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Introduction

he forests of North America are diverse, covering the spectrum of forested landscapes from the northern taiga of Canada and Alaska to the tropical humid forests of Mexico. The Commission for Environmental Cooperation has identified 15 broad ecosystems of North America (including Canada, USA, and Mexico) (NAEWG 1997). Twelve of these macro-ecosystems have a substantial forest cover. Canada, for example, includes all or portions of seven of these North American forested ecosystems covering a total forest area of 418 million hectares, or nearly half of the Canadian landscape. Although this chapter concentrates on the forests of Canada, there is an implicit understanding that the forests of one nation cannot be isolated from those of its neighbours. Equally, forests cannot be thought of in isolation of the continental and global cycles operating in the rest of the world community. Table 1 provides a comparison of forest land among Canada, United States and Mexico (Cantin et al. 1998).

Country	Forested Area (million ha)	% of Total Land Area of Country	% of North American Forests	% of Global Forest
Canada	417.6	45	55	10
USA	298.1	33	39	7
Mexico	49.6	26	6	1

Table 1. Area of forest within Canada, United States and Mexico

The national ecological classification of Canada (ESWG 1996; Wiken et al. 1996) stratifies Canada into 15 ecozones which meld with the North American ecosystem units (NAEWG 1997). Nine of these ecozones are considered as having a substantial forested component. The following section, extracted from the publication *Forest Health in Canada: An*

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Overview (Forest Health Network 1999), provides a descriptive ecological and demographic synopsis of each of these forested ecozones.

The Forested Ecozones of Canada

The Pacific maritime ecozone occupies an area of 21.9 million ha (10.6 million ha of forest) and has a mostly urban population of 3 million people. Canada's most productive forests and its biggest and oldest trees, some attaining ages of 500 years and older and heights to 70 m and more, are found here. The forest ecosystems vary with elevation and precipitation. Major species include western hemlock, western red cedar, Douglas-fir, Sitka spruce and subalpine fir. The ecozone is dominated by a coastal temperate rainforest. Globally, these rainforests are scarce, with a worldwide distribution of only 40 million ha (Kellogg 1994). Overall, the forests have low endemic populations of tree-damaging insects and diseases. There is an infrequent fire history, although large burns have occurred in the past. Harvesting is the major human disturbance.

The montane cordillera ecozone occupies an area of 49.2 million ha (34.9 million ha of forest) and has a mostly urban population of one million people. It is the most diverse of all of the ecozones, consisting of alpine, forest, and grassland ecosystems. Major tree species include Douglas-fir, ponderosa pine, subalpine fir, Engelmann spruce, western white pine, and lodgepole pine. The major historical agent of disturbance has been fire. Insects and diseases, such as the western hemlock looper, mountain pine beetle, and Armillaria root rot, have also been primary agents of ecological change.

The **boreal cordillera** ecozone occupies an area of 46.5 million ha (28.8 million ha of forest) spanning northern British Columbia and the southern Yukon. The population of 31,000 people is mostly rural. There is less diversity in tree species than in the more southern ecozones, with subalpine fir, lodgepole pine, white spruce, and trembling aspen being dominant. The valley and lowerslope ecosystems historically have been fire-dominated. Within the ecozone, the tree line is reached at elevations of 1,000 to 1,400 m.

The taiga plains ecozone occupies an area of 64.7 million ha (50 million ha of forest) and has a population of 22,000 people spread among several settlements. The ecozone is characterized by poor soils and frequent fires. It comprises a transition forest between mixed forest-tundra and dense coniferous forest. Black spruce is predominant. Within the ecozone, it generally grows slowly under open forest conditions. A vigorous forest, however, characterizes the Mackenzie River valley and its tributary valleys, containing some of Canada's largest white spruce and balsam poplar trees.

The taiga shield ecozone occupies 136.6 million ha (52.7 million ha of forest), covering much of the Canadian Shield from Labrador to as far west and north as Great Bear Lake in the Northwest Territories. It has a population of 34,000 people. This ecozone is an ecological crossroads where climates, soils, plants, birds, and mammals from two biomes-the boreal and the Arctic-meet. Permafrost is prevalent. The open, stunted forests are dominated by a few highly adaptable tree species, such as black spruce and tamarack. These forests are characterized by innumerable surface waters, wetlands, and lichen rock outcrops.

The **boreal plains** ecozone occupies an area of 73.8 million ha (49.8 million ha of forest) and has a population of 710,000 people. The Peace River area is predominantly agricultural with ongoing forest clearing. White and black spruce, balsam fir, lodgepole, and jack pine and trembling aspen are the dominant tree species. Much of the forest area is dissected by seismic lines associated with oil and gas exploration.

