Forest Genetic Resource Conservation and Management in Canada

Compiled by T.C. Nieman, A. Mosseler, and G. Murray
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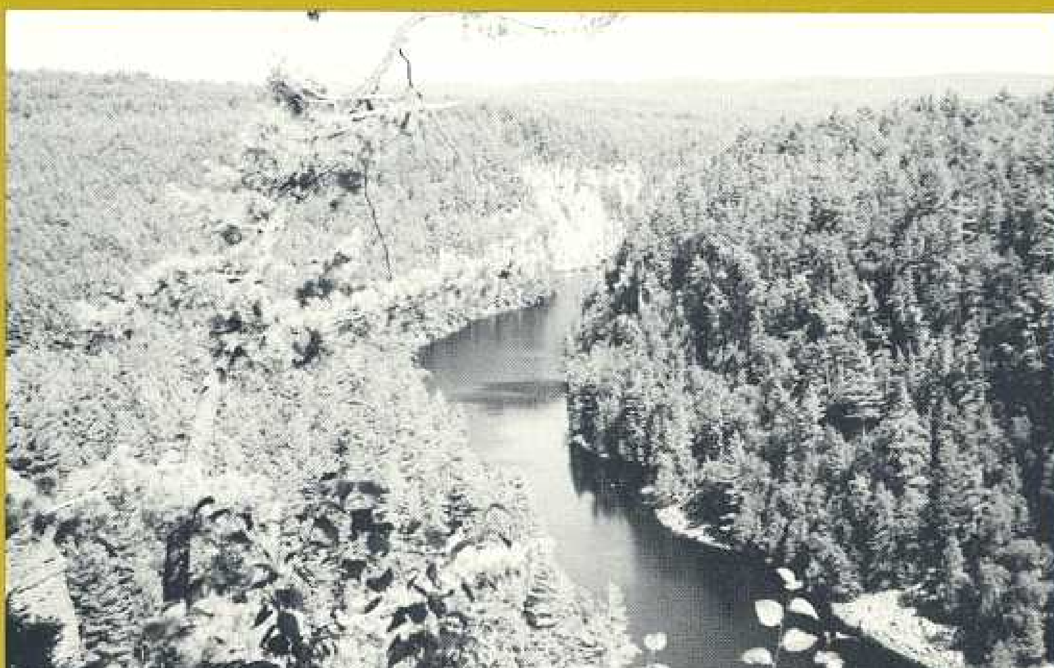

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Forest Genetic Resource Conservation and Management in Canada

Toronto, Ontario
Novmber 15-18, 1993

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Introduction

In November 1993, the National Forest Genetic Resources Centre at the Petawawa National Forestry Institute hosted a national workshop in Toronto, Ontario to address issues relevant to the conservation and management of Canada's forest genetic resources. The workshop was attended by representatives from industry and from provincial and federal governments.

The workshop included presentations by participants highlighting the current status of conservation efforts and ideas and strategies for optimal *in situ* and *ex situ* conservation of forest genetic resources in Canada. Working Group discussions were a major component of the workshop aimed at:

- identifying gaps in current conservation efforts;
- identifying conservation priorities;
- identifying research initiatives to support conservation priorities; and
- promoting opportunities for increased collaborative efforts.

A major output of the workshop was the development of a framework for a national strategy to focus on the sound management of Canada's forest genetic resources. The papers in these proceedings are published as submitted by the authors. The views expressed by them are strictly their own and in no way necessarily reflect the views of the Canadian Forest Service.

En novembre 1993, le Centre national des ressources génétiques de l'Institut forestier national de Petawawa a organisé à Toronto (Ontario) un atelier national sur la conservation et la gestion des ressources génétiques forestières du Canada auquel ont participé des représentants de l'industrie et des gouvernements fédéral et provinciaux. Des exposés traitant de la situation des efforts de conservation et de différentes idées et stratégies pour une conservation optimale *in situ* et *ex situ* des ressources génétiques forestières au Canada y ont été présentés. Les discussions en groupes de travail ont constitué une partie importante de l'atelier dont les objectifs étaient :

- cerner les lacunes des efforts actuels de conservation;
- définir les priorités en matière de conservation;
- déterminer des recherches pour répondre à ces priorités;
- promouvoir des possibilités d'accroître la collaboration.

L'atelier a permis d'élaborer un cadre pour une stratégie nationale visant à favoriser une gestion judicieuse des ressources génétiques forestières du Canada. Les communications sont publiées telles qu'elles ont été fournies par les auteurs. Les opinions qui y sont exprimées sont strictement celles de leurs auteurs et ne reflètent pas nécessairement celles du Service canadien des forêts.

Contents

The papers in these Proceedings have been printed as received from the authors.

Conservation of Forest Genetic Resources Workshop

Welcome and Introductory Comments

G. Murray

Petawawa National Forestry Institute, Canadian Forest Service, Chalk River, Ontario, Canada

I thank you for agreeing to participate in this workshop on the Conservation of Forest Genetic Resources.

As preparations for this workshop have progressed, it has been reassuring for the organizers at the Petawawa National Forestry Institute to find that many others share their views on the importance of forest genetic resources and their conservation and wise use.

For many people, these concerns about forest genetic resources are not new, as they have already taken various initiatives to translate these concerns into constructive actions to improve forestry practices. Nevertheless, it is also a fact that issues of forest genetic resources, the diversity of these resources, and their conservation currently enjoy greater worldwide prominence as a result of their association with the highly publicized issues of sustainable development and maintenance of biodiversity. These are, without doubt, issues that will have a major influence on future activities in our forests. For example, the Biodiversity Convention, which was signed and ratified by Canada, will come into force at the end of December 1993 and Canada will be expected to live up to the commitments it has made.

Whether or not we like the idea that our activities owe some of their current momentum to a "biodiversity bandwagon" effect, I am somewhat thankful that the political and public outcry on the related environmental issues has created an atmosphere in which it has been easier to win support for work related to conservation and wise use of forest genetic resources. For example, without the financial support of the federal government's Green Plan, the National Forest Genetic Resources Centre would probably have been unable to support activities such as this workshop.

At this time I want to express my thanks to Tom Nieman and Tim Boyle for taking the lead in organizing this workshop, which grew out of some earlier work done at PNFI. This work led to the realization that, although there was a lot of activity across Canada related to genetic resources and their conservation, the lack of a national profile or general strategy for these activities meant that many of them went unnoticed and unappreciated by the public, the policy makers, and even by those directly responsible for decisions affecting the management of our forests. This is clearly a dangerous situation to be in because, as pointed out by Dr. Namkoong to a meeting on "Biodiversity in Managed Landscapes" last year, without the guidance of general policies (on genetic diversity) based on biology and genetics, we are likely to be presented with policies derived from *ad hoc* political decisions.

It is my hope that this workshop will enhance our knowledge about current and future conservation needs and activities across the country, and that this knowledge and the associated recommendations will be made available in a format that will invite their use by the policymakers in the development of a national strategy.

In developing a strategy for conservation of forest genetic resources it is important to remind ourselves that genetic diversity is only one of at least four commonly recognized hierarchical components/levels of biodiversity, the others being diversity at the species, ecosystem, and landscape levels. My point is that, while we focus our attention on the genetic diversity of the trees themselves, we should not ignore the fact that long lasting and large scale conservation of these particular genetic resources will only be achieved in a sensibly integrated program of land and forest management that considers ecosystems, landscapes, and all the associated, and interacting life forms.

I recognize that this workshop is only a small step in the right direction, but I can assure you that, with the support of you and your colleagues and associates, the National Forest Genetic Resources Centre at PNFI plans to see this particular initiative through to a satisfactory conclusion. I look forward to an enlightening and profitable workshop.

Conservation of Forest Genetic Resources

Keynote Address

G. Namkoong

Department of Forest Sciences, Faculty of Forestry, University of British Columbia

On the one hand, defining a program on genetic conservation is trivially easy for Canada. There are perhaps 150 tree species, only about 10 of which are actively bred and tested, and an additional 20 or so that are used and can be considered to be of potential breeding interest. There may be two or three species that can be considered to have threatened genetic resources including *Taxus brevifolia*, *Castanea dentata*, and *Quercus garryana*, all of which are wind pollinated and otherwise can be widely disseminated, and are present elsewhere. Finite sample sizes of many provenances of the 30 or so commercially important species can be made and seed samples taken to establish *ex situ* collections to supplement *in situ* stands. For the other 120 species, their ranges can be defined, and one to several stands designated as *in situ* reserves containing a few tens or hundreds of individuals would preserve most present alleles, even the rarer ones. Since there is a wealth of experience in managing and breeding at least the commercially important tree species, we can envision that a strategy for gene conservation would be to merely repeat for all other species the same development plan as for the commercial species but at a less intensive level of management. The strategy is easy to articulate and would include various levels of pre-breeding such as sampling, collection, testing, screening, etc., and the same plan would be iterated for each species as it entered into our capacity for management.

On the other hand, several varieties or provenances of many species exist, and no finite sample can ever save all unique genotypes of any one species since allelic variants at many loci exist, new mutations are being generated all the time, and populations never quite catch up to changing selection demands. Furthermore, *in situ* conservation affects more than only the trees, and much of the concern in forest conservation involves also herbaceous vegetation and the animal kingdom. Programs that consider only the forests but ignore the adjacent agricultural or other fields and streams, and the impacts of roads and human uses, exist in an unreal vacuum and are ultimately doomed to failure. The problem is then not addressable on a species by species basis, but is so large and complex that no targeting efforts are useful and conservation tactics would only involve saving as much of the biota as can be contained in seed banks or strict nature reserves as can be afforded. Similar to the previous situation, conservation strategy is a simple iteration of a chosen technique, this time involving banking the resource rather than breeding and would require that we solve only the questions of collection sizes and the number of reserves.

Both of the above strategies are simple because only single tactics are assumed, a single common status of the species and a single common method of management is assumed, and the goals of management are assumed to be identical for all. If the development of a national strategy is limited to these choices, then the national strategy will continue to be as it is now, one of adjudicating where the boundary between breeding and banking lies. However, none of the assumptions of uniqueness is even approximately true and an optimum strategy would involve many more options and require determining goals, using an array of management tactics, and integrating gene conservation with ecosystem conservation.

The same framework exists for global programs in forest gene conservation which are different in scale and contain problems of different biotas, different management systems, and layers of inter-governmental interactions, but which are nevertheless qualitatively similar. It is, therefore, tempting to consider the Canadian program as a small part of a global effort and to infer that we can address our problems in isolation and to iterate our solution for the rest of the world. However, additional factors intrude so that global solution requires a higher-level strategy. In terms of germplasm evolution and movement, Canadian interests extend well beyond its boundaries and, in terms of political considerations, Canadian influence extends around the world. There are offshore exchanges and genetic connections that can be parts of a global/Canadian program that may be even more important if future global climatic changes occur. In addition, with the closing of the global timber frontier, not only do the effects of market supply and demand reverberate throughout the world, but conservation programs that affect total supplies have effects that cross national boundaries. Furthermore, the same kinds of conservation interests that we see in local confrontations in Canada are expressed in conservation interests elsewhere in the world and in the marketing of Canadian goods. While none of these effects are simple, an implication for a Canadian national strategy is that we cannot afford to consider the national strategy in isolation from global programs.

Genetic Elements

While this is not a conference on genetic techniques, it would be remiss to omit some discussion of the implications of genetic dynamics to management tactics and to an understanding of the resource that is the object of conservation. In the common but naive view that the genes and alleles are a fixed and limited resource, sampling designs can be described for achieving low probabilities of losing rare alleles. It is also possible to sub-sample for greater efficiency in saving alleles (Brown and Briggs 1991) when sample sizes for multiple species exceed the capacity of even large national seed storage facilities to maintain collections. In terms of reserves, it is also possible to define minimum population sizes to maintain viability due to demographic, environmental, or catastrophic variations (Soule 1987), and to suggest probability levels for the existence of populations for any given number of years. These views, however, assume a static resource and passive management.

An alternate view is that the genes themselves evolve, and that many if not most species are continually evolving in their average performances and in the distribution of their variations. On an individual locus basis, mutations are rare events, but the rate of mutations is not constant among loci or over time, and on a whole trait or whole organism basis, the number of mutations that occur every generation can be very high. Mukai and Cockerham (1977) estimate that mildly deleterious mutations occur in *Drosophila* at the rate of one individual in every four in every generation. In populations of 20 to 50 parents, each with a few tens of progeny, the accumulation of mutations can maintain high levels of genetic variation that can be used in selection programs such that steady state levels of genetic variation that are comparable to "natural" population levels of variation can stabilize. Thus, even without disruptive selection to further diversify the populations, new sources of genetic variation can regenerate genetic variance. Organisms and their genetic resource are evolving entities, and even with low levels of mutation, selection can change phenotypes and the effects of alleles. In maize breeding experiments, it is clear that the selection process itself can operate on different genes depending on the types of gene action that is tested for, and in tobacco experiments with multiple trait breeding different traits and hence different genes can contribute to total yield depending on the generation in which selection is effective.

Within single populations, gene effects can change, and between populations, the differences can be increased or decreased in several component traits, as selected by "human" or "natural" criteria of fitness. The natural structure of between population variation is determined by the relative strengths of selection, migration rates, and effective population sizes within the component populations. Because these are all subject to directed or accidental forces, the degree and form of inter-populational differentiation is subject to rapid change. Physical environmental changes and biotic responses to those and other biotic changes have influenced the evolutionary history of all organisms and will influence in the future. Human effects and human evolution have been part of that global evolution and will continue to be whether by direction or default. The choice of withdrawing human impact on an ecosystem is one choice of management, in the broad sense, that will have consequences for the organisms contained but will not necessarily be the "best" or "good" by any particular measure, and probably not for maximizing or stabilizing genetic or ecosystem diversity. Thus, by managing either plantings or natural regeneration, selection of source materials and the segregation of mating demes, we can increase or decrease the variation between populations or provenances and hence the total genetic variation available to the species. In effect, this implies that what is defined as the species is subject to variation and the rate of evolution is subject to management. The sizes and patterns of genetic variation are evolutionary results as well as causes and can be influenced to protect or advance the diversity, stability, or other products or measures of forest values.

