SUSTAINABLE DEVELOPMENT AND BIODIVERSITY IN CANADA'S BOREAL FOREST

Dieter H. Kuhnke
Forestry Canada, Northern Forestry Centre, Canada

Abstract

Canadians are keenly aware that practising sustainable development to perpetuate the forests' biodiversity, productivity and renewal capacity must become the *modus operandi* of forestry practices. The attention of Canadians has focused on the preservation of old growth forests, the conservation of wildlife and the practice of clear-cut harvesting. Two case studies examine how sustainable development in the boreal forest may be put into practise.

The first case study examines how conventional clear-cut logging can be altered to retain a high proportion of softwood understory during harvest of a mixedwood stand. The benefits of apparent preservation of habitat suitable for large mammals and as much as 85% retention of the original softwood component must be weighed against reductions in logging production relative to conventional clear-cut logging.

The second study models the effects of clear-cutting on marten (*Martes americana*) habitat in an 11 321 ha area. The study suggests that a minimum of 1 600 ha of optimum-equivalent marten habitat will be kept through one rotation, but some old growth stands may have to be left uncut to ensure sufficient habitat in the following rotation.

Attitudes among foresters, governments, corporations and the public must change to adopt a holistic attitude if sustainable development is to be achieved.

Keywords: Biodiversity, wildlife, clear-cut, sustainable development

Introduction

Humanity is becoming aware of the finiteness of Earth's resources as never before, and as a result of the urgency in tempering man's economic and material desires with the need for preservation and maintenance of a healthy environment. On a global scale, it is the preservation of the biosphere, the thin skin of soil, water and air that sustains all life, that is ultimately at stake.

Sustainable development is a concept that was popularized following the 1987 Brundtland Commission report "Our Common Future". The Brundtland report had as a cornerstone recommendation that mankind "meet the needs of the present without compromising the needs of future generations to meet their own needs". It argued that the environment must be incorporated into the economic decision-making process as a forethought, not an afterthought.

This paper presents an overview of the concepts of sustainable development and biodiversity generally and in the Canadian context, and illustrates how these concepts are being put into practice by presenting synopses of two prominent on-going projects in Canada's boreal forest that are intended to preserve facets of biodiversity as an integrated part of forest management planning and operations.

Sustainable development in forestry: what it means to Canadians

Sustainable development in forestry from a national perspective may be thought of as the management of the forest resource in a manner that does not compromise the forest's biodiversity, productivity or its renewal capacity. Sustainable development includes the notion of sustained fiber yield, but encompasses all the values and benefits that forests provide such as gene pools, wildlife and fisheries habitats, watershed regulation and recreational opportunities. It is the perpetual preservation of the natural character of the forests, to keep them free of pollution and other deleterious effects of mankind, that is the essence of the concern Canadians are expressing about the condition of the nation's forests. Among the major issues that have emerged out of this general concern for biodiversity, which are being expressed in the popular press as well academic and professional publications, are the preservation of old growth forests, the conservation of wildlife and the practice of clear-cut harvesting.

The concept of biodiversity

Biological diversity, simply defined, means the diversity of life within a given area or ecosystem. It is necessary to be more explicit about its meaning, however, if research and forest management are to be directed towards its preservation.

The basic organization of biology begins at the molecular level of the gene and extends to the macro level of the ecosystem. The degree of biological complexity increases profoundly along this gradient, as genes form the basis of cell differentiation to form organisms, like organisms form species, species form populations and populations form ecosystems.

The importance of genetic diversity

Genetic diversity is central to the concept of biological diversity because genes are the ultimate source of diversity of components at all levels of biological organization (Wilcox 1984). Preserving genetic diversity is crucial to the ability of all organisms (and thus entire ecosystems) to resist or to adapt to changes in their environment. The most important aspect of genetic diversity is likely to be the buffering it provides against varying environmental conditions (Perry and Maghembe 1989).

Genetic diversity is also essential to counter a host of harmful genetic processes that become more probable in smaller populations. Inbreeding and genetic drift play a significant role in species extinctions. Genetic drift refers to the stochastic or random extinction of particular genes in the gene complex of a population. In general, inbreeding has been viewed as the principal threat to short-term survival and genetic drift as the principal threat to the loss of genetic variation thought essential to continuing adaptation (Shaffer 1987). The preservation of genetic diversity is one of the underlying reasons for maintaining minimum viable populations.