The **boreal shield** is the largest ecozone in Canada, covering 194.6 million ha (151.1 million ha of forest) and stretching from Newfoundland to northeastern Alberta. The largely urban population numbers 3 million people. Balsam fir predominates in the east; elsewhere, black spruce, white spruce, jack pine, and balsam fir are common. The forests are typically mixed with wetlands, lakes, and major rivers that contribute to the landscape diversity of the ecozone. Major natural ecological influences are fire, insects, and diseases.

The mixedwood plains ecozone covers the lower Great Lakes-St. Lawrence River Valley, occupying 24.4 million ha (3.7 million ha of forest). This industrial and urban heartland of Canada has a population over 14 million people and the smallest forest land area of all the forested ecozones. Before the arrival of Europeans, this ecozone was forested and supported a greater diversity of trees and plants than any other part of Canada. Today, only small pockets of the Carolinian forest, the basswood-sugar maple forest, and the hickory-sugar maple forest remain. Most of these forests have been cleared for farms, orchards, highways, and cities.

The Atlantic maritime ecozone covers an area of 20.4 million ha (16 million ha of forest). The largely rural population exceeds 2.6 million people. Centuries of forestry and agriculture have left few pockets of oldgrowth forest. The typical Acadian forest is characterized by a mix of softwood and hardwood species, including red spruce, sugar maple, beech, yellow birch, balsam fir, and white pine. Fire suppression has reduced the role of fire in ecosystem development. Insects and diseases, particularly the spruce budworm, remain a major ecological influence. Introduced insects and diseases pose an increasing threat to native plant species.

Most of the country's forests are publicly owned, with 71% controlled by the provinces. Twenty-three percent are federally owned; some are managed by, or in cooperation with, the territorial governments; and the balance is in private hands. Export products from Canada's forest sector contribute over \$31 billion to the country's net balance of tradealmost as much as energy, fishing, mining, and agriculture combined. These forests also support industries providing billions of dollars in sales, including tourism, recreation, wild foods, fur trade, Christmas trees, and maple products (CCFM 1998).

Protected Forests versus Commercial Forests

Of the forest land base, 23 million ha are recognized as heritage forests and, as such, are by law to be left in their natural state. Another 28 million ha are considered protection forest, where timber harvesting is excluded or modified by policy. In total, of the 418 million ha, some 235 million ha are considered capable of producing timber. Currently, 119 million ha are managed primarily for timber production.

Terms such as "heritage forest," "protection forest," "national parks," "provincial parks," "wildlife sanctuaries," etc., all conjure up some no-

tion of protection. The problem is that all these notions tend to confuse the definition of protected area rather than clarify it. For example, most of the Canadian national parks can be equated, with confidence, to IUCN Category II (IUCN 1994). Provincial parks cannot; some allow resource extraction and some are not intended to be there for purposes of ecosystem representation. What of protection forest? In commercial forests, not all of the areas can be freely harvested as they may have importance as wintering grounds for certain wildlife or as erosion control zones. These sensitive ecosystems are as important to identify and protect as is the sustainability of the timber surrounding these areas. However, having a policy rather than regulatory basis, these "protected areas" are not considered as protected by many. Indeed, in at least one province, such areas are simply given longer rotation lengths or harvesting must be conducted as partial cuts rather than the usual clearcuts.

The problem is amplified when comparisons of protected areas are made among countries. IUCN Categories V and VI are particularly open to interpretation among countries, to such a degree that one may not be able to readily compare these areas. Canada has a strong environmental and protected area lobby. As such, in most cases, when provinces report areas under protection, they tend to equate protected lands to those that meet the requirements of IUCN categories I and II—those that are legislated to prohibit resource extraction.

Reporting and Indicator Initiatives

Canada has emphasized the need for criteria and indicators of sustainable forest management over the past several years. Two similar processes have resulted in comparable sets of criteria and indicators: the international Montreal Process and the domestic Canadian Council of Forest Ministers (CCFM) process. The CCFM set has been adopted nationally for reporting on an array of ecological, economic, and social indicators of forest sustainability (CCFM 1997). One of the ecological indicators tracks the representativeness of forest types in protected areas. Others are intended to track various aspects of ecosystem, species, and genetic diversity trends in forest landscapes, including commercial and protected forest. In the United States, researchers have indicated similar needs for scientifically sound and defensible indicators and assessments (Gillespie 1996).