It is, therefore, within our capacity to change the nature of the subject of our conservation efforts as well as to expand the options available for "natural" or for guided evolution. There can be little doubt that we have not already massively changed the course of evolution and that simply to withdraw directed selection is not to return to any original state that is pristine, maximally diverse, or maximally resilient and stable. The major problem is that the means of intervention are costly and therefore limited to a relatively few cases where intensive effort is affordable, and that because the science is as yet highly uncertain, it is effectively limited to simple systems. While we know how to breed for commercial objectives in those species that are also relatively easy to manage due to their large levels of genetic variation and amenable silviculture, efforts in Canada are concentrated on about 10 species, and globally, on no more than twice that number. We also know how to conduct heroic rescue efforts as on the Speke's gazelle (Templeton and Read 1983) where genetic variation is almost gone, but where intensive breeding efforts can still increase population size. However, all such efforts do little for most species and may not do much for the most ecologically valuable, or for species that have reasonable chances of being useful for humanity in the future.

These techniques do indicate that substantial capacity exists for developing the genetic resource and that options exist for directing evolution for present or future human uses and for the sake of non-human species if so desired. They also indicate that other management options can be created such as in managed reserves, genetic resource reserves, extractive reserves, partial harvesting systems, etc. that can form devices for managing the genetic resource and that allow for more intervention than strict nature reserves which allow for virtually no human intervention. Therefore, many strategies can exist for genetic management such as use of mutations, controlling effective population sizes and migrations, and selection. Management tactics can include directed breeding, rescue breeding, development of multiple population breeding, controlling metapopulation structures, managing reserves of various sorts, etc. These various management tactics can then be woven into a genetic management strategy to maximize some goal. Thus an evolutionary perspective on the genetic resource vastly expands the options that we have for achieving multiple objectives, but brings with it the loss of simplicity in not only choosing among tactics but also in determining objectives. We can see that we are not bound by single management or non-management techniques but, given the array of techniques and tactics that are available, multiple objectives can be satisfied. We have also removed the simple objective of knowing that the ideal state was what exists now, or existed at some time in the knowable past. We have succeeded in seeing that no one objective is best and excludes all others, and that a larger synthesis is possible, but we have not yet achieved that larger synthesis.

As a step to approaching the larger synthesis, it is possible to say that immediate economically valuable species are reasonable starting points for conserving value and may serve for long periods of time into the future. It is also possible to conceive of the second rank species as those with present secondary value and those with high but as yet unrealized potential value. It is also possible that with some effort we could conceive of key species that can serve as ecologically important markers, for present and foreseeable future ecosystems, that we would wish to ensure can successfully evolve. It is then possible to consider which of the various genetic management tactics and techniques is most appropriate for these species and to develop an array of tactics for a conservation strategy. Such considerations can extend to all species, as all other species would serve as means to the ends of ensuring the well being of the primary species, but we would have a system to order priorities. A large research and development project would be to establish such a list and ordering, but I believe that this can be done. In order then to establish a strategy, we would only have to consider how the various management tactics can be integrated so that an optimum allocation of effort could be designed. One of the interesting features of this approach is that rarity does not necessarily increase the value of any species unless it increases its utility. The other effect that rarity can have is that it increases the impact that management can have on otherwise equally valuable and manageable species. This is just one example of how an approach to management of the genetic resource can be a dynamic conservation system and can provide policy guidelines for a strategy.

Global Strategies

In developing a global strategy, it is clear that the multiplicity of objectives and state of the species involved require that an array of management systems be used to provide the flexibility needed for any programs to be useful. There are perhaps 50 000 woody species to consider with perhaps some 500 or so that have been used or are of specific value of general or of high local significance. Since the IUCN began listing species, the number of woody species that have been considered to be threatened in whole or in some significant part has grown from 57 in 1978 to 133 in 1981 to around 485 at last count. There is some overlap between the lists of species of at least local value and the Threatened or endangered lists. Far less is known about the status of species that can be known to be of ecological significance either because they are ecological keystone species, important mutualists or indicators, or otherwise of value. Most of the species occur in the tropics where the greatest source of threat is forest conversion and, hence, there is a common threat of species and genetic loss with general habitat destruction and forest conversion. However, just as species and values are not uniformly distributed, so too the techniques of management cannot be uniformly prescribed. Much of the losses occur in semi-arid and other marginal lands where human pressure is heavy. For such regions, agroforestry can moderate some of the pressures and the establishment of village tree farms can be useful. Industrial forestry may or may not be effective in reducing pressure on fragile ecosystems or reduce the rate of forest conversion since the people served may not be those that compete for those lands.

One model for developing strict nature reserves where other multiple uses exist is the UNESCO model of reserves surrounded by concentric zones of alternate uses where the intensity of intervention decreases as the distance to the strict reserve boundaries are approached. A series of management systems can be envisioned: from the edges of agricultural fields and agroforestry to industrial forestry; to reserves managed for limited harvest and extractive reserves with genetic resource areas; and, to forms of management with less and less human intervention. One can also envision that sets of large and small reserves could simultaneously exist, each with greater or lesser security for long term status and with varying degrees of temporal as well as spatial connectedness. Whether these are organized contiguously or not, the economic, ecological, recreational, and other needs of the residents need to be integrated with what is biologically desirable, and the multiple users and methods of management need a system of adjudication.

In addition to national governmental programs, there are multiple agencies within countries that are not necessarily easily coordinated because, even among the governmental agencies, agricultural, fishery, and forestry departments often have different constituencies. Between government and business and non-governmental environmental groups, there is also as much division as exists in Canada. Into this maelstrom step international agencies of various sorts, from governmental bilateral, and multilaterals to international United Nations agencies to global funding efforts like GEF, and to non-governmental agencies like The Nature Conservancy. It has been estimated that the total annual investment from all sources in forest tree genetic resource conservation (and development supporting conservation) amounts to $5 million (U.S.) but that less than 20% of these funds are devoted to other than internal national objectives. Since a one-person breeding or gene conservation program can be estimated to require about $200,000 (U.S.) per annum, a large need exists for new international efforts.

Because the objectives of conservation are diverse, and because the available management methods are also diverse, there is also a tendency for the different agencies presently active in gene conservation to have different comparative advantages with respect to areas, species, and types of practices that could be effective. There is very little need for NGOs to be viewed as other than important elements of an overall global strategy as there is little need to consider forest industries to be other than significant actors on the conservation stage. Yet, neither of these groups have been effectively incorporated into the planning and program development of conservation efforts. In particular, there is a gap in the conservation and development of species of known utility for local or industrial use but which have not thus far been the focus of large breeding programs. Genetic inventories of species whose distribution or mating system may subject them to being genetically threatened and that may be ecologically significant or useful as indicator species, have also not been widely supported. By listing these or any other set of particular targetable needs, we do not thereby define a strategy. It may be that on a global scale, this is all that we can effectively do, but I suggest that a great intellectual and moral challenge for us is to begin thinking about global objectives, and whether we can define the means to achieve them and, among the feasible set, choose a strategy.

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Contributed Papers

A Gene Conservation Strategy for B.C. Conifers: A Summary of Current Approaches

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Abstract

A two-part strategy is discussed, with emphasis on technical justifications, for the conservation of conifer genetic resources of 23 British Columbia species. The first part is a survey of the frequency of conifers in current land reserves in B.C. The second part outlines an approach that may be useful in setting priorities for additional gene conservation activities. This attempts to use information we have on individual "species status," from i) the survey of protected areas, ii) the status in provenance and breeding programs, and iii) the relative capabilities for natural regeneration. This process is illustrated using a few example species. In general, the protected status of the 23 native conifer species in the current network of protected areas is good. Although this is an ongoing process (i.e., incorporating new data from both new and old *in situ* reserves, and setting new priorities among species), it appears species like western hemlock are under little threat, whereas Pacific yew and whitebark pine require more attention. However, recent information and special gene conservation collections may have reduced the perceived threat to Pacific yew, at least in the short term. Follow-up work is required and attention must now be equally focused on certain populations not located in B.C. as they could be as important as those currently protected in that province.

Résumé

On examine une stratégie en deux volets, mettant l'accent sur des justifications techniques, visant la conservation des ressources génétiques de conifères de 23 essences de la Colombie-Britannique. Le premier volet est un relevé de la fréquence des résineux dans les réserves foncières actuelles en Colombie-Britannique, et le deuxième volet souligne une approche qui peut être utile pour l'établissement des priorités touchant les activités supplémentaires de conservation génétique. On tente d'utiliser l'information disponible sur «l'état de essence» se fondant sur i) l'étude de secteurs protégés, ii) leur état d'après les programmes de provenance et de reproduction et iii) les capacités relatives de régénération naturelle. On illustre ce processus à l'aide de quelques essences utilisées comme exemple. En général, l'état de la protection des 23 espèces indigènes de conifères du réseau actuel de secteurs protégés est bon. Bien que cette étude soit encore en cours (c.-à-d. qu'on est en train d'incorporer de nouvelles données de réserves *in situ* nouvelles et anciennes et d'attribuer de nouvelles priorités aux espèces), il semble que des espèces comme la pruche occidentale soient peu menacées, alors que l'if occidental et le pin albicaule requièrent plus d'attention. Toutefois, selon des informations récentes, et grâce à des collections spéciales de conservation génétique, il semble que l'if occidental soit moins menacé qu'on ne le croyait, du moins à court terme. Des travaux de suivi sont nécessaires et l'attention doit également porter sur certaines populations qui ne sont pas situées en Colombie-Britannique, étant donné que celles-ci pourraient être aussi importantes que les populations actuellement protégées en Colombie-Britannique.

Introduction

Needs, justifications, and strategies for the conservation of forest tree genetic resources have been discussed at length by many authors (e.g., Ledig 1986, 1988; Namkoong 1984; Zobel 1978). However, very little has been reported on details of development and implementation of conservation theories. This is probably due to the difficulty in setting priorities among species (or, as we shall see, populations), as well as determining which gene conservation approaches, i.e., *in situ* versus *ex situ*, or some mixture thereof, are appropriate. While philosophical justifications for this work are relatively easy to develop, technical justifications are much more difficult because each conservation activity must be knowledge (or assumption) based. In addition, no clear separations are generally present for either utilitarian or ecological needs. In other words, does this work have, as an end point, gene conservation for trait improvements for tree breeders of the future, or is it based on our obligation to the integrity and perpetuation of "natural" ecosystems where the species is present? The former is much easier to defend in cost-benefit terms, and perhaps even carry out. The latter, although appealing, is less easy to defend, and in many situations may not be genetically defensible.

From an evolutionary point of view, however, maintaining some wild forest stands so that they can continue to respond to natural evolutionary pressures *in situ*, even though these may be quite subtle (Frankel 1974, Levin and Udovic 1977), seems desirable and perhaps the only cost effective long-term approach to gene conservation. *In situ* reserves, with ecological representation as the main goal, can lend security to *ex situ* collections made for breeding purposes; i.e., *ex situ* collections may be the only security for *in situ* conservation of populations threatened with local extinctions (Namkoong et al. 1988). Therefore, both *in situ* and *ex situ* approaches are necessary in a viable gene conservation strategy (Falk 1987), irrespective of a utilitarian or ecological justification.

In this paper, and in our current gene conservation initiative, an emphasis is placed on "utilitarian" needs. First, most can agree that the "utilitarian" approach is an important first step in the development of a gene conservation strategy (Namkoong 1991). Second, a large initiative of setting aside additional protected areas based on ecological representations is underway in British Columbia, which will add an additional level of protection of *in situ* conservation (Province of British Columbia 1993).

The objectives of this paper are to:

1) briefly describe the justification, technical assumptions, rationale for certain tactics and the tactics themselves for the current gene conservation strategy of conifers for British Columbia;
2) within tactics, briefly present the results of the survey of protected areas for the maintenance of genetic resources of conifers in B.C. (Lester et al. 1993);
3) within tactics, show the contribution of breeding populations and provenance research germplasm (i.e., *ex situ*) to the gene conservation efforts in B.C.;
4) at a general level, incorporate silvical information about each species in the conservation strategy, and;
5) illustrate one approach to setting priorities for future action.

A Justification for Gene Conservation

The development of a clear justification for gene conservation of many of our native conifer species is not simple. There are three reasons why this is so:

1) Many commercial important conifers have a large geographic distribution and are quite common in many ecosystems. For example, white spruce (*Picea glauca* Monch. Voss) occurs from B.C. to Quebec. Moreover, many of our species are capable of substantial reproduction and re-colonization in many highly disturbed ecosystems. Except in special situations (such as outlier populations), these species (or populations) may require no or very little attention. Decisions to do nothing, however, must be viewed as part of a carefully considered gene conservation strategy!
2) Many breeding populations (for species in some type of genetic improvement program) contain a large number of genotypes which likely carry many of the useful alleles a breeder may require. Population sizes as small as 120 individuals (diploid homozygous) have a probability greater than 90% of sampling an allele at a frequency of 5% (Gregorius 1980). Therefore, many genes will be present in most breeding populations, and the dynamic nature of breeding probably will allow us to create allelic combinations needed to meet any future trait requirements (Eriksson et al. 1993)
3) Even with population sizes that are relatively small (e.g., population sizes of approximately 40), substantial genetic response has been observed over many generations (Madalena and Robertson 1975) as new genetic variance becomes present from mutation (Hill 1982) and from the break up of non-additive variance (Bryant et al. 1986).