Elements of biodiversity

A number of widely used qualitative elements or characteristics of biodiversity form the basis for general descriptions of biodiversity at specific locales or over broad areas, and form the basis for work that has gone into measuring biodiversity.

. Species richness

One of the most obvious measures of biodiversity is the number of species in a given area. Many researchers have noted, however, that the number of species tends to increase with the area sampled, causing significant problems in using sampling data to estimate populations over a larger area like a forest stand. Species richness was the term widely accepted over species number (but still includes the notion of number of species) as a relative expression of the vibrancy and abundance of life in a given area.

. Relative abundance or heterogeneity

This element of biodiversity characterizes the frequency distribution of species in any given area, that is, the number of individuals per each species.

. Importance

Importance refers to the proportion of a community's resources a particular species can command in competition with other species. Importance is synonymous with dominance, and can be expressed in any number of ways such as ungulate density or basal area, depending on the species or species groups of interest. A substantial amount of work has gone into developing statistical distributions that describe heterogeneity in relation to importance. Preston's "lognormal" distribution has been shown to fit many different kinds of community samples (Peet 1974).

. Alpha, beta and gamma diversity

Whittaker (1972) proposed a more sweeping classification of biodiversity. Alpha diversity describes the variety and relative abundance of species within a distinct habitat, like a forest stand. Beta diversity refers to changes between habitats that occur along environmental gradients such as soil, elevation or latitude. Beta diversity is affected by changes in species richness and relative abundance along environmental gradients and by the pattern of distribution (pattern diversity) over an area of land. One way to envision beta diversity is to look at the variety, quantities and patterns of cover types and successional stages on an aerial photograph (Salwasser *et al.* 1984), keeping in mind that the photograph is only a snapshot of a continuum of changes in beta diversity over time. Gamma diversity is the product of alpha diversities of communities within a landscape or geographic area and the degree of beta differentiation between them.

The measurement of biodiversity

Practising sustained development by maintaining or preserving biodiversity by necessity means having some way of measuring biodiversity. It is not the objective of this paper however, to delve into the extensive research that has been done on biodiversity indexes. Most of these indexes attempt to measure alpha diversity. Among the common indexes are Simpson's Index and the Shannon-Weaver Index. The Simpson Index is strongly affected by the importance of the first two or three species (Whittaker 1972) whereas the Shannon-Weaver Index is more sensitive to changes in the importance of rarer species (Peet 1974). Although biodiversity indexes are useful analytical tools, they are limited measures of single components of biological diversity (Wilcox 1984).

Minimum viable populations

Minimum viable populations (MVPs) are more meaningful measures of biodiversity when dealing with roving wildlife that defy the statistically rigorous sampling required by biodiversity indexes. Minimum viable population can be defined as the number of individuals in a population that ensures the species will continue to evolve indefinitely. It can also be viewed as a threshold or breakpoint below which the probability of long-term survival is unacceptably low (Soule and Simberloff 1986).

The concept of MVPs is more intuitively connected to the determination of success or failure of sustained development efforts. Conservation of MVPs of "indicator" or "keystone" species that represent a broad range of species and habitat types is, in the face of clear-cutting and forest management operations, perceived as a surrogate for the preservation of biodiversity.

The determination of an MVP is hardly an exact science. There exists no set procedure or method for determining an MVP. Some have suggested that as few as 20 individuals of a species can constitute an MVP, however, this figure is considered by many to be too low. For instance, Shaffer and Samson (1985) concluded that, based on 12 years of data on the Yellowstone National Park grizzly bear (*Ursus arctos*) population, a bear population of 20 has about a 36% chance of surviving for even 100 years. A population should be at least large enough to ensure the input of new genetic variation from mutation balances the loss from genetic drift (Soule and Simberloff 1986). It must also have the resilience to recover from stochastic environmental factors. Franklin (1980) suggested that an effective population size (N_e) of 500 would be sufficient to achieve this resiliency. This figure has been corroborated by others (Lande and Barrowclough 1987; Harris and Allendorf 1989). Studies of the effects of environmental uncertainty however, would require still larger numbers (in the upper 100s to the 1000s) to ensure long term population persistence (Salwasser *et al.*, 1984; Shaffer 1987). Intuition, common sense and the judicious use of scarce data are the tools of wildlife management (Soule and Simberloff 1986).