Canada recognizes the need to integrate protected areas with the working forest, meaning that the biodiversity values that government agencies and other organizations seek to protect cannot be maintained without consideration of surrounding landscapes. Likewise, the protected areas should contribute environmentally and economically, if possible, to the surrounding area. There is also recognition that static preservation of protected areas is impossible. Ecosystems, by nature, are dynamic and constantly changing due to a myriad of ecological factors. The term "islandization" is being used to describe existing protected areas that have become isolated from their surroundings, to a degree that their own viability is questioned. For example, in several regions, logging has occurred up to the boundaries of national parks. These parks have become refugia of landscapes that were once much larger, and may be too small and isolated to maintain ecological functions and processes essential to sustain desirable ecosystems. Several initiatives, both provincial and federal, are under way looking at options and opportunities to enhance this integration. One such initiative is embodied by Canada's Model Forest Program.

Model forests were initiated in Canada in 1991, as part of the federal "Green Plan" program. The intention was to establish examples of sustainable forest management in a "working-sized" forest with multiple stakeholders. The examples were intended to represent each forest region in the country, as defined by Rowe (1959). Model forests are administered differently in different parts of the country depending on their membership and the important issues in the area. All were expected to address biodiversity and other environmental issues. Most model forests contain protected areas within their boundaries, commonly provincial parks or ecological reserves, and, in one case, a national park. This provided an opportunity for development of management approaches that would treat protected areas as part of an integrated landscape. The work conducted by the Greater Fundy Ecosystem Research Group, for example, culminated in a set of management guidelines to protect native biodiversity in the Fundy Model Forest, in the context of maintaining and enhancing the protective role of Fundy National Park (Woodley and Forbes 1997).

In addition to the protected areas contained within the boundaries of the model forests at the beginning of the program, researchers conducted gap analyses in several of the model forests to identify and fill gaps in representation of ecological diversity. The purpose was two-fold: to develop and promote methods to be applied in the rest of the forest region, and to take advantage of model forest objectives to achieve increased protection of elements within the model forests. Gap analyses were conducted at different scales, and resulted in a number of initiatives to protect or develop stewardship approaches to maintain ecologically significant features.

The Model Forest Program focuses most attention on the rest of the forest; in maintaining the natural mix of community types across the landscape, and developing and demonstrating management practices that aim to sustain all native biodiversity. Protected areas are generally recognized as an important component of a larger strategy in the model forests, aimed at maintaining sustainable forest ecosystems into the future.

The Canadian Model Forest Program has spawned interest from other countries. Today, as part of the international model forest network, these working forests have been established in Mexico (two such forests exist and a third one is being considered) and Russia. The United States has integrated three adaptive management areas along the Pacific coast as part of the international network. Discussions are under way to include Malaysia as part of the network (Natural Resources Canada 1996).

Forest Ecosystem Classification

Another Canadian initiative addresses the need for a unified system for ecosystem classification across the country. The existing national ecological land classification (ESWG 1996) is most useful at relatively coarse scales, but the scale of information required for reporting and planning purposes is often finer. For example, in the absence of a national forest type nomenclature, it is difficult to answer basic questions such as that posed by the CCFM indicator on "Area, percentage and represen-

tativeness of forest types in protected areas." In contrast to the USA, Canada does not have a national forest type classification system. The Canadian Forest Service is developing such a classification system in collaboration with the provinces and territories. Its approach is to build on work that has been done by provinces using vegetation and site attributes to develop a hierarchical system. Wherever possible, structural or taxonomic conventions from existing provincial or territorial ecosystem classification systems will be used. This work has been given high priority nationally, in part to facilitate reporting on national criteria and indicators of sustainable forest management. Several CCFM indicators, in addition to the one cited above, require reporting at the level of forest type. In the absence of a recognized classification system for forest ecosystems, such reporting is difficult and imprecise, at best.

British Columbia Protected Areas Strategy

In Canada, responsibility for land management lies at the provincial government level, so responses to calls for expanding systems of protected areas have been inconsistent across Canada. British Columbia is an example of a province that made a substantial commitment and has been steadily working toward that goal. There, protected areas are seen as an important means of preventing loss of biodiversity. A protected areas strategy was released in 1993, with a stated goal to protect 12% of the province by the year 2000 (Morrison and Turner 1994). Between 1992 and 1996, the provincial protected area percentage grew from 6% to just over 9%, and it continues to increase.