Why, then, are we so concerned?

The primary justification, once again from the utilitarian view, is as follows: *if breeders do need genes currently at low frequencies in breeding populations to deal with some future trait objectives, effective population sizes will be reduced because relatively few genotypes within the population are likely to have the gene. Small effective population sizes contain enough genetic variation for short-term genetic response, but long-term response requires relatively large numbers. We need, therefore, to be able to raise the probability that rare genes will be available to us in genotypes largely unrelated to that in "current" breeding populations.*

Technical Assumptions and Rationale for Certain Gene Conservation Activities

The justification presented above now acts as the controlling principle behind the gene conservation strategy for conifer tree species in B.C. Next, however, we need to present some of the technical rationale that allows us to implement certain activities to meet our overall goal.

First, "populations" are considered the unit for gene conservation, even though we are basically targeting alleles. The assumption is that enough individuals can be "sampled" to capture alleles at their current (or approximate) frequencies in the population — so populations are a convenient unit of conservation.

Second, populations at the edge of a species distribution, particularly outlier populations, may be worthy of the first conservation activities. (Core populations, by the definition presented later, could be considered the most important, however, as we shall see the "core" populations are generally well protected). Outlier populations may have experienced unique environmental selection pressures and, in general, reduced gene flow. Furthermore, relatively small populations may have been established from a few progenitors (i.e., gene frequency differences may largely be due to drift). While the actual genetical reasons for the increase in "value" of genes in outlier populations may be currently unknown, significant genetic gains could be realized from these populations (e.g., Russian Gulch sources of Sitka spruce grown in B.C. could exhibit significantly higher growth potential: J. King, pers. comm.). A classic example in forest trees is the Guadalupe and Cedros Island populations of *Pinus radiata*. These populations have shown large differences in disease resistance (Old et al. 1986) and other characteristics (see Moran et al. 1988).

Third, populations in seemingly "central" areas of the species distribution may occupy slightly different ecologies and may have undergone some unknown selection pressures in the past, even though we may have no current indications of this. While this may be rare, we have important examples of where this must have occurred (e.g., weevil resistance in *Picea sitchensis*, Ying 1991). Unfortunately, these unique selection pressures (and therefore populations) may be unpredictable as to where they will occur, so many "random" populations would be needed. Hence, a large number of genetic "redundancies" would likely occur. This is where an *in situ* conservation strategy based on ecological considerations may assist greatly.

An additional issue, usually mentioned as important in gene conservation, is the presence of "co-adapted gene complexes" and why we might need to preserve them. However, as pointed out by Ledig (1986), our interest in co-adapted gene complexes is rather minimal, as the genes will be incorporated into a somewhat "new" genetic background, removed from their original context. Genetically, a co-adapted gene complex must reside in linkage disequilibrium, which we may be able to change by selection and breeding. Even though the need for co-adapted gene systems may be important, they are probably best accommodated by conservation *in situ* because naturally regenerated local stands will maintain these gene associations, irrespective of what the evolutionary origin might be.

Tactics

Although the terms *in situ* and *ex situ* have very distinct meanings, as they relate to gene conservation "activities," some overlaps and confusions can arise. The following discussion of tactics will attempt to clarify some of the potential confusions (at least for the purposes presented here), as well as to describe the utility of each of the proposed tactics.

1) Use of Current Reserves

Current protected areas are attractive as long-term conservation "vehicles," but a few inherent problems need to be discussed. First, they are not managed specifically to keep the current forest composition intact. Management to maintain the species composition might not even be possible due to natural stand dynamics (i.e., successional replacement). Second, protected areas are typically natural stands and will be relatively low heritability environments in which to observe genetic variation. A related point is that the desired environmental challenge may not even be present to elicit genetic variations of interest (e.g., some pest). Third, any loss by political, biotic, or abiotic causes is always possible. Although reserves are probably quite safe for one human lifetime, that may be a soft definition of "long-term" gene conservation.

While there are some problems with using current protected areas for gene conservation, they do offer large, relatively undisturbed areas that are well protected (i.e., by protective legislation). In most cases in B.C., they are quite large and are relatively intact natural areas that have not been substantially manipulated by man. Moreover, efforts to keep them in their current "natural" state are reasonable (even though fire suppression policies in Parks sometimes encourage fires) as they are typically managed to minimize large impacts of human use.

2) New Reserves Systems "Managed" for *in situ* Purposes

One of the best description of these types of land units for gene conservation purposes is presented in "Douglas-fir Genetic Resources: An Assessment and Plan for California" (Riggs 1982). The "Genetic Resource Management Unit" (GRMU) has, as a primary objective, to be an area managed for the integrity of the local gene pool. These areas are now being considered in California gene conservation activities (Millar and Libby 1991). Timber harvesting is allowed, and perhaps even required, to accomplish the objective, as long as natural regeneration of the target species is possible. Artificial regeneration is also allowed, as long as it uses only "very local" seed.

GRMU's could contribute substantially to the B.C. gene conservation initiative. They meet the *in situ* requirement for gene conservation and yet allows for a dynamic management of the local gene resource; i.e., higher heritability environments for mass selection can be created. However, they are not being proposed in B.C., at this time, for two reasons. First, the Protected Areas Strategy and our survey of currently protected areas require acceptance and formalization before we could identify candidate areas for GRMU status. Second, development and implementation of operating procedures for maintaining particular species in a GRMU would take substantial efforts. This task is being avoided at present but, in some situations, we might need to use the GRMU vehicle for gene conservation.

3) *Ex situ* Collections and Experimental Plantations

a) General

Ex situ collections can take many forms. The definition for *ex situ* used here is that it is any collection or planting of material not purposely established or held to regenerate itself naturally. Obviously, storage of seed with cryopreservation techniques is *ex situ* and, therefore, so are provenance and progeny tests. While provenance and progeny tests are usually established in areas where one could be interested in an *in situ* activity, the material itself is not intended for natural regeneration. In other words, collections are being "held" in forest environments, the same as their seed might be in cryopreservation.

b) Provenance Collections and Tests

Provenance tests typically sample a large part of the species distribution, or at least populations that might be economically relevant to the Province's objectives. Of greater importance, however, is that provenance tests expose many diverse genotypes to new "high heritability environments;" i.e., our ability to detect important genetic variation will be much greater because these tests are designed to minimize "environmental noise." (In these proceedings, Ying has described the importance of the trials for informational purposes in planning for gene conservation activities for a number of B.C. conifers).

Unfortunately, many peripheral (marginal) and outlier populations are not sampled in these types of tests. Many times their inclusion will not be cost effective because the new test environments will be quite ecologically unsuitable (e.g., Douglas-fir material from Arizona does not do very well in coastal B.C.). Nevertheless, more extreme sampling could be desirable in future provenance studies.

c) Breeding Populations

Tree breeding is the most dynamic and flexible means of gene conservation (Eriksson et al. 1993). It may behoove breeders to now invest some of their resources in breeding for increased genetic variation, which would require only slight changes to current strategies. As described above, the Douglas-fir material from Arizona planted in B.C does not provide a useful product; however, when crossed with local genotypes (and subsequently producing F_2's) "new" genetic variation could be exposed in useful form (G. Namkoong, pers.comm.). Also, intra-genus hybridization could provide a source of genetic variation for adaptation to new environments (e.g., Lewontin and Birch 1966).

Step 1: Survey of Protected Areas for the Maintenance of Genetic Resources of Conifers in B.C.

The first task was to assess the status of each species within the current reserves protected by legislation (i.e., Ecological Reserves, Provincial Parks, National Parks). The key assumption made with this approach is that genetic variation tracks geographic, climatic and ecological variation: i.e., genetic differentiation is mostly the consequence of natural selection. While known to be untrue in a number of species (e.g., *Pinus monticola*, Rehfeldt 1979), in species where no prior knowledge exists this is the safest and most reasonable assumption to make. Even when substantial research has been done on a particular species, the assumption is still valid because marginal or outlier populations may not be adequately represented in such studies.

The following steps describe the approach used in the survey of currently protected areas:

1) For each of the 32 terrestrial ecoregions in the Province (Fig. 1), Ecological Reserves, Provincial Parks, and National Parks greater than 250 ha were listed for each combination of biogeoclimatic zone and the tree species' expected occurrence. (Species codes for the 23 tree species are given in Table 1 and the codes for the 14 biogeoclimatic (BGC) zones are given in Table 2). Reserves of 250 ha or greater should have a reasonably large number of individuals of the target species to meet our

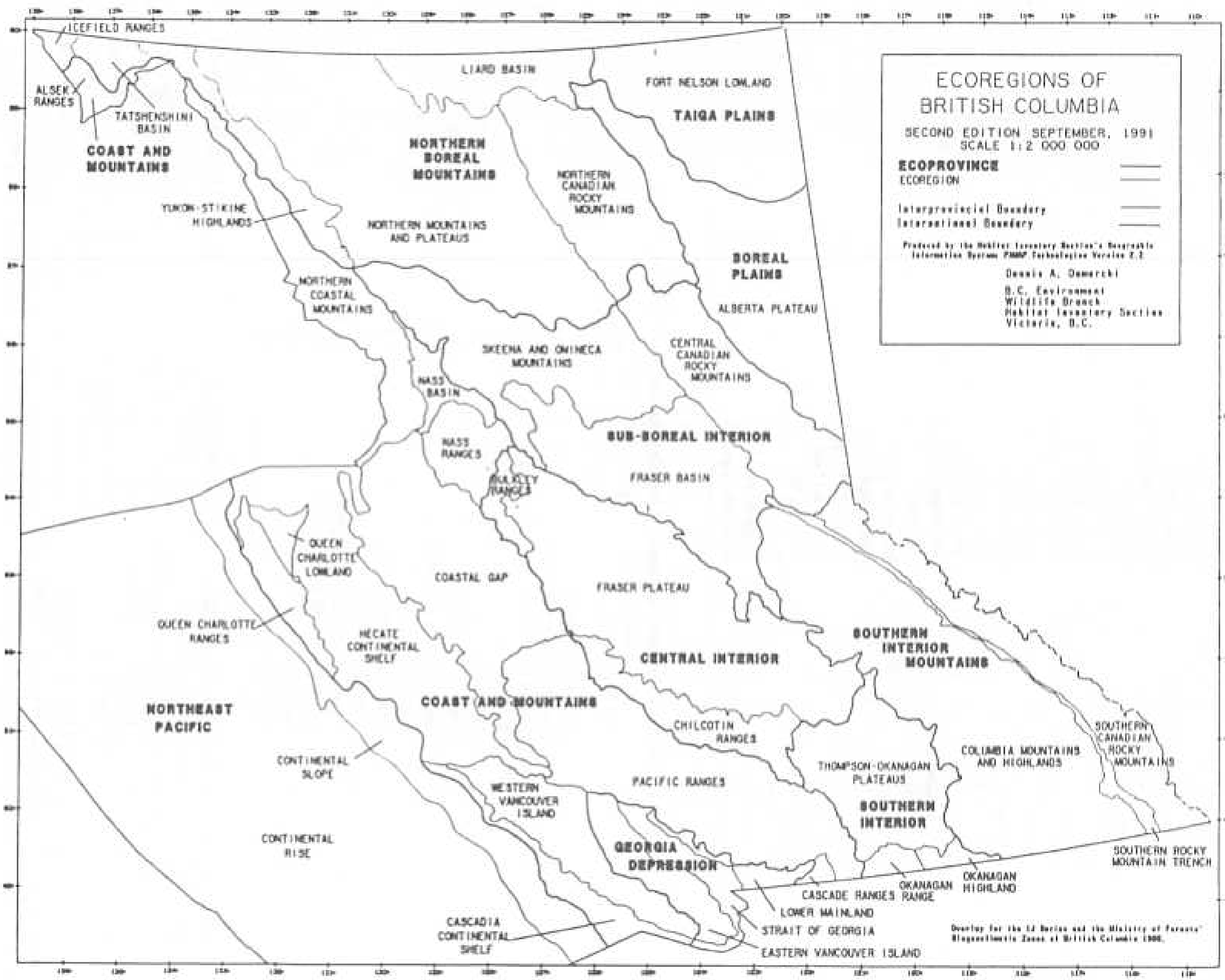

Figure 1. Ecoregions of B.C.

Table 1. Species list for conifer species currently under review for gene conservation status in B.C.

Scientific Name	Common Name	Code
Abies amabilis	Pacific silver fir	Ba
A. grandis	grand fir	Bg
A. lasiocarpa	subalpine fir	Bl
Chamaecyparis nootkatensis	yellow cedar	Yc
Juniperus scopulorum	Rocky Mountain juniper	Jr
Larix laricina	tamarack	Lt
L. occidentalis	western larch	Lw
L. lyallii	alpine larch	La
Picea engelmannii	Engelmann spruce	Se
P. glauca	white spruce	Sw
P. mariana	black spruce	Sb
P. sitchensis	Sitka spruce	Ss
Picea hybrids	spruce hybrids	Sx
Pinus albicaulis	whitebark pine	Pa
P. banksiana	jack pine	Pb
P. contorta	lodgepole pine	Pl
P. flexilis	limber pine	Pf
P. monticola	western white pine	Pw
P. ponderosa	ponderosa pine	Pp
Pseudotsuga menziesii	Douglas-fir	Fd
Taxus brevifolia	Pacific yew	Tw
Tsuga heterophylla	western hemlock	Hw
Tsuga mertensiana	mountain hemlock	Hm

Table 2. List of the 14 biogeoclimatic zones of British Columbia and code abbreviations

Zone Name	Code
Coastal Douglas-fir	CDF
Coastal Western Hemlock	CWH
Mountain Hemlock	MH
Bunchgrass	BG
Ponderosa pine	PP
Interior Douglas-fir	IDF
Interior Cedar - Hemlock	ICH
Montane Spruce	MS
Sub-Boreal Pine - Spruce	SBPS
Sub-Boreal Spruce	SBS
Engelmann Spruce - Subalpine Fir	ESSF
Boreal White and Black Spruce	BWBS
Spruce - Willow - Birch	SWB
Alpine Tundra	AT

conservation concerns. The threshold of 250 ha results in an underestimate of the number of reserves where important protection may exist. For problem areas that were identified after this first screening, smaller units were considered.