A distinction ought to be made between a local population, one resident in a particular locale, and the total population of the species on the planet. Local populations that become extinct can be reestablished through migration from other local populations. The importance of corridors for migration, as well as the study of migratory habits, minimum area requirements (inherent in MVP determinations) and the pattern of habitat distribution becomes paramount. A great deal of research has been done on the pros and cons of large reserves versus several smaller ones. The establishment of reserves of sufficient size or number in the locations to truly act as they were intended rarely occurs because of political and economic realities.

The boreal forest

Canada is divided into 10 ecological provinces[1] (Canada Committee on Ecological Land Classification 1989). Ecological provinces are groupings of ecological regions, the groupings being based on general similarities in vegetation development. The largest ecological province by far is the boreal ecoclimatic region that covers roughly 60% of the forested area of Canada.

Old growth forests

Old growth forests are perceived as reserves of genetic diversity, as habitats for wildlife that cannot survive anywhere else, and more recently, as buffers to mitigate the effects of climate change. Certain groups within the Canadian cultural mosaic, aboriginal peoples in particular, also attach considerable spiritual value to these forests. One has only to look to the northern spotted owl controversy in the U.S. Pacific Northwest to appreciate how intense debate and litigation over the preservation of old growth forests can become. All of the ingredients for a similar debate over the boreal forest are in ample supply, including the decline of old growth forests, rare species that are dependent upon these forests and a rapidly expanding forest industry.

Boreal old growth forests on upland sites are characterized by mature, dense stands of white spruce (*Picea glauca* (Moench) Voss) mixed with either species of fir (*Abies*). Maximum tree ages average between 120 to 140 years, however stands of trees over 200 years are not uncommon. Lowland sites are usually wetlands characterized by black spruce (*Picea mariana* (Mill.) B.S.P.) and tamarack (*Larix laricina* (Du Roi) K. Koch). Boreal old growth forest possesses high alpha diversity through its vertical structure, through the provision of small clearings created by fallen trees, and a profusion of life on the forest floor due to high loadings of rotting trees and other vegetation.

The motives for the rapid decline of old growth forests are both economic and forestry-related. These forests contain a high volume of quality fiber per tree and per hectare. Less of the expensive roadbuilding required for harvesting is needed to fulfil mill requirements than would be needed for lower volume stands. Growth rates are declining or are stagnant and boreal old growth forests are susceptible to insect and disease outbreaks and forest fires. The age class structure of the Canadian boreal forest is highly imbalanced, with 47% estimated to be mature or overmature. All of these reasons combine to provide the impetus to liquidate these forests with the result that old growth forests are being harvested more rapidly than they can be replaced by younger age classes. Foresters, however, have run into a wall of opposition and criticism in their zeal to achieve the regulated forest and meet industrial requirements.

The clear-cut harvesting issue

Canadians view clear-cutting as an unacceptable forest harvesting practice. Clear-cutting is seen as a disruption of the forest ecosystem, as the cause of excessive erosion (resulting in the deterioration of aquatic habitats) and other effects that severely reduce the productivity of the sites. The aesthetic aspects of clear-cuts, a perception of an ugly scar on the face of the landscape, is another facet of clear-cutting that reinforces the negative attitude Canadians have toward the practice. The prominent reporting of infamous cases of the abuse of clear-cutting, particularly the size of these clearcuts, in the popular media has also contributed to the perception that clear-cutting is bad forest management. Paradoxically, fully 91% of the area harvested in Canada since 1986 was done by clear-cutting.

Alternatives to clear-cutting in the boreal forest: a case study

Recent increases in the demand for aspen (*Populus tremuloides* Michx.) fiber has raised new concerns over the use of clear-cutting. This is especially true in mixedwood forests because their softwood components are a primary source of softwood timber. In response to public pressure and client concerns, a study investigated how traditional clear-cutting methods could be altered to minimize the impact sites by reducing damage and mortality to the white spruce component. The study also investigated the effects of these alterations on logging production. The study was conducted by Forestry Canada

---

[1] This should not to be confused with Canada's 10 governmental provinces.

in cooperation with four forest products companies, a forest engineering research agency and the forest management agency of the province of Alberta. The results were promising.

