Species Management/Habitat Retention

4 Do you see green-tree retention as an important tool for maintaining biodiversity? (If so please continue in this section, If not please skip to next section)

5. Are timber reserves (leave areas) predominantly composed of otherwise merchantable or non-merchantable material (Are leave areas part of the productive landbase)?

6. Do the timber reserves (leave areas) have similar species composition?

7. If timber reserves (leave areas) have multiple species composition, what are the three predominant species?

8. Are timber reserves (leave areas) managed for later seral stages/other management objectives? If so in what way?

9. Does management activity for biodiversity objectives change within timber reserves (leave areas) of different species composition?

10. Are timber reserves (leave areas) separate from other sensitive areas (such as riparian buffers)?

Direct Management for Biodiversity Objectives

11. Are specific monitoring programs implemented within leave areas?

12. Are specific monitoring programs implemented throughout all managed areas?

13. What organisms are assessed in biodiversity monitoring programs?

14. How often are biodiversity inventories undertaken?

15. Are collaborative efforts with specialists (i.e., University Researchers, Government Scientists, National Museum Scientists, private consultants) included in biodiversity monitoring?

16. Are data from biodiversity inventories archived or made available to other parties?

17. How is biodiversity assessed (i.e., What variables are measured during biodiversity inventories)?

18. Are specific taxa chosen as bioindicators for monitoring programs or is a complete inventory undertaken?

19. What are the criteria for bioindicator selection?

20. Are results of biological monitoring programs incorporated into timber production objectives/management goals? If so how?

21. Is monitoring of rare/endangered organisms incorporated into timber production objectives/management goals? If so how?
22. Are monitoring of invasive/exotic pest organisms incorporated into timber production objectives/management goals? If so how?

Implementing biodiversity goals

23. How much money is budgeted to biodiversity monitoring (what percentage of total budget)?

24. Have positions been created to oversee/implement biodiversity management goals? If so, what kind?

25. If long-term biodiversity goals have been proposed, have proposed deadlines/benchmarks been met so far?

26. How is the success of biodiversity management goals evaluated?

Progress in biodiversity goals

27. How have management activities changed within the past 5 years with respect current biodiversity objectives? Within the past 10 years?

28. How do you see biodiversity management to change in the next 10 years?

Gaps in Current Knowledge

29. What knowledge/information/tools do you perceive is most needed to incorporate biodiversity objectives into other management objectives?

30. What factors would better improve the implantation of biodiversity objectives (i.e., more funding, decision support systems, consultations with researchers, other research programs)?