Any reserve, of course, only becomes relevant when the tree species is expected to be present based on its known distribution in the Province. These were noted for each species on four levels of expected frequency in each biogeoclimatic unit in each ecoregion (e.g., Table 3, for the Northern Coastal Mountains Ecoregion). Krajina et al. (1982) was the source for the range maps and initial identification of species associations in biogeoclimatic zones. Changes since 1982 have been made (B.C. Ministry of Forests 1991), and these were incorporated where appropriate. Species community lists were usually available for Ecological Reserves. Cover maps were generally available for Provincial Parks and National Parks, as well as some volume data.

Table 3. Expected frequency of species (based on ecological associations) in respective biogeoclimatic zones (BGC) in the Northern Coastal Mountains ecoregion and protected areas in each BGC zone. Species codes are in Table 1 and GCC codes are in Table 2. Percentages are the proportion of the ecoregion containing the indicated BGC zone. Expected frequencies are: +++ high, ++ moderate, + low and (+) rare frequency. Protected areas are given by number: PP is provincial park, RA is recreational area, ER is ecological reserve

	Biogeoclimatic Zones in Ecoregion					
Tree Species	AT (51%)	BWBS (<1%)	MH (16%)	ESSF (5%)	ICH (2%)	CWH (19%)
Ba			+++	(+)		+++
Bl		++ PP689 RA783	++	+++ ER59	++	+ ER59
Se			+	+++ ER59	++	
Sw		+++ PP689 RA783		+ ER59		
Sb		+++ PP689 PP783		+		
Ss			+			+++
Pl		+++ PP689 PP783 RA783	+	+++ ER59	+	++ ER59
Hw			++	+	+++	+++ ER59
Hm			+++	++	+	+
Yc			+++	(+)		++
Cw			+	+	+++	+++
Tw			(+)	(+)	++	++

Volume estimates were provided by the Forest Inventory Report System of the Ministry of Forests (see Lester et al. 1993).

2) The number of ecological reserves and parks, where a given species might be protected, was tallied by species. An example is given in Table 4 for Sitka spruce.
3) Ecoregions, by their virtue of location, were then assigned to three categories for each species. First, were "core" ecoregions — these were areas typically in the central distribution of the species range in B.C and the most "common" biogeoclimatic zone where the species is present. Second, were "peripheral" ecoregions — those being on the edge of the species distribution. Peripheral distribution was considered in both the geographical and biogeoclimatic sense (Lester et al. 1993). Third, were "outlier" ecoregions - those ecoregions where populations outside the continuous distribution of the species were present. Of course, these assignments were somewhat arbitrary but necessary to avoid many potential genetic redundancies.

It was also recognized that tree species differ in the degree to which they conform genetically to the landscape. Current knowledge of the patterns of genetic variation associated with geography and the distribution of genetic variation among and within populations was used. This kind of information originates from genecological studies (e.g., Rehfeldt 1984, Ying et al. 1985). Past and future allozyme studies will be an additional source of information, because they continue to be important in species comparisons and in answering specific questions of population structure (Lewontin 1989). For example, Yang and Yeh (1993) have suggested, from the allozyme data of Adams (1981), that an optimal strategy for *in situ* conservation in Douglas-fir is to set aside a single large population with the maximum number of alleles.

Table 4. Number of ecological reserves (ER), provincial parks (PP) (including Recreational Areas and others) and national parks (NP) where Picea sitchensis is expected to occur. First column under each BGC denotes the number of ER's, second column the number of PP's and the third column the number of NP's present in each ecoregion. X denotes no reserve present. Blanks denote not relevant to Sitka spruce ecological associations

	BGC Zone								
Ecoregion	CWH			CDF			MH		
Eastern Vancouver Island	0	0	0	0	2	0	0	2	0
Strait of Georgia		X		1	4	0			
Lower Mainland	1	5	0		X				
Western Vancouver Island	6	7	1				3	2	0
Cascade Ranges	0	2	0				0	1	0
Pacific Ranges	1	4	0				0	4	0
Queen Charlotte Ranges	2	0	1				1	0	1
Queen Charlotte Lowland	1	1	0						
Coastal Gap	3	4	0				2	3	0
Nass Ranges	1	1	0					X	
Nass Basin	1	0	0						
Northern Coastal Mountains		X						X	
Fraser Plateau		X							

4) Within each of the ecoregion-BGC zone combinations, the Forest Inventory Report System was used to estimate the "number of stems" present in each of the protected areas; wood volumes were converted to the "number of trees" based on expected relationships of volume per tree and number of stems per hectare. This review confirmed that, for some species, large numbers of trees are protected from harvesting by law. For other species, information was either currently unavailable or protection is lacking or inadequate (Lester et al. 1993).

As expected, some problems were encountered in the survey. Below are a few examples of items that still require resolution:

a) many *Abies* species are only identified as "balsam," hence, detailed breakdown by *Abies* species was not possible;
b) the separation of black spruce and white spruce, and Engelmann and Sitka spruce hybrids is quite difficult in certain parts of the ranges of spruce in B.C. However, the later is a well known "genetic" problem of spruces in B.C. (e.g., Kiss 1989) and not strictly a shortcoming of inventory data;
c) similarly, separations of western from mountain hemlock in inventory data is not possible in some parts of the Province.

5) Areas were identified where additional protection is recommended. For example, the six "X's" denoted in Table 4 show where Sitka spruce is expected to occur but where there are no reserves present. However, two of these were determined not to be important, at this stage of the assessment, as they were not assigned to a "core," "peripheral," or "outlier" population status; i.e., only the CDF and MH BGC zones in the East Vancouver Island, Strait of Georgia and the Pacific Ranges Ecoregions were identified as requiring some level of protection *in situ*. The first two could be considered "peripheral," as they are on the ecological "edge" of the species distribution, as opposed to the Pacific Ranges, which is more on the geographical "edge." (The Northern Coastal and Fraser Plateau Ecoregions were viewed as less important at this

time, although this becomes an arbitrary decision with some level of risk).

6) The definition of "adequate protection" had several elements and these are briefly described below:

a) for most species a "population" in a reserve was considered adequately protected if it had more than 5000 m^3 of wood present in the reserve. A conversion to "number of trees" was obviously necessary. Assuming an average of 0.5 m^3 per tree, this translates into 10 000 trees of a volume large enough (i.e., "merchantable" and probably at least 70 years old) to be noted from classical forest inventory techniques. This, of course, will vary substantially by species in different areas of the Province. For example, the number of old-growth coastal Douglas-fir trees would be overestimated, and the number of interior spruce trees underestimated, by this approach (Lester et al. 1993). Species differences in average volume per tree and volume per hectare were incorporated but, in most cases, the numbers of trees was still quite adequate.

b) population sizes estimated by this approach would not have considered trees below merchantable size; therefore, they are conservative estimates. We would value small trees as much as large trees in *in situ* gene conservation.

c) even in situations where only 1200 trees are present for a species (in a reserve), it is expected that alleles at frequencies as low as 1% will be conserved with a 99% probability, even if the genotypes are homozygous (Gregorius 1980). Complete homozygosity is rare in tree species, and the sample numbers required to capture alleles at these frequencies is reduced as Hardy-Weinberg equilibrium is approached.

d) we also assumed that because the census numbers will be relatively high in most reserves > 250 hectares (for individual species), population genetic concerns arising from small numbers or demographic problems (Lande 1988) will be minimal.

Step 2: Utility of the Survey of Protected Areas in B.C. and the Integration of Breeding Material and Species Silvics

While Step 1 accomplishes an important first step in the conservation strategy for the 23 conifer tree species of B.C., it is not sufficient by itself. At some point, for each species, the forest geneticist must reconcile which approach is appropriate for each population of interest. With the information from Step 1, we can now attempt to integrate some of the strategies mentioned earlier. One of these is to acknowledge the potential self-sustaining ability of many species in parts of their range. The primary purpose of this activity is to prioritize which particular populations, for the 23 species we've examined, are in need of some conservation activity.

But what criteria do we use to prioritize species and their respective populations? The following are the criteria we chose. Others may be valid but these could be "scored" according to the species status, albeit arbitrary in many cases.

a) *Is it a "common" species?* This was considered relevant because a species can dominate a particular ecosystem, e.g., western hemlock in the Coastal Western Hemlock BGC system (CWH in Table 2). Also, we assume here that a common species would have reasonably high natural regeneration potential in areas where it is a major component of an ecosystem. Therefore, outlier populations, particularly "small" ones, may be the only populations of concern.

b) *Does it have a large range?* A species with a large geographic distribution will likely "sample" many extreme environments, particularly at the edges of its range. Since threats to the important genetic variation seem minimal in central populations, populations on the periphery or outlier populations may be more important to conserve. However, unless some evidence exists for comparative adaptability of marginal populations, no bias should be given to marginality *per se* (Brown and Briggs 1991). This is not unrelated to criterion #1 mentioned above, except that it is based on a sampling of more extreme environments. Of course, this is quite arbitrary as any scores assigned to this category can be debated at length (e.g., is Sitka spruce scored a 1 or a 2 for its range, particularly relative to a species like white spruce?).

c) *Does the species have a large capacity for natural regeneration?* This is important because some species, with or without large site disturbances, are able to "turn over" generations (which should theoretically perpetuate the relevant local gene pool) on their own (e.g., western hemlock). In these situations, based on where the species is expected (from anticipated ecological associations), we could presume that an adequate level of self-perpetuation will occur. However, on the edges of its distribution (ecologically or geographically) in small populations, this capacity could be lowered by many demographic and ecological factors which could put these populations at risk.

d) *Status of species in current reserves.* Obviously, a species that is well represented in currently protected areas can be considered to be at lower risk than a species which is not. In the setting of priorities for gene conservation activities, these species are assigned lower scores.

e) *Status of species in provenance and breeding programs.* Clearly, a species under some genetic testing scheme can be considered better protected than a species which is not. The number of populations represented in the testing, the number of parents, and their distribution can all be weighted, but variations in program quality seem less important at this time than the simple fact that something is, or will be, in *ex situ* collections or under genetic improvement.

f) *What is the current or potential economic value of the species?* Once again, we are in the difficult area of utilitarian or ecological justifications. For example, Pacific yew required more immediate attention after its rise in profile due to potential use in cancer treatments (see Wheeler and Hehnan 1993) than did Rocky Mountain juniper. This, at least as it is acknowledged in terms of current value or threat, needs some consideration in prioritization of gene conservation activities.

Many approaches could be used to integrate the abovementioned criteria into a meaningful priority list. At the very least, the chosen method would point to the species and populations where immediate action might be required. Subjective "scores" for each of the categories were chosen as a first approximation to rank individual species. Table 5 presents a sample of four species out of the 23 surveyed. The overall "species score" for each criteria was on a 1 to 3 scale, although some other scale (e.g., 1 to 5) could be used, as well as differential weighting of each criteria (e.g., "Reserve Status" could be doubled and assumed twice as valuable, compared to a score of species "Value"). The four species presented in Table 5 indicate how this approach separates species at relatively high risk from those at relatively low risk. For example, western hemlock has a relatively low score (i.e., 8 points) and is probably not in great jeopardy, except for the score of "2" for the lack of outlier populations in good reserve status. A species like whitebark pine, however, obtained a high score. Moreover, the risk to whitebark pine seems greater because of the threat of blister rust in these particular ecosystems (Keane and Arno 1993).

Table 5 only confirms what we expected from a common sense supposition of all the species assessed to date. Gene conservation for western hemlock in B.C, at least at this point in time, requires little attention relative to Pacific yew and whitebark pine. Even for Pacific yew, based on our ecological surveys and genetic variation studies (El-Kassaby and Yanchuk 1994), the immediate threat is not great. Many of the other concerns might also be overstated simply because of our relative ignorance of how severe the threat might be (in the example of whitebark pine). Four years ago, the threat to Pacific yew seemed ominous. But in this short period of time, technological solutions (Wheeler and Hehnan 1993) combined with more knowledge about the distribution and ecology of yew, has reduced immediate concerns.

Table 5. Scores for four species based on six criteria for priorizing gene conservation activities (with scores assigned on a scale of 1 to 3, 1 being yes or "good status" and 3 being no or "poor status.") The criteria described as "value" is simply assigned high or low since it works counter to the 1 to 3 scoring system

CRITERIA	western hemlock	whitebark pine	Sitka spruce	Pacific yew
common	1	2	1	3
range	1	2	1	1
regeneration	1	3	2	3
provenance testing	2	3	1	2
breeding program	1	3	1	2[1]
reserve status	2	3	2	3[2]
economic value	high	low	high	high
Total	8+	16	8+	14+

[1]Pacific yew is not in a breeding program *per se* but special gene conservation collections have been made.
[2]Pacific yew is a 3 in "reserve status" because of very poor information as to its status in reserves.