The study was conducted in seven stands at three locations in west-central Alberta (Table 1). There were substantial differences between stands in terms of softwood and hardwood overstory composition, volume and quality, average stem size and softwood understory density and distribution (Brace 1990). Three harvest procedures were conducted using various combinations of logging machinery and protection effort (Table 1). Protection effort represents the combined effects of planning, trail layout, supervision, crew experience and crew attitude. Protection effort was rated as high, medium or low as quantitative measurement of the variables that constitute protection effort would be very difficult and was not attempted in this study.The importance of protection effort cannot be overemphasized.

Table 1. Harvesting method by treatment (Adapted from Brace 1990.)

Treatment and location	Equipment	Procedures
Conventional clearcut - Location 1 (CC - L1)	Feller-buncher with grapple skidder	Hand limbing at landing
Location 2 (CC - L2)	–[a]	Stroke delimber and slasher
Alternative treatment 1 Location 1 (AT1 - L1)	–	Main skid trails prelocated. Feller-buncher operator chose own trails. Hand limbing at landing.
Location 2 (AT1 - L2)	–	Main and secondary skid trails prelocated. Limbing by hand before skidding. Rub stumps along trails.
Alternative treatment 2 Location 1 (AT2 - L1)	–	Same as AT1 - L1 except trees thatched on skid trails by feller-buncher operator.
Location 2 (AT2 - L2)	Swedish shortwood processor	Skilled operators chose trails and controlled operation
Location 3 (AT2 - L3)	–[b]	Same as AT2 - L2

[a] Same as conventional clear-cut, location 1.

[b] Same as alternative treatment 2, location 2.

All of the alternative treatments suffered losses in felling production relative to the conventional clear-cut method. These losses were partially recovered by increased forwarding production for the full-tree and tree-length systems in two out of three cases, however (Table 2). The Rottne system delimbs and bucks at the felling stage (rather than at the landing), which inflates the felling production losses, and utilizes up to 20% more of the aspen trees than the other systems. These factors would tend to compensate for the higher losses in productivity, though a quantitative analysis of the effects of these factors on overall productivity was not conducted. An estimated gain of up to another 20% in felling productivity by the short wood processor could be realized if the cutting head were equipped with a larger grip to handle large aspen trees.

Table 2. Production summary for felling and forwarding (Adapted from Brace 1990.)

Treatment and location	Protection effort	Felling production m^3/PMH[a]	Felling production change (%)	Forwarding production m^3/PMH	Forwarding production change (%)
CC - L1	low	73	100	12	100
AT1 - L1	medium	56	-24	17	42
AT2 - L1	high	52	-29	11	-8
CC - L2	low	28	100	21	100
AT1 - L2	high	25	-11	26	24
AT2 - L2	high	12	-57	11	-48
AT2 - L3	medium	10	-64	11	-48

[a] Productive machine hour.

Studies that seek to draw conclusions concerning ungulate and bird use of some of these stands and in the surrounding area are currently underway. Therefore, for the time being, evidence that nontimber values have been maintained (or at least higher biodiversity has been maintained relative to a conventional clear-cut) is entirely empirical. Increased use by wildlife like moose (*Alces alces*) and elk (*Cervus elaphus*) in the stands that were logged with the alternative treatments has been noted suggesting that these stands are of acceptable similarity to natural stands. Aerial views of the treated areas also show little apparent visual disruption of the site (L. Brace, personal communication, August 1991). As much as 85% of the softwood timber was retained by the alternative treatments (Table 3).

Table 3. Stand densities, percent damage and percent mortality to understory spruce trees 2.5 to 14 metres height during aspen harvesting (Adapted from Brace 1990.)

Treatment and location	Initial density (stems/ha)	Final density (stems/ha)	Undamaged (%)	Damaged[a] (%)	Mortality[b] (%)
CC - L1	550	357	33	32	35
CC - L2	1 744	750	13	30	57
AT1 - L1	391	289	44	30	26
AT2 - L1	323	274	65	20	15
AT1 - L2	740	585	51	28	21
AT2 - L2	1 994	1 595	29	51	20
AT2 - L3	567	391	17	52	31

[a] Percent damage from felling and forwarding combined. Damage is in terms of broken tops and branches, scrapes on stems, and leaning trees.

[b] Percent mortality from felling and forwarding combined. Includes 6% for harvesting (and other reasons for removal of) large spruce in CC - L1. AT2 - L3 had 11% for harvesting (and other reasons for removal) of large spruce. All other treatments include 4% or less for harvesting (and other reasons for removal) of large spruce.