The strategy encompasses steps all the way from identifying study areas through the eventual management of areas that are designated. A comprehensive set of criteria was developed to identify and evaluate the study areas, including: representativeness, naturalness, viability, diversity, and vulnerability. From the socio-economic perspective, two additional criteria were added: opportunity for public use and appreciation, and opportunity for scientific research. After areas were recommended, the strategy called for Cabinet approval before going to a landuse planning exercise which involved consultation with all interests at the regional and sub-regional levels, with assurances of that principles of planning and public participation be followed. The decision to designate particular protected areas is taken by Cabinet.

Threatened Major Forest Ecosystems within Canada

Several of the forested ecozones have forests that are under continuing threat from land-use activities. The following table describes the

Table 2. Threatened forest ecosystems by ecozone					
Ecozone	Forest Ecosystem	Concern			
Pacific maritime	Coastal temperate rain forest Garry oak–Arbutus forest Coastal Douglas–fir forest	Old-growth component from harvesting Entire ecosystem from urbanization and land conversion Conversion to urban and agricultural uses			
Montane cordillera	Ponderosa pine forest	Fire suppression, non- forest land use activities			
Boreal plains	Southern aspen forest	Conversion to agricultural use			
Boreal shield	White pine forest Red pine forest	Old-growth component from harvesting			
Mixedwood plains	Carolinian forest Hickory–sugar maple forest Basswood–sugar maple forest	Urbanization and conversion to agriculture Urbanization and conversion to agriculture Urbanization and conversion to agriculture			
Atlantic maritime	Wet cedar forest Rich, tolerant hardwood forest	Over-harvest with poor regeneration Old-growth component to harvesting and conversion to agriculture			

major threatened forest ecosystems by ecozone.

All these forest ecosystems, except for the aspen forests of the southern portion of the boreal plains ecozone, extend into the USA. All have a key role to play as habitat, source of food and shelter for various North American migratory wildlife species. Each represents a unique assemblage of gene pools, critical for the survival of North American forest ecosystems as environmental conditions change.

In response to concerns about the old-growth pine forests in Ontario, a conservation strategy has been developed for red and white pine ecosystems. The goal is "to ensure that red and white pine forest ecosystems, including old growth stands are present on the landscape of Ontario now and into the future, while permitting a sustainable harvest of red and white pine" (Ontario Ministry of Natural Resources 1998). The strategy will include protected areas and sensitive forest management.

One function of protected areas is to protect genetic diversity of natural populations. Genetic diversity is that portion of biodiversity that is probably the least easily measured and most often ignored. Global change renders genetic diversity especially important today. Maintaining genetic diversity means maintaining the potential for evolutionary change, thus ensuring the potential of a species to adapt to environmental change. Genetic diversity of most forest species may be adequately maintained under commercial forest management conditions. However, opportunities for genetic processes to occur under conditions that are as natural as possible, are important to avoid modifying species by imposing inadvertent selection pressures.

Any forest-harvesting regime has potential effects on species occupying the site. For example, it is clear to all forest managers that the forest can be changed in commercially detrimental ways by harvesting only the best trees of a particular species over a wide area and a long time. But removing only the (commercially) worst can result in changes as well, that are good in the short term from a commercial perspective, but may not be so beneficial in the long run. To maximize the probability of our forest species surviving ecosystem change, large diverse populations must be maintained.

Butternut provides an example of the importance of maintaining large diverse populations. A devastating new disease has swept the range of the species and left many trees dead in its wake (Ostry et al. 1994). The disease is efficient, rapidly spreading through entire stands and killing the trees. If genes are not available in existing populations, which are already adapted to survive the disease, the species is doomed. There is no particular reason for such preadapted variants to exist before the disease struck, but, given large and diverse enough populations, experience has demonstrated that there is a reasonable possibility of the existence of such resistant variants. The butternut is just one example of a species experiencing catastrophic impacts of introduced pathogens.

The best safeguard against losses due to ecological change, regardless of the cause, is maintenance of large populations of native species that are free to evolve under conditions that are as natural as possible. This is an important function of representative protected areas.

Conclusion

Protection of forest biodiversity is especially challenging in Canada, where the federal government makes international commitments but the provincial or territorial governments

are responsible for land management. There remains a very high degree of interest in protecting and reporting on forests at the international level. Canada has been called upon by the G8 Action Programme on Forests (May 1998) to identify key forest types that are insufficiently represented within the existing network of protected areas. Canada also faces significant challenges in defining forest types, identifying those that are insufficiently represented in protected areas, and then filling the gaps. At present, government agencies lack the tools to accomplish these things. Continuing initiatives to co-ordinate efforts among the levels of government, First Nations groups, non-governmental organizations, and industry are crucial to meeting the challenges.

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