Conclusions

One obvious limitation to this "made in B.C." analysis is that it has not or cannot consider populations in the U.S. and in other provinces in Canada. So far, only the provenance research program and a few specific breeding programs, which have sampled parents or populations outside of B.C., accommodate this concern to some degree. It will be important for us to become involved in North American forest tree gene conservation activities, particularly of *in situ* programs, to monitor the safety of relevant wild populations, or, at the very least, to make strategic *ex situ* collections. We hope that the logic of our approach is something that could be considered in national or international gene conservation activities.

Table 5 is very much a first approximation for the four species presented there, and ranking could easily change with small amounts of new information. (A similar table is being developed for the remainder of the conifer species). Our challenge is to continue to gather this information and implement the necessary strategies to ensure that we have a good chance of success for adequate conservation of the conifer genetic resources of interest.

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Long-Term Provenance Tests as Source Information for Gene Conservation of Forest Species

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Abstract

The first and foremost objective of gene conservation of native forest species is to protect gene complexes that convey adaptedness to their native environments resulting from generations of natural selection. The mode of adaptive genetic variability across species' geographic range, derived from long-term provenance tests, provides the foundation framework for decisions on which adaptive gene complex to conserve, and where and how to conserve (*in situ* or *ex situ*). Equally critical is the preservation of genes for their future value for breeding, e.g., pest resistance. It requires decades of exposure to natural environments for genetic differences in environmental adaptedness or pest resistance to become evident. There seems to be no shortcut from long-term field testing to knowledge of genetic variability of traits critical to a species' capacity to adapt to diverse and unpredictable situations in the future. Provenance testing results in British Columbia are highlighted and how this information can help decisions on gene conservation planning are discussed.

Résumé

Le premier et principal objectif de la protection génétique des essences forestières indigènes est précisément la protection des complexes géniques qui confèrent aux plantes un certain degré d'adaptation à leur milieu naturel sous l'action de la sélection naturelle qui s'est exercée sur plusieurs générations. La forme de la variabilité génétique de l'adaptation, lorsqu'elle est considérée dans l'ensemble de l'aire géographique de l'essence en question et qui est déduite de tests de provenance à long terme, fournit les critères nécessaires pour choisir les complexes géniques liés à l'adaptation qui seront conservés, ainsi que le moment où ils seront conservés et la méthode utilisée (sur le terrain ou ailleurs). En outre, il est essentiel de préserver le matériel génétique pour des travaux de sélection comme l'établissement de souches résistantes à certains organismes nuisibles. Il faut des décennies d'exposition aux conditions des milieux naturels pour que ressortent les différences génétiques qui correspondent à une adaptation au milieu ou à la résistance à des organismes nuisibles. Il n'existe apparemment pas de façon rapide pour gagner du temps sur les essais à long terme sur le terrain en vue d'établir la variabilité de caractères génétiques dont dépend la capacité d'une espèce de s'adapter à de nouvelles conditions variées et imprévisibles. Dans cet article, on fait ressortir les résultats des tests de provenance faits en Colombie-Britannique et on montre comment les renseignements obtenus peuvent aider à prendre des décisions relatives à la planification de la protection du matériel génétique.

Introduction

What makes gene conservation a complicated and difficult task is the requirement that such a conservation scheme has to consider not only biological effectiveness, but also economical and social impact; that is, to protect a healthy gene pool optimizing its capacity for continuing and stable evolution without infringing other resource uses (Frankel 1974, National Research Council 1991). This requires precise knowledge about the distribution and organization of adaptive genetic variation across the species' geographic range on which a rational decision can be made regarding the choice of populations and locations for conservation and methods of conservation (Rehfeldt 1991).

Longevity of tree species often requires decades of continuous exposure to the natural environments for adaptive genetic variation to become evident, e.g., adaptive tolerance to cumulative environmental stress, and insect and disease (Ying and Liang 1993). There seems to be no shortcut from long-term field testing to understanding adaptive variability of tree species; surveys of genetic differences based on biochemical gene markers or short-term tests in "artificial environment" may not reflect a species' capacity to adapt to the changing situations and environments which are often diverse and unpredictable (National Research Council 1991). This report summarizes what we have learned from our long-term provenance tests in British Columbia and discusses how this information can be used to facilitate a conservation scheme that is efficient biologically (*in situ* or *ex situ*). Weaving economical and social considerations into a conservation scheme that has a sound biological basis would be much more simple.

Provenance Research in British Columbia

Provenance research in British Columbia has been carried out by the B.C. Ministry of Forests since the early 1960s. L. Roche's genecological study of interior spruce at that time pioneered provenance studies in B.C. The Douglas-fir provenance trials were established by R.L. Schmidt. K. Illingworth was the driving force in organizing the most comprehensive lodgepole pine provenance research program ever attempted. Provenance study was further expanded in the early 1980s to the coastal true fir species. A total of 138 long-term test plots of seven conifers has been established (Fig. 1). Provenance research has been focused on the major commercial species and the recently introduced western red cedar, yellow cypress, western larch, and hardwood species.

Highlights of Results

The following summary highlights the main features about the mode of adaptive geographic variation and provenance differences in tolerance to pest attack among the major conifers which have been in field tests for at least two decades.

Mode of Geographic Variation

Lodgepole pine

The species' genetic organization and distribution is complex but four geographic regions can be readily detected. Table 1 gives a synoptic description of the distinguishing genetic characteristics of each region.

Interior Douglas-fir

Adaptive variation resides largely among provenances associated with environmental gradients, e.g., elevational cline. Provenances from wet-belt low elevation and coast-interior transition are among the most productive (Jaquish 1991).

Interior Spruce

Provenance differentiation is clinally associated with elevation, particularly in the southern interior of British Columbia (G. Kiss, pers. comm. 1993), otherwise there is no clear pattern along latitudinal or longitudinal gradients.

Table 1. Genetic characteristics of adaptive variability among lodgepole pine provenances from different regions

Geographic region	Genetic adaptation
Pacific Coast	narrow ecological adaptation
Coast-Interior transition	high within-population genetic diversity
Yukon-Northern interior	distinct regional adaptation (ecotypic?)
Central & Southern interior	steep clinal adaptation along elevation

Provenance testing for both interior Douglas-fir and spruce is much less thorough than for lodgepole pine.

Coastal Douglas-fir

Genetic differentiation parallels major climatic regions: maritime, dry maritime, and submaritime, but is not clearly defined within these climatic regions (Ying 1990).

Sitka Spruce

Sitka spruce shows a gentle north-south cline and sharp differentiation from coast (maritime) to inland (submaritime) in growth and hardness. Evidence suggests local adaptation of provenances in the hybridization zone (Ying 1990).

Genetic Resistance to Insect, Disease, and Small Mammals

Genetic resistance of Sitka spruce provenances to the white pine weevil (*Pissodes strobi*), the most devastating pest to plantation Sitka spruce, is unequivocal; differences in weevil resistance observed in provenance tests were experimentally repeated in clonal screening (Ying 1991). The Haney (lower coast) and Big Qualicum (Eastern Vancouver Island) provenances are the most resistant, and those from the hybridization zone are also highly resistant (Fig. 2).

Recent pest assessment has identified lodgepole pine provenances highly resistant to western gall rust (*Endocronartium harknessii*); most of these resistant provenances are from the introgressive hybridization zone of jack and lodgepole pine, Swan Hills (Alberta) in particular (Fig. 3). Some provenances from the same hybridization zone, e.g., Mt. Watt and Hawk Hills (Alberta) (Fig. 3), were highly tolerant of porcupine (*Erethizon dorsatum*) attack. Earlier studies on needle cast (*Lophodermella concolor*) have shown almost complete resistance of some provenances from wet-belt low

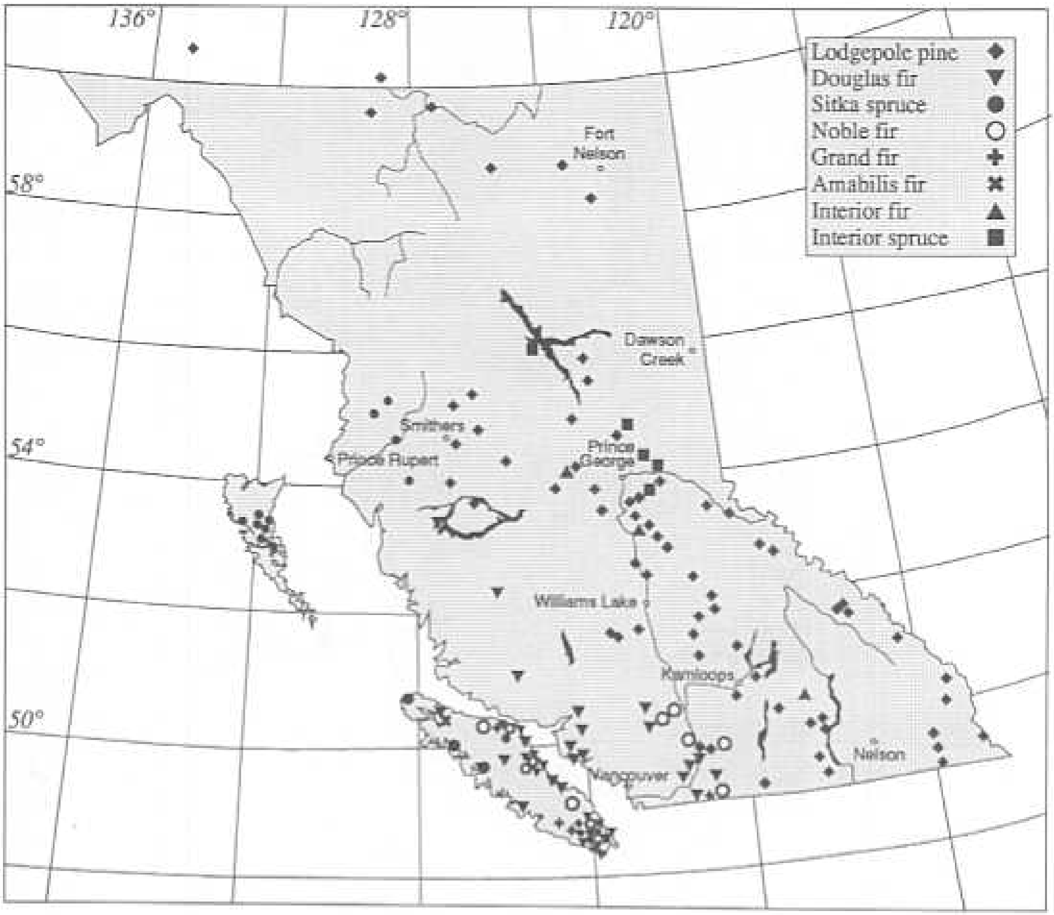

Figure 1. Locations of long-term provenance tests in British Columbia.

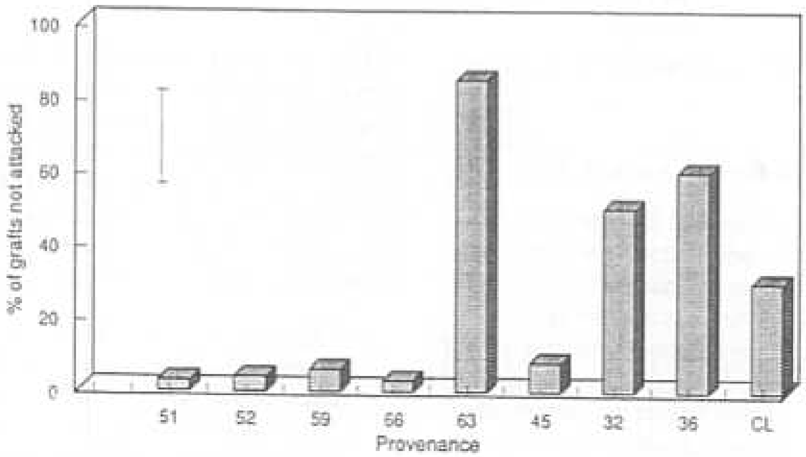

Figure 2. Differences among Sitka spruce provenances in percent of grafts free of attack by the white pine weevil (*Pissodes strobi*); No. 63 (Haney) the most resistance; Nos. 32 and 36 from hybridization zone of the introgressive Sitka and white spruce also highly resistant.

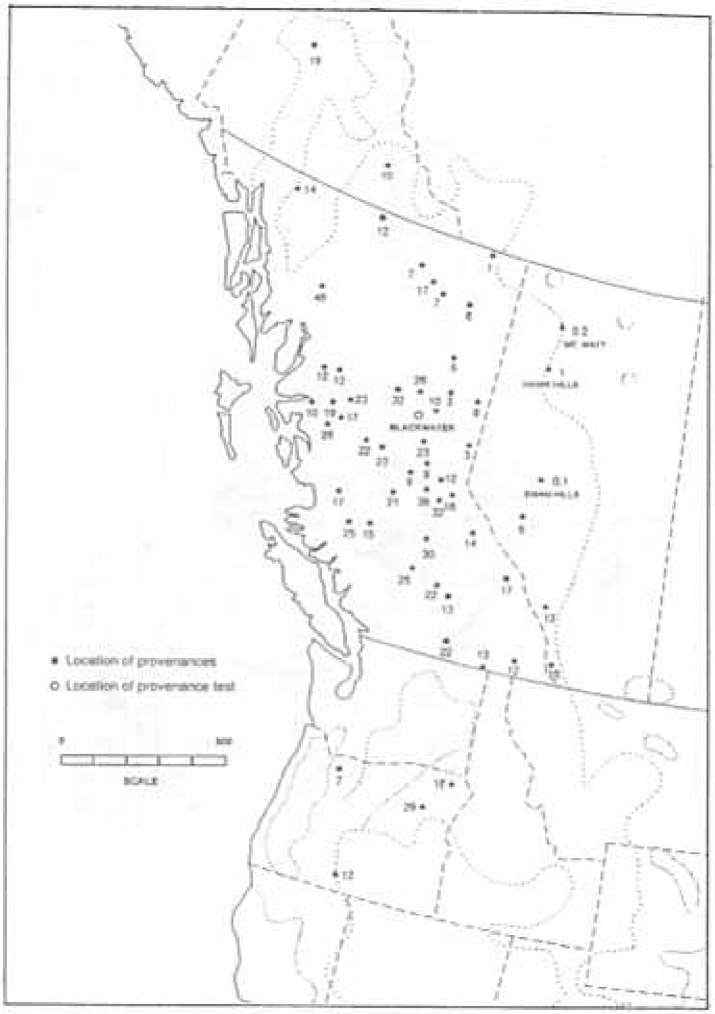

Figure 3. Differences among lodgepole pine provenances in average number of galls per tree infected by western gall rust (*Endocronartium harknessii*).

elevation, e.g., Inonoaklin, southern interior B.C. (Hunt et al. 1987).