Besides the advantages of retaining a substantial portion of the softwood component from a wood supply perspective, the costs associated with reduced production have to be weighed against the significant benefits that appear to result from this study. These benefits include the minimization of soil compaction (compaction restricted to main skid trails), minimal expenditures for silvicultural treatments because little in the way of treatments are required, and most significantly, the potential to retain higher alpha diversity and wildlife habitat with its accompanying aesthetic amenity value. The study may show the way towards more integrated forest management in the boreal forest.

An example of habitat modeling in an operational forestry context

A major forest products company in west-central Alberta, long known for its progressive attitudes towards forest management, has begun a project that seeks to integrate the management of wildlife resources with its regular timber management operations. These operations supply a kraft pulp mill and a sawmill that consume 2.8 million m^3 per year of softwood timber. The overall goal is to establish a process to facilitate prediction of timber management impacts on wildlife habitat and populations (Bonar *et al.* 1990). The incorporation of all 284 species of wildlife on the 10 437 km^2 of forest land that the company has leased from the province of Alberta would be prohibitively expensive. Instead, 30 "indicator" species were selected that represent, in theory, all habitat conditions on the lease area.

For the sake of brevity, I will concentrate on the marten (*Martes americana*) for this presentation. This member of the weasel family has a long (50-60 cm), slender body with short limbs and a bushy tail. Males average one kg, 15% heavier than females. Marten prefer boreal old-growth forests because coarse woody debris is essential for denning, concealment and feeding, particularly during winter when this debris provides critical access to subnivean (beneath the snow) prey species. Marten feed primarily on birds and small mammals like the southern red-backed vole (*Cletrionomys gapperi*) and red squirrels (*Tamiasciurus hudsonicus*).

Marten populations are structured around male home ranges (Allen 1982), with female home ranges generally falling within male home ranges except during breeding season when they enlarge to the size of the male home range. Studies into the sizes of home ranges suggest that they can vary from 2.1 km^2 (Raine 1982) to 10 km^2 (Steventon and Major 1982), however this assumes that all of the range is accessible. Snyder (1984) found that insular habitat must be greater than 15 ha to be considered suitable. The findings of Lofroth and Steventon (1990) that optimum marten habitat may support a winter density of two marten per km^2 was used as a maximum relative species density in this study. Soutiere (1979) showed that clear-cutting reduces the carrying capacity of an area for marten, resulting in larger home ranges and lower population densities (Steventon and Major 1982).

The study area used in this presentation is an 11 321 ha area called the Athabasca 28 compartment. The compartment has a predominantly coniferous character, with approximately 2 600 ha of 95-99 year old (95 year age class) and 4,600 ha of 105 year age class softwood and softwood-dominated mixedwood stands. A small area (roughly 900 ha) of softwood and softwood-dominated mixedwood stands are present in the 125 year age class. A total of 2 850 ha of deciduous and deciduous-dominated mixedwood stands are spread among the 95, 105 and 125 year age classes. The remainder of the compartment is made up of nonforest land and water.

In predicting the effects of harvesting each stand greater than 15 ha with a coniferous component, more than 30% crown closure and more than five metres height was multiplied by a habitat suitability index (HSI) to determine its equivalent optimum habitat. A HSI increases linearly from zero to one and is determined by taking the square root of the product of four factors crucial for marten habitat (Table 4).

Table 4. Crucial factors for determining a habitat suitability index (HSI) for marten (Adapted from Bonar *et al.* 1990.)

Habitat factors essential to marten	Minimum acceptable value of factor	Optimum value of factor	Effects of factors greater than optimum
Canopy closure (%)	30	50	No effect[a]
Spruce and fir canopy component (%)	0	50	No effect
Tree height (m)	5	16	No effect
Woody debris > 7.6 cm diameter (%)	0	25 - 50	Value of factor declines to HSI = 0.5 at 100% ground cover

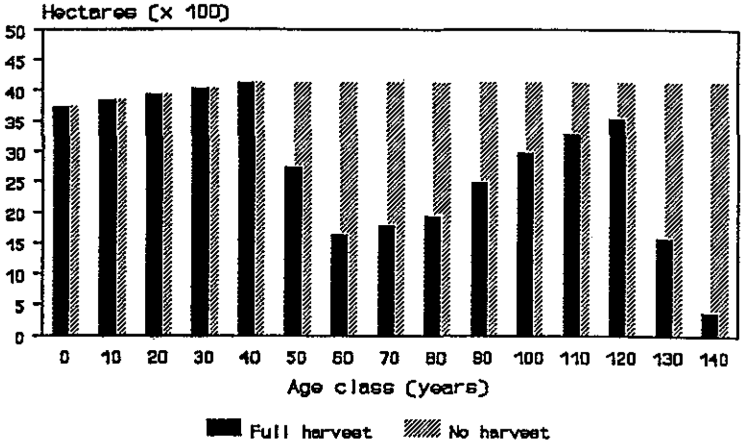
[a] Factor remains at optimum.

This procedure slightly overestimates marten habitat for the compartment (Bonar *et al.* 1990) because proximity to the nearest acceptable habitat is not available in the forest inventory data. Proximity analyses using a geographic information system are underway (R. Bonar, personal communication, September 1991). The importance of corridors and tolerances of exposed habitat are crucial because marten will generally not cross clearings greater than 50-100 m unless small clusters of trees or mounds of woody debris are available for cover (Soutiere 1979, Steventon and Major 1982). Another limitation of the forest inventory is the lack of information on the percent ground cover of large woody debris. A preliminary study of percent ground cover of large woody debris in relation to cover types was conducted for this study, but further work is required to improve the reliability of this relationship (R. Bonar, personal communication, September 1991). Greater attention must be paid to including standing and downed dead material in forest inventories (Hunt 1989).

Average rotation in the lease area is 80 years using two-pass clear-cut harvesting. The results of integrating the above procedure with the company timber supply model is compared to a no-harvest scenario in Figure 1. Harvesting is scheduled to begin in 2040. Current yield curves used in the timber supply model end at 150 years of age, thus the effects of succession beyond this age are not captured in the no-harvest scenario. The model assumes that all harvested stands will be regenerated naturally or artificially to stands that, through forest succession, become increasingly suitable for marten according to the HSI model. The results suggest that marten habitat will be sharply reduced in the second rotation because no regenerated stands have become more than 80 years of age (Fig. 1). This suggests that some old growth stands may have to be preserved to maintain sufficient areas of marten habitat. The Athabasca 28 compartment is also one of 135 compartments; marten habitat will increase in other compartments while it is decreasing in this compartment.

Further work is needed on a number of facets including tailoring the HSI model to local conditions and determining local density relationships. In spite of these weaknesses, this endeavour aptly demonstrates how wildlife habitat considerations can be integrated with operational timber management to ensure that sustained development will be practised.

Figure 1. Equivalent area of optimum marten habitat



Adapted from Bonar et al. 1990

Sustainable development: a question of attitude

Canada's seemingly endless bounty of forests and her historical pattern of development lead to the mind set of single use rather than multiple use or integrated management of this resource. Nontimber forest values have always been secondary to logging with consequent land use conflicts that polarize foresters and environmentalist interest groups (and sometimes much of the public). These conflicts are symptoms of a malaise in resource management in Canada that arises from conflicting values and attitudes about the forest (Thompson 1987).

M'Gonigle (1989) attributes much of the conflict to the professional foresters' paradigm, a structure or framework of thinking that dominates intellectual activity. It is the paradigm that poses an obstacle to democratic debate and to the cooperative accommodation of diverse insights and understandings (M'Gonigle 1989). Fundamental shifts in the forestry paradigm are required to adopt the holistic attitude necessary to achieve true sustainable development of the forests.

Foresters are not alone, however, in their need to adopt new values and attitudes about forest use. Roughly 87% of Canada's forests are on public lands of which governments have leased portions to multinational companies. These corporations raise the sceptre of heightened unemployment and lost export earnings in conflicts over land use. This results in a lack of political will to compel forest companies to consider more than the profit motive. No single aspect of resources from forested lands should have a preferred status; all government and nongovernment agencies should participate in land-use planning; and no single agency should unduly influence decisions (Fox 1985).