Implication in Gene Conservation

"The genetic resource cannot be preserved, conserved, controlled, manipulated, or reconstituted without an understanding of the manner by which species have achieved adaptedness to heterogeneous environments" (Rehfeldt 1991). The very first priority of any conservation scheme has to be designed to capture the unique characteristics that Nature has developed through generations of screening within a particular environment (Zobel 1977). Knowledge of distribution and organization of adaptive genetic variability within the species' geographic range allows us to make intelligent decisions on what and where to conserve (e.g., size and number of reserves strategically dispersed across the species' natural range), and how to conserve (*in situ* or *ex situ*). This is the foundation framework for any effective scheme of gene conservation. Otherwise, gene conservation is not much different from sailing in an open sea without a compass.

- Lodgepole pine: Obviously, the four geographic regions (Table 1) have to be considered as building blocks in order to capture the "whole" of the species' genetic diversity which reside in ecotypic differentiation across the species' natural range.

Effective protection of the species' coastal gene pool has to be in its natural habitats (*in situ* conservation) because of its narrow ecological adaptation, unless a series of plantations, with each containing populations sampled from a similar ecological zone, can be established. Because shore pine is not an important commercial species, it is difficult to justify any form of expensive *ex situ* gene conservation. Natural shore pine grows mostly in bogs and muskegs and there is very little risk of loss of these natural habitats.

Large within-provenance variation (segregation of both morphologically coastal and interior types) suggests that Coast-Interior Transition may be the centre of the species' diversity. Natural stands are only scattered. Its regeneration has not been specifically addressed because of low commercial value. Protection of this gene pool deserves some specific attention.

Provenances from the northern limit of the species' range seem to have evolved adaptedness to the northern environments (sharp genetic differentiation from other interior provenances in growth, phenology, and pest resistance). This northern gene pool may be of global significance, northern Europe in particular, if global warming happens as predicted (Pollard 1990). However, protection of the gene pool has to be carried out locally *in situ* or *ex situ*; these provenances tend to be vulnerable to environmental stress and pests at sites south of their native habitats (Hunt et al. 1987).

Significant erosion of genetic resources is probably of least concern in Central-Southern Interior from the perspective of gene conservation *per se*; extensive sampling for the genetic improvement program should have captured most of the genetic variability of natural populations (Carlson 1993). The high elevation populations in the southern interior are the only exceptions.

Specific effort may be required to protect the introgressive populations within the areas where natural ranges of jack and lodgepole pine overlap. Our recent assessment suggests this interspecific gene pool may be of extreme significance to pest resistance. We know very little about the evolutionary significance of introgressive hybridization related to pest resistance.

- Sitka spruce: Either *in situ* or *ex situ* measures can be effective to conserve gene resources, except in the hybridization zone where *in situ* conservation seems to be the optimal option because of evident local adaptation. Sitka spruce was one of the major target species when coastal forests were first exploited, which resulted in fragmentation of natural stands, particularly along the outer coast. The white pine weevil devastation to young spruce stands further eroded the natural forests. *In situ* preservation of the residual natural stands should be the immediate concern; most of the old growth stands are probably already in protected reserves (Yanchuk 1993). However, to reconstitute the north-south adaptive clines, stands of local source may be needed to fill geographic gaps which may impede clinal gene migration.

Ex situ preservation of the weevil resistant provenances may be the only viable option since their natural habitats are vulnerable to urban expansion. Selection, screening and preservation of resistant genotypes are now well in progress.

- Douglas-fir: Conservation of peripheral provenances at the species' northern limit and provenances in the coast-interior transition (submaritime) should be of immediate concern. These northern provenances are small and isolated, and thus vulnerable to loss of both natural and non-natural causes. Such transition provenances may possess unique gene complexes valuable to the long-term breeding of high yield variety for the interior region (Jaquish 1990).

Otherwise, loss of any genetic diversity in the center of the species' distribution (coastal maritime, and low- and mid-elevation of southern interior), where this species is ubiquitous through natural and artificial regeneration, is very slim. Extensive provenance sampling and tree selection for tree improvement programs add another layer of genetic diversity protection *ex situ*.

General Discussion

Protection of biodiversity has been focused on species; the real danger of loss of biodiversity in many forest species may lie in the hidden erosion of within-species genetic diversity (Ledig 1993). The first and foremost importance in gene conservation is to preserve gene complexes that convey adaptability residing within geographic races or provenances through generations of screening selection in their particular environments (Zobel 1977, Rehfeldt 1990). Equally important is the preservation of provenances carrying valuable utility traits such as good form and growth and pest resistance. Despite the unpredictability of future demand on forest products, there is no reason to assume that the economic traits of the present day, such as good form and growth, will not be needed. Traits like pest resistance are always universally desirable and essential for the long-term success of any breeding program.

Recognition of the gene complex associated with site adaptability or pest resistance requires continuous and diligent observation of trees in well designed experimental plantations in forest environments. There seems to be no short-cut. Assessment of genetic diversity increasingly relies on biochemical gene markers; large amounts of data can be accumulated quickly and cheaply. However, biochemical gene markers, largely evolutionary genetic relics, provide useful indicators of genetic diversity and population structure. But there is no convincing evidence of biochemical genes related to adaptability or utility traits.

Long-term provenance testing has been a major component of tree improvement in Canada; about 900 hectares of experimental plantations involving 27 coniferous and 12 deciduous species have been established, and many of them are range-wide and have been in the field for at least two decades (Ying and Morgenstern 1988). These long-term provenance tests contain valuable information on adaptive genetic variation which can be extremely useful to a nationwide gene conservation scheme, *in situ* or *ex situ*, if our experience in British Columbia is any indication.

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Ecological Reserves

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Abstract

Conservation is achieved to varying degrees across the entire forest landscape, but is most comprehensive in protected areas, and particularly so in Ecological Reserves. The Canadian Forest Service Ecological Reserves Project has examined Canada's list of three thousand protected areas with a view to developing a national list of highly protected forests. At present, representation of ecosystem diversity is incomplete, as indicated by the absence of any highly protected areas in 46 of 148 non-arctic Ecoregions. Nevertheless, 265 areas are being considered as candidates for the list. The Project has initiated pilot studies that examine levels of human intervention across the entire forest landscape, as a context for the effectiveness of protected areas, through pilot studies in three Model Forests. The communication of values of protected areas to the forest sector is a continuing priority.

Résumé

La conservation s'effectue à divers degrés dans toute la forêt, mais elle est plus complète dans les aires protégées, et notamment dans les réserves écologiques. Dans le cadre de son Programme de réserves écologiques, le Service canadien des forêts a dépouillé une liste de trois mille aires protégées du Canada, en vue de dresser une liste des forêts hautement protégées. En ce moment, les écosystèmes ne sont pas représentés dans toute leur diversité, car aucune aire ne fait l'objet d'une très grande protection dans 46 des 148 écorégions non arctiques. Cependant, 265 aires pourraient figurer sur cette liste. Ce programme a aussi permis d'entreprendre des études pilotes dans trois forêts modèles, afin de déterminer le degré d'intervention humaine qui prévaut dans l'ensemble de la forêt. Ces données serviront de balises pour mesurer l'efficacité des mesures de protection. Parmi les priorités du programme, on notera aussi la sensibilisation du secteur forestier aux valeurs des aires protégées.

Introduction

The goal of conservation is the maintenance of productivity and resiliency in the biosphere. In this role, ecological reserves are instruments par excellence.

The Canadian Council on Ecological Areas (CCEA) has defined ecological reserves as legally protected natural areas where human influence is kept to a minimum (Taschereau 1985). They form the majority of the CCEA's National Registry of "highly protected" reserves, which recently included 776 national parks, provincial ecological reserves, and other protected areas (Forestry Canada 1991) .

Canadian ecological reserves have characteristics in common with protected areas elsewhere. Moir (1972) listed six basic features of natural areas in the United States:

i) they are integral parts of a systematic network, representing the diversity of natural environments; ii) they are relatively undisturbed by man; iii) they are selected according to ecological criteria; iv) they have assured permanency; v) they are set aside for scientific and educational purposes; vi) they harbour genetic materials of value to society.

While these features are certainly to be found in ecological reserves, as Moir pointed out, they also characterize a wide range of protected areas, such as wilderness areas, wildlife refuges and others. In other words, conservation objectives can be met to varying degrees in more than "highly protected areas". Indeed, conservation must be pursued inside and outside all Canada's 3000 protected areas listed in the National Conservation Areas Data Base (NCADB) (Turner et al. 1992). Nevertheless, beyond that basic framework, assurance of meeting conservation objectives is diminished, especially where objectives entail undefined features, such as microbial and fungal complexes involved in carbon and nutrient cycling, or the surprisingly rich ecosystems in old growth forest canopies.

The priorities of conservation do not remain static. For decades emphasis has been placed on critical habitat and endangered species. In this workshop we are examining the need of the forest sector, itself an expanding concept, to conserve genetic resources. In some parts of Canada, protection of watersheds has been the prime concern. It is entirely possible that we shall be protecting forests to conserve carbon in the future. And if ecosystems change, as some climate models imply, protected areas will be harbouring the greatest range of genetic materials from which new ecosystems can evolve (Pollard 1992). Protected areas protect many things, some living, some dead, some physical, and some quite intangible. This is why protected areas are to be viewed as vital elements of sustainable development. But we should not neglect the unique opportunities that protected areas offer research and education. As Aldo Leopold (1941) put it before many of us were born, "A science of land health needs, first of all, a base-datum of normality, a picture of how healthy land maintains itself as an organism".

The "healthy land" of Canada is in practice a very diverse land, with many ecosystems, communities, species, and varieties having evolved in adaptation to enduring features of landform and climate. The "base-datum of normality" must perforce be representative of this diversity, as argued by the CCEA (Peterson and Peterson 1991). The CCEA has proposed a systems plan for protected areas Canada that calls for defining this diversity in workable terms and representing it in protected areas (CCEA 1992).

The Ecological Reserves Project

In its Report to Parliament, Natural Resources Canada (Forestry Canada 1991) undertook to "ensure the preservation of representative areas of each forest ecosystem in Canada" with its Green Plan project, Ecological Reserves. In the two years following initiation of the Ecological Reserves Project (ERP), the forest sector has experienced a rapid escalation of public interest in natural forests, especially those regarded as old growth.

A new National Forest Strategy, issued by the Canadian Council of Forest Ministers (CCFM 1992) states:

"By the year 2000, all members of the forest community will complete a network of protected areas representative of Canada's forests, to provide ecological benchmarks, protect areas of unique biological value, and ensure wilderness experience."

If this can be achieved on a sufficiently extensive and comprehensive scale, some major concerns for conservation, including maintenance of biodiversity, opportunities for baseline monitoring and reference networks, and opportunities for scientific investigation and education, will be addressed in the process.

How Representative is the Existing Network of Protected Areas?

Representivity is a fundamental principle in the selection of protected areas, but a large number of protected areas, especially smaller sites, are concerned with more specific objectives. These are usually aimed at protecting critical habitat for a few or even a single species; often these species are rare, threatened or endangered. A preoccupation with such imperatives, under continuing pressure from incompatible land uses, has not addressed the need to protect viable examples of natural, locally evolved ecosystems. Clearly, both are important, and although much of the ERP is concerned with the latter, it embraces all forms of protected area in its terms of reference.

In initial consultations with some of the major interest groups, including World Wildlife Fund Canada and the CCEA, the ERP was dissuaded from establishing an independent National Register of Forested Ecological Reserves. Over the past year, however, the forest sector has increased its interest in protected areas. The new National Forest Strategy has strengthened the need to provide the Minister, the forest sector, and the interested public with periodic assessments of progress made towards the completion of a system of protected areas that is representative of the diversity of forest ecosystems in Canada. The intention is to make such assessments on the basis of best available information, and to refine these assessments as more selective criteria are developed and as the information base improves.

A first approximation of representation has been derived from the NCADB. Because larger, highly protected areas (IUCN Category I and II; see below) are most likely to represent the Ecoregion they occupy, the ERP developed a list for each Ecoregion in the 12 Ecozones that feature forests (three other Ecozones are essentially Arctic and treeless). The list comprises the larger protected areas that in aggregate form at least 80 percent of the total area protected under IUCN Categories I and II within each Ecoregion. This approach sets no minimum size on protected areas to be considered as representative, and thus accommodates the great diversity in size encountered among different Ecoregions.