Discussion

Canadians and other peoples around the world will continue to demand increasing quantities of forest products, and foresters are employed to provide it. The challenge is to provide these products simultaneously, and from the same general area, with the nontimber benefits that forests also provide, to truly practice integrated forest management. The effects of single use forestry are already apparent in some parts of Canada. There exists a high probability that marten will become extinct in Newfoundland within the next 50 years, and current forestry practices in New Brunswick will result in extremely low marten populations within the same period (Thompson 1991) unless drastic corrective measures are taken. In Alberta, there has been a precipitous decline in the numbers of woodland caribou (*Rangifer tarandus*), though the reasons for their decline are unclear. The on-going work described as case studies herein are promising examples of how integrated forest management may be achieved.

This does not mean that no further tracts of virgin forest should not be preserved. That would be ecological folly. The best available forest regeneration information in Canada suggests that about 80% of the area harvested in Canada (1 021 000 ha in 1989) regenerates through natural or artificial means. While the non-regenerated area does not remain devoid of vegetation indefinitely, the resulting growth is often merely brush with low densities of trees. This is particularly true in the mixedwood forests of the boreal forest zone, where conventionally clear-cut areas regenerate to pure aspen stands despite the application of costly silvicultural treatments intended to establish coniferous plantations. Given the high levels of uncertainty about what second-growth forests may be like, it would seem prudent to strike a balance of sustained development in forests designated for their timber value and areas set aside for preservation.

Although integrated resource goals are not mutually exclusive, optimization of each is seldom possible (Thompson 1987). There are too many simple answers being touted by Canadians that fail to recognize that compromises and balanced decisions will be necessary to achieve sustained development. The question arises, how much are Canadians willing to pay for the costs of sustained development? Willingness-to-pay is closely tied to attitude, an attitude among many that humanity that mankind is somehow separate from Nature and immune from her laws. There is a rising tide of evidence that quite the opposite is true. Quoting Stan Rowe, noted Canadian ecologist, "We will not save the riverine forests without protecting the floodplains, nor will the orchids be preserved without preserving the marshes. Our own fate is linked to the limits we set on the domestication of the world around us and to the offsetting effort we devote to maintaining the life-blood of the Home Place, the natural beauty and health of the creative, sustaining, enveloping Ecosphere" (Rowe 1990).

References

Allen, A.W. 1982. Habitat suitability index models:marten. U.S. Dep. of Int.,Fish and Wildlife Service. FWS/OBS-82/10.11 9pp.

Bonar, R.;Quinlan,R.;Sikora,T.;Walker,D.;Beck,J. 1990. Integrated management of timber and wildlife resources on the Weldwood Hinton forest management agreement area. Weldwood of Canada Ltd., Hinton Division, Hinton Alberta 126 pp.

Brace, L.G. 1990. A test of three logging systems in Alberta. Pages 77-81 in Can. Pulp and Paper Ass. Woodl. Sec. Montreal Quebec. 71st Ann.Meeting Proceedings.

Burkey, T.V. 1989. Extinction in nature reserves: the effect of fragmentation and the importance of migration between reserve fragments. Oikos 55:75-81.

Canada Committee on Ecological Land Classification. 1989. Ecoclimatic regions of Canada. Ecological Land Classification Series No. 23 Can. Wildl. Serv. and Environ. Canada Ottawa On Canada.

Fahrig, L.; Merriam, G. 1985. Habitat patch connectivity and population survival. Ecology 66:1762-2768.

Fox, I.K. 1985. Socially optimal allocation of publicly owned resources among competing users. For. Chron. 61:140-142.

Hunt, F.A. 1989. The forest inventory: incorporating fisheries and wildlife values. pp. 475-477 in LaBau, V.J.; Cunia, T. eds. State-of-the-art methodology of forest inventory: a symposium proceedings. U.S. Dep. Agric., Portland OR PNW-GTR-263 592 pp.

Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-150 in C.M. Schonewald-Cox, S.M. Chambers,B. MacBryde and L. Thomas eds. Genetics and conservation: A reference for managing wild animal and plant productions. Benjamin Cummings Co., Menlo Park, Calif.

Harris, R.B.; Allendorf, F.W. 1989. Genetically effective population size of large mammals: an assessment of estimators. Conservation Biol. 3(2):181-191.

Lande, R.; Barrowclough, G.F. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 in Soule,M.E. (ed). Viable Populations for Conservation. Sinauer Associates,Sunderland, Mass. 189 pp.

M'Gonigle, R.M. 1989. The unnecessary conflict: Resolving the forestry/wilderness stalemate. For. Chron. 65(5):351-358.