The list generated in this process (Pollard 1993) contains 265 Protected Areas totalling 23.7 million hectares. All 12 Ecozones are represented (Table 1), with up to 11 percent of their area protected; however,

Table 1. Summary of protected areas and Ecoregions in Non-Arctic Ecozones

Terrestrial Ecozone	Protected Areas		Ecoregions		Ecozone	
	Number	Area (km^2)	Present	Represented	Total Area (km^2)	% protected
Tundra Cordillera	3	10872	10	3	322061	3.4
Boreal Cordillera	10	30875	13	6	367004	8.4
Montane Cordillera	35	14784	10	10	202456	7.3
Pacific Maritime	36	51270	6	6	467536	11.0
Boreal Plains	19	24390	12	12	834208	2.9
Taiga Plains	7	30366	6	6	472706	6.6
Prairie	10	3538	6	6	462270	0.8
Taiga Shield	6	417	22	3	1069698	<0.1
Boreal Shield	66	39643	44	31	1840801	2.2
Hudson Plains	4	25822	3	3	391239	6.6
Mixed Wood Plains	26	962	4	4	142289	0.7
Atlantic Maritime	43	2737	12	12	163677	1.7
Non-Arctic Canada	265	236598	148	102	6735945	3.5

Prairie, Taiga Shield, and Mixed Wood Plains are severely underrepresented, with less than 1 percent protected. Of the 148 Ecoregions occupying the non-Arctic Ecozones, 46 had no representation in the list. All unrepresented Ecoregions occurred in the Tundra Cordillera, the Boreal Cordillera, and the Taiga Shield (where only 3 out of 22 Ecoregions are represented).

Clearly, this is only a first approximation of a national list of protected areas, although some large gaps are already evident. More refined selection criteria are required for areas representing forest diversity, and the areas themselves must be examined in more detail for their suitability. An ad hoc working group has been formed to refine the selection criteria and to guide the development of data for listed protected areas.

As a first step, the ERP collaborated with State of the Environment Reporting to fund a pilot study to enhance the NCADB. The work was based on all 15 Ecozones of Canada, and dealt with both forests and wetlands. In this case, work was focused on the larger protected areas that in aggregate form at least 80 percent of the total area protected under IUCN Categories I, II, and IV within each Ecozone.

A total of 216 protected areas, 38.7 million ha in aggregate, were surveyed (Bryson 1993). Of these, 68 (13.6 million ha) were covered by the National Forest Inventory; satellite-derived AVHRR (Advanced Very High Resolution Radiometer) Land Cover data were derived for 145 protected areas, including 35 National Parks. The AVHRR data are widely applicable, although they should not be used on smaller (<1 km x 1 km) areas. More detailed stand information is available from the Canada Forest Inventory (CanFI), although relatively few protected areas are identified.

A follow-up to this work is currently under way. Data from AVHRR, CanFI and other sources will be compiled into NCADB descriptive "green pages" for the 265 accessions in the provisional list of the larger protected areas representing forests in Canada's Ecoregions.

Assessing Potential for Conservation at a Landscape Scale

While protected areas are undeniably vital elements of sustainable development, they are part of the broader landscape, and all contribute to conservation in some way. Protected areas are critical in severely disturbed landscapes, but less so where disturbance is low or moderate. The extent to which conservation objectives are met depends on the pattern of disturbance in the region considered, and thus on the mix of protected, managed, and unmanaged lands.

Many conservation objectives, including those for forest genetic resources, can be addressed outside formally protected areas and, in this regard, the value of Canada's forest landscapes may be underestimated by foresters and environmentalists alike. What is needed is an indicator of sustainability for given units of landscape.

To be effective, the indicator should be applicable at any scale, from local to regional, national, and even continental and global levels. It should reflect the landscape's capacity to support the diversity of organisms and natural processes that are essential to self-perpetuating ecosystems. Such an indicator should be widely accepted, outside as well as within Canada, because conservation strategy often crosses sectoral and national boundaries.

Recently, Lowe (pers. comm.) has proposed that the "reserved" class of the 1996 Canadian Forest Inventory (CanFI) be overlayed with assessments of protection, based on the six Categories of Protected Areas Management, as revised recently by the International Union for Conservation of Nature and Natural Resources (IUCN). Prompted by the introduction of a new IUCN Category, CVI: Managed Resource Protected Areas (which provides for a limited amount of resources utilization), Lowe also proposed extension of the series for application to the entire forest inventory, with three additional categories designed to classify other landscapes; the complete nine-category scheme is presented in Table 2.

Through the ERP, the concept of a nationwide assessment of inventoried forest land will be piloted with studies in Model Forests. In the proposed studies, the entire land base of each Model Forest will be classified in terms of the nine Categories in Table 2.

The land base will be analyzed at the stand level, or through any scheme by which a unit of land can be characterized by a single Category. The main task is to assess protection and management according to the scheme described and with a defined and generally acceptable rationale (all interested partners in the Model Forest should subscribe to the process of assessment). The pilot nature of this work is emphasized, however, and latitude will be allowed for interpretation of the Categories, in particular those addressing forest management. The following products are planned from each of the Model Forest studies:

i) working definitions of Categories (especially C7.1, C7.2, C8 and C9) as agreed to by the Model Forest partners.

ii) a short report to include (a) the rationale and resulting framework for landscape units to be categorized, and (b) the procedures adopted and agencies consulted for the definition and application of Categories to landscape units.

iii) an overlay of the Model Forest displaying protection and management according to defined categories, compatible with the Model Forest GIS system.

iv) a quantitative assessment of protection and management in the Model Forest with respect to its ecological framework, ie., aggregation of land area within each category for each Ecodistrict and Ecoregion in the Model Forest.

The overlay may be used for a variety of purposes; for example, the potential distribution of a species may be estimated if its tolerance of human intervention is known within the context of the nine categories, and if

Table 2. IUCN protected area management categories (CI-CVI) and proposed additions for Canada's Forest Inventory (C7-C9)

CI	Strict nature reserve/wilderness area CIa Areas managed mainly for science CIb Areas managed mainly for wilderness protection
CII	National park: protected areas managed mainly for ecosystem conservation and recreation
CIII	National Monument: protected areas managed mainly for conservation of specific natural features
CIV	Habitat/species management areas: protected areas managed mainly for conservation through management intervention
CV	Protected landscapes: protected areas managed mainly for landscape/seascape conservation and recreation
CVI	Management resource protection areas: protected areas managed mainly for the sustainable use of natural ecosystems
C7	Sustainable Timber Management C7.1 Extensive Sustainable Timber Management C7.2 Intensive Sustainable Timber Management
C8	'de facto' Wildland Protection
C9	Not Protected or Not Classified

its ecological requirements can be defined in terms of the ecological classification used in the Model Forest. The overlay may be used to plan forest management to maximize the extent of contiguous landscape units with high conservation potential or to buffer critical areas with low impact land use.

Links With Other Programs

The CFS is an active member of the CCEA and has been since 1982, when the CCEA was inaugurated. The CCEA provides a national forum for communication and debate among all major government and non-government agencies with interests in protected areas.

The Ecological Reserves program has supported a number of regional agencies, including:

i) the Atlantic Region Protected Areas Working Group which held a Workshop in June 1993. Keynote presentations were made by Stan Rowe, a long-time advocate of protected areas and conservation, and Derek Thompson, Director of Planning and Conservation for B.C. Parks. The development of an Atlantic Region Conservation Areas Data Base is also being supported;

ii) the Wilderness and Protected Areas Association, to develop proposals for a Protected Areas Strategy for Newfoundland. The Wilderness and Ecological Reserves Advisory Council for Newfoundland has secured funding for Model Forest initiatives from the Western Newfoundland Model Forest committee; and

iii) in British Columbia, the Conservation Analysis Working Group of the Protected Areas Strategy to conduct a special Workshop on Methods, Standards and Responsibilities for Conservation Analysis, December 10-11, 1992.

To date, the program has not forged working links with the CFS Ecological Land Classification network, although it is recognized that the topic is central to the concept of representation. Several schemes have been developed in Canada, some of which are compatible with classification adopted or developed by provincial and territorial agencies. Currently, the most acceptable and flexible is an hierarchical scheme developed by the Canada Committee for Ecological Land Classification (Turner et al. 1992). The scheme comprises 15 Ecozones, 45 Ecoprovinces, 177 Ecoregions, and 4557 Ecodistricts, although it is also in the process of revision.

Some important links may be made in the future with the Climate Change Working Group; the roles of protected areas in a changing climate were described by Pollard (1992).

Links With Model Forests

In addition to the proposed pilot studies on protected areas and forest management categories, the ERP examined the protected areas complement in or near Model Forests (Pollard and Bryson 1992). In 1993, three projects new studies were initiated:

i) in Fundy Model Forest, ERP is leading a gap analysis to identify critical and unique areas, sensitive species, centers of species richness, and major ecosystem types. If successful, the approach will become a model for the rest of New Brunswick.

ii) a similar initiative has been undertaken by a new Forest Ecological Reserve Working Group for the Eastern Ontario Model Forest and will include special studies of the three main site districts comprising the Model Forest. A prototype system for evaluating forest stands for ecosystem representation potential will be completed in this fiscal year; and

iii) in the Foothills Model Forest, a partnership will identify and recommend to the Province of Alberta areas suitable for inclusion as Ecological Reserves within or adjacent to the Model Forest. The task began with a series of public meetings to identify potential sites.

Communications

An annual report of ERP activities is published by the CCEA.

A newsletter of the Forest Ecological Reserves Network (FERN) is produced twice a year; a revised format is planned to facilitate wider distribution.

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Conservation of Forest Genetic Resources: British Columbia's Coastal Industry Perspectives

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Abstract

Sound management of the genetic resources in British Columbia's forests is an integral and indispensable element of any successful sustainable development strategy. The development of successful forest management strategies requires a deep understanding of a wide array of topics such as the extent and diversity of forest ecosystems, the impact of forest management practices on biological diversity, and strategies for gene conservation. The understanding of these topics will allow forest managers and gene conservationists to work together to combine utilization with conservation in the most efficient manner.

Successful, practical conservation strategy in British Columbia should consider logistical factors (for example, the ratio of the coastal industry forest land relative to the total biogeoclimatic zone land mass, the intermingled nature of present tenures over the landscape, the difference between crown and private land tenure, corporate land base classification (i.e., "operable" or "inoperable"), the type of regeneration systems used (i.e., natural vs. artificial), proximity of parks, ecological reserves, and protected areas to managed forest land bases, industry-government coordination, and the clear identification of governmental agencies concerned with conservation) and biological principles (such as the maintenance of the genetic variation needed for population viability and the evolution of the species in question; consideration of whether the genetic variation of a species and its structure among and within populations are inherent features of the species' evolution; differentiation between large vs. small genetic variation, wide distribution vs. endemic, abundant vs. rare, clinal variation vs. small genetic variation, wide distribution vs. endemic, abundant vs. rare, clinal variation vs. ecotypes; and species with commercial vs. non-commercial values, the status of the species in question from intact to destroyed, and account for species resilience level). Finally, it is imperative to all agencies concerned that extensive efforts should be directed to narrowing the present information gaps and supporting the basic research needed.

Résumé

Une gestion équilibrée des ressources génétiques est un élément primordial de toute stratégie de développement durable des forêts de Colombie-Britannique. L'élaboration de stratégies d'aménagement forestier nécessite une profonde compréhension d'une gamme de sujets tels que l'étendue et la diversité des écosystèmes forestiers, les répercussions des pratiques d'aménagement forestier sur la diversité biologique ainsi que les méthodes et stratégies de conservation des ressources géniques. La compréhension de ces domaines permettra aux responsables de l'aménagement forestier et aux responsables de la conservation du matériel génique d'allier leurs efforts en vue de combiner le plus efficacement possible l'utilisation et la protection.

En Colombie-Britannique, toute stratégie de protection pratique devrait tenir compte des facteurs d'ordre logistique. Il peut s'agir, par exemple, du rapport entre les terrains productifs côtiers et la totalité de la superficie de la zone biogéoclimatique, du caractère parcellaire et diffus des tenures à l'échelle du paysage, de la différence entre la tenure gouvernementale et la tenure privée, de la catégorisation des terres privées (c.-à-d. selon qu'elles soit exploitable ou non), du type de système de régénération appliqué (c.-à-d. régénération naturelle ou artificielle), de la proximité de parcs, de réserves écologiques et d'aires protégées par rapport aux terres forestières aménagées, de la

coordination des activités entre les gouvernements et l'industrie ainsi que de l'identification précise des organismes gouvernementaux intéressés à la protection). Toute stratégie de protection doit aussi tenir compte de principes de biologie. Il peut s'agir, par exemple, du maintien de la variation génétique nécessaire à la survie des populations et à l'évolution des essences dont il est question, de la question de savoir si la variation génétique à l'intérieur de l'essence comme du caractère qu'elle prend entre les populations et à l'intérieur de celles-ci sont des caractéristiques inhérentes à l'évolution de l'essence, de la différenciation entre de petites et d'importantes variations génétiques, de l'étendue de l'aire de répartition, soit une présence générale par opposition à endémique, de l'abondance par opposition à la rareté, de la variation clinale par opposition aux écotypes, du fait que des essences ont une valeur commerciale ou non et du statut de l'essence (essence disparue à non menacée) et de la prise en compte de la capacité de récupération des essences. Enfin, il est primordial que tous les organismes intéressés à la question tentent avec énergie de combler les lacunes dans nos connaissances et qu'ils appuient la recherche fondamentale nécessaire à cette fin.