Perry, D.A.; Maghembe, J. 1989. Ecosystem concepts and current trends in forest management: Time for reappraisal. For. Ecol.Manage.,26:123-140.

Peet, R.K. 1974. The measurement of species diversity. Annu. Rev. Ecol. Syst.5:285-307.

Preston, F.W. 1962. The canonical distribution of commonness and rarity. Ecology 43: 185-215,410-432.

Raine,R.M. 1982. Ranges of juvenile fisher and marten in southeastern Manitoba. Can. Field. Nat. 96:431-438.

Rowe, J. S. 1990. Home Place - essays on ecology. NeWest Publ. Ltd. Edmonton Canada 253p.

Thompson, I.D. 1991. Could marten become the spotted owl of eastern Canada? For. Chron. 67(2):136-140.

Thompson, I.D. 1987. The myth of integrated wildlife/forestry management. Queen's Quart. 94(3):609-621.

Salwasser, H.; Thomas, J.W.; Samson, F. 1984. Applying the diversity concept to national forest management. Pages 59-69 in J.L. Cooley and J.H. Cooley, eds. Natural Diversity in Forest Ecosystems: Proceedings of the workshop, Inst. of Ecol., Univ. of Georgia, Athens, 290 pp.

Simpson, E.H. 1949. Measurement of diversity. Nature:163-688.

Shaffer, M.L. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 in Soule, M.E. (ed). Viable Populations for Conservation. Sinauer Associates, Sunderland, Mass. 189 pp.

Shaffer, M.L.; Samson, F.B. 1985. Population size and extinction: A note on determining critical population size. Am. Naturalist 125(1):144-152.

Shannon, C.E.; Weaver, W. 1949. The mathematical theory of communication. Univ. of Illinois Press, Urbana. 117 pp.

Soule, M.E.; Simberloff, D. 1986. What do genetics and ecology tell us about the design of nature reserves? Biol. Conserv. 35: 19-40.

Soutiere, E.C. 1979. Effects of timber harvesting on marten in Maine. J. Wildl. Manage. 43:850-860.

Steventon, J.D.; Major, J.T. 1982. Marten use of habitat in a commercially clear-cut forest. J. Wildl. Manage. 46(1):175-182.

Wilcox, B.A. 1984. Concepts in conservation biology: Applications to the management of biological diversity. Pages 155-172 in J.L. Cooley and J.H. Cooley, eds.Natural Diversity in Forest Ecosystems: Proceedings of the workshop, Inst. of Ecol., Univ. of Georgia, Athens, 290 pp.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Unpublished reports:

Lofroth, E.C.; Steventon, J.D. 1990. Managing for marten winter habitat in interior forests of British Columbia. B.C. Min. Env.,Wildl. Branch, Victoria BC Canada 13 pp.

Snyder, J.E. 1984. Marten use of clearcuts and residual forest stands in western Newfoundland. MSc. Thesis Univ. of Maine, Orono 31 pp.

ISBN4-915870-01-4

Proceedings of the Symposium on

INTEGRATED FOREST MANAGEMENT INFORMATION SYSTEMS

– An International Symposium –

October 13–18, 1991

Tsukuba, Japan

Sponsored by:
Japan Society of Forest Planning
IUFRO Subject Group S4.02.00
IUFRO Subject Group S4.04.00

Co–sponsors:
The Japanese Forestry Society
Japanese Forestry Agency
Forestry and Forest Products Research Institute
Japan Forest Technical Association

Japan Society of Forest Planning Press

Publisher;
Japan Society of Forest Planning Press, April, 1992

Editors;
Mitsuhiro Minowa (Department of Forestry, University of Tokyo)
Satoshi Tsuyuki (Department of Forestry, University of Tokyo)

Designer;
Satoshi Tsuyuki

Photographs taken by;
Kimihiko Hayashi
Seiji Ishibashi
H. Gyde Lund
Kenji Naito
Fumihiko Takahashi

Copies of this book may be obtained from Japan Society of Forest Planning Press

c/o Fuculty of Agriculture, Tokyo University of Agriculture and Technology
3-5-8 Saiwai-cho, Fuchu, Tokyo 183, Japan

This symposium was supported by a grant-in-aid of
The Tsukuba Expo '85 Memorial Foundation,
Fuji Film Green Fund and
IUFRO-J