Introduction

The genetic resources of our planet are among its most valuable raw materials. The maintenance of genetic diversity of plant species allows plants in their natural environment to evolve and adapt to a changing world. It also provides the opportunity to select and breed new varieties suitable for a range of environments and end uses. Therefore, protection and conservation of this national and international heritage should be given high priority by all governments.

Sound management of the genetic resources in British Columbia's forests is an integral and indispensable element of any successful sustainable development strategy. The attainment of this goal encounters at least two major and potentially conflicting challenges. These are: 1) the maintenance of the rich biological diversity currently found in our natural forest ecosystems, and 2) yield and value enhancement of commercial wood products per unit area.

The development of successful forest management strategies requires an understanding of a wide array of topics such as the extent and diversity in existing forest ecosystems, the impact of forest management practices on biological diversity, and strategies for gene conservation. The understanding of these topics will allow forest managers and gene conservationists to work together to combine utilization with conservation in the most efficient manner. This is necessary to maintain our competitiveness in world markets and to meet increasing demands on an ever shrinking forest land base.

Public concern about forestry practices in British Columbia has implied that monoculture forests in the province are increasing, thus simplifying forest ecosystems, reducing biological diversity, and diminishing ecosystem resilience. Knowledge regarding the level of ecological diversity, the structure of the genetic variation, and the biological factors that affect this variation, are needed for the development of a sound conservation strategy on both industrial and crown forest lands in coastal British Columbia.

In the following sections we will present our view, as industrial operators, on the role of the forest industry in the development and implementation of a well-coordinated conservation strategy in conjunction with the various governmental agencies responsible for conservation.

Genetic Conservation Parameters

An understanding of how ecosystems function is a central issue for successful, sustainable, forest management strategies. Ecological site classification, such as the Biogeoclimatic Classification of British Columbia's forests (Klinka et al. 1984) provides foresters with the "blueprint" by which many forestry practices and associated activities, including conservation, should be conducted. A total of 14 biogeoclimatic zones have been identified in British Columbia. The coastal forest industry holdings fall within three biogeoclimatic zones, namely, Coastal Western Hemlock, Mountain Hemlock, and Coastal Douglas-fir.

The development of a successful, practical conservation strategy should consider the following:

1. The ratio of the coastal industrial forest land relative to the total biogeoclimatic zone land mass.

The coastal western hemlock biogeoclimatic zone covers the majority of the managed forest lands in coastal British Columbia. However, the area managed for forest products represents only a small portion of this zone. A similar situation exists for the mountain hemlock biogeoclimatic zone: this zone represents the second largest forest industry land base but it covers an even smaller portion of this zone. Finally, the coastal Douglas-fir biogeoclimatic zone covers a very small portion of the industrial land holdings but it represents a large component of a small zone. The proportion of an ecosystem that is being modified should dictate the level of urgency for conservation. Special consideration should be given to unique situations. For example, where a significant proportion of an ecosystem is within a single or a few corporations' land holdings, the conservation responsibility should be that of the forest industry.

2. The intermingled nature of present tenures over the landscape.

The coastal industrial forest land holdings are intermingled over the landscape and it is not necessary for every corporation to design and implement independent conservation plan. To be effective, a coordinated overall plan is needed.

3. The difference between crown and private land tenure.

Conservation on crown land should be the responsibility of government agencies. The crown should be responsible for coordination with the industry. Distinct attention should be given when a significant proportion of an ecosystem is within a single corporate holding or few corporations' private land holding. For example, the majority of the coastal Douglas-fir biogeoclimatic zone exists within the private land of a few corporations.

4. Corporate land base classification.

In most cases the industrial forest land base is classified as areas that are "operable" or "inoperable" due to various reasons such as inaccessibility, low productivity, and that of soil stability, wildlife, or fisheries considerations. Conservation strategies should consider areas that are in the "inoperable" class as possible target areas.

5. Proximity of parks, ecological reserves, and protected areas to managed forest land bases.

The development of a coordinated conservation strategy should recognize the overlay of all parks, ecological reserves, and protected areas in relation to managed forest land base. Under such a scenario it is expected that, in the majority of cases, minor adjustments might be required to ensure conservation of most species.

6. Natural and artificial regeneration.

The proportion of areas regenerated by natural and artificial methods plays an important role in species/genetic conservation. Naturally and artificially regenerated stands should be considered in the conservation plan due to their important role as an effective means of *in situ* conservation.

7. Industry-government coordination.

The development of a well-coordinated conservation policy is necessary in order to eliminate redundancy. Coordination between industry and government will make it possible to develop a comprehensive and cost effective genetic conservation programs.

8. Identification of a single governmental agency.

The clear identification of a single governmental body responsible for conservation, planning, and implementation will, without a doubt, make the conservation task more manageable and efficient.

9. Compensation and incentives.

Given the mixed tenure system, some form of buy-back or tax incentive system (i.e., a compensation mechanism) should be considered developed by government to encourage gene conservation on both private and public land and to ensure that costs are shared equitably.

Tenants of Successful Conservation Strategy

A successful gene conservation strategy should contain various tactics suitable for accommodating the biological peculiarities of different species and different situations. The development of a "generic" strategy is counterproductive and, in most cases, does not secure successful conservation. The conservation strategy should embrace the dynamic state of biological systems. This includes the consistent change in population size including founding and extinction, as well as phenotypic and genotypic variation and fluctuations caused by the various evolutionary, biological forces such as mutation, selection, migration, and random genetic drift. A gene conservation strategy should: 1) be tailored to the maintenance of the genetic variation needed for population viability and the evolution of the species in question; 2) consider whether the existing level of genetic variation of a species, and its structure among and within populations, are inherent features of this species' evolution; 3) differentiate between large vs. small genetic variation, wide distribution vs. endemic, abundant vs. rare, clinal variation vs. ecotypes, and species with commercial vs. non-commercial values; 4) consider the status of the species in question from intact to destroyed; and, 5) account for species resilience level.

Tree Improvement Programs in Coastal British Columbia

Tree improvement activities in coastal British Columbia are coordinated between the Ministry of Forests and the forest industry on a cooperative level. A

Coastal Tree Improvement Council (CTIC) was established in 1979 to enhance this cooperation and to avoid redundancy. Breeding activities are for the most part done by the Ministry of Forests, while the maintenance of the tree improvement delivery system is done by both the Ministry and the forest industry. At present, a total of five species are in active Ministry of Forests' tree breeding programs. These are Douglas-fir, western hemlock, western redcedar, yellow-cedar, and Sitka spruce. Seed production is secured through the management of 26 producing, 18 established, and one developing seed orchards representing a total of 3863 parent trees (Reid 1993, Appendix 2).

Tree Improvement Delivery System and Genetic Variation

After the amendment of British Columbia's Forest Act in 1987, the cost and responsibility for basic silvicultural activities on crown land, including seed and seedling production, shifted to the forest industry. As a result, the control of genetic quality of seed orchard seed and resultant seedling crops became a central issue. A systematic evaluation of the genetic quality of the current tree improvement delivery system was required. In addition, an assessment of the potential for genetic erosion, during the seed production, processing, and storage, as well as seedling production phases, was also needed. Work on seed orchard genetics focused on the biological factors and management practices affecting the genetic quality of seed crops (El-Kassaby 1989). In addition, an assessment of the other phases of the delivery system (i.e., seed handling and storage, and seedling production) has also been conducted and some adjustments have been incorporated to assure the production of seed and seedling crops with high genetic quality (El-Kassaby 1992). Monitoring processes have been developed to ensure that seed meets the required genetic quality.

Current and Planned *Ex Situ* Programs

Most of the *ex situ* conservation activities in coastal British Columbia are in the form of either reproductive material, such as seedlots, from natural stands and seed and pollen lots from seed orchards as well as live trees in provenance trials, progeny test sites (see C.C. Ying, these proceedings), and clone banks (see Reid 1993). However, it should be stated that the main purpose of the reproductive material (seed and pollen) *ex situ* program is the production of seedlings for reforestation programs or the management of seed orchard crops. These seed and pollen lots represent a wide array of material with different species and genetic background. They have the added advantage of being rejuvenated, and thus do not suffer from the loss of genetic variation caused by ageing (El-Kassaby 1992; Chaisurisri et al. 1993).

Information Gaps and Needed Research

The development of a sound gene conservation strategy is dependent on the various tactics available for implementation. The use of a specific tactic is dependent on the level of biological intimacy acquired. Basic biological information on the species targeted for conservation is required for efficient effective conservation strategies. At present, our biological knowledge of a tree species tends to depend on its economic value. A much greater amount of knowledge still remains unknown for all species. In particular an understanding of the distribution of genetic variation among the various community structural levels (region, population, individual, and gene) is essential (see El-Kassaby and Yanchuk 1993, for example). Research on life history attributes and the dynamic trade-offs between competing functional demands under constantly changing environmental conditions cannot be assumed, but must be determined empirically. Knowledge on species interaction and the impact of forest management practices are required to effectively evaluate combining utilization with conservation. The relationship between habitat management and human activities pleads for evaluation so that the true impact of forestry management activities on a specific species' conservation could be evaluated. Finally, research on the meta-population level is needed for critically evaluating the network/connections/corridors concepts. In summary, while the amount of knowledge available is large, it is obvious that we still need to acquire and coordinate a great deal new knowledge to increase our conservation effectiveness.

Conclusions

The genetic resources of our forests represent a significant component of our national heritage. The contribution that conservation of this heritage makes to our long term well-being should be considered and evaluated on a level that is outside of the classical economic principles. It should be stated that the conservation of any natural heritage should not fall victim to the debate of who should invest and who will benefit. However, it should not be conducted capriciously nor should the burden be born disproportionately. Emphasis on the importance of attaining a balance between the biological intimacy required for managing and conserving our forest genetic resources, understanding of the ecological parameters that are shaping our forests, and the economic practicality needed for achieving this goal through cooperation, coordination, and effective communication is essential for any successful gene conservation strategy.

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Forest Genetic Resources and Conservation in Alberta

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Abstract

Alberta is characterized by a very diverse topography and ecological zonation. About sixty percent of the province is forested and almost all of this forest land is publicly owned. A total of 24 tree species are native to Alberta, none of which are considered threatened or endangered. The province has an extensive network of protected areas which consists of 1048 sites at present. These sites cover the major ecological zones of Alberta although some zones are considered to be poorly represented. The province also has a well developed tree improvement program and a strong program for *ex situ* conservation of genetic stock. These efforts, however, are mostly limited to a few commercially important species. This paper reviews the status of conservation of forest genetic resources in Alberta and discusses gaps and future work needs

Résumé

L'Alberta possède un territoire très varié du point de vue topographique et écologique. La forêt occupe environ 60 % de ce territoire et appartient presque entièrement au domaine public. La flore indigène compte 24 essences, dont aucune n'est considérée comme menacée ou en voie d'extinction. La province dispose déjà d'un vaste réseau de 1 048 aires protégées, où toutes les grandes zones écologiques de l'Alberta sont représentées; cependant, cette représentation est jugée insuffisante pour certaines zones. La province possède en outre un programme avancé d'amélioration des arbres et un programme solide de conservation *ex situ* du patrimoine génétique, qui portent toutefois uniquement sur quelques essences d'intérêt commercial. La présente communication examine l'état actuel de la conservation des ressources génétiques de l'Alberta et traite de ses lacunes ainsi que des domaines qui nécessiteront des recherches.

Introduction

Alberta is located between latitudes 49° and 60° N and longitude 110° and 120° W. The province is characterized by a very diverse topography. Elevations in the southeastern portion of the province begin around 900 m and rise across the plains to around 1200 m at the base of the Rocky Mountain foothills. The Rockies then rise to nearly 4000 m at their summit which forms the southwestern provincial boundary. Elevations decline gently northward to around the 300 m level found at the northern provincial boundary.

The climate of Alberta is predominantly continental. Summers are hot (mean July temperatures range from 16°C in the north to 20°C in the south) and winters are long and cold (mean January temperatures range from -24°C in the north to -8°C in the south). This continental climate is modified in the Rocky Mountains and their foothills by the influence of mild and moist western air masses and high elevations which results in cooler summers and milder winters. The frost free period in the province varies from about 60 days in the north to about 120 days in the south. However, at higher elevations in the Rocky Mountains, the frost free period may be as short as 15 days (Strong and Leggat 1981).

Annual precipitation in the province is also quite variable, ranging from about 30 cm in the southeast to as high as 50 cm at some locations to the north. The mountains and foothills generally receive higher amounts of precipitation with the subalpine receiving 60 to 120 cm per year (Strong and Leggat 1981).

Land Base and Forest Resource

The total area of Alberta is 661 185 km^2 (644 389 km^2 land and 16 796 km^2 water). Privately owned land accounts for 28% of the land base and crown land 72%. Forested area is about 60% of the total area. Almost all forest land is publicly owned.

Alberta is the fourth largest forestry province in Canada after British Columbia, Quebec and Ontario. Total forest growing stock is estimated to be about 2.2 billion m^3. Roughly two-thirds of the growing stock is coniferous and the remaining deciduous. White spruce, lodgepole pine, and trembling aspen are the most important commercial timber species. Provincial annual allowable cut (AAC) is 24.7 million m^3, of which 14.3 million m^3 is coniferous and 10.4 million m^3 deciduous. Very rapid development of the forest industry has taken place in Alberta over the last decade with nearly a threefold increase occurring in timber harvest between 1982 and 1992. The total area cut at present is about 60 000 ha per year. This is expected to almost double as new industry developments currently in progress or proposed are completed.

Ecological Zonation

Ecological land classification in Alberta is based on two systems. Strong and Leggat (1981) and Strong (1992) developed a system based primarily on vegetation and climate while Achuff and Wallis (1977) and Achuff (1992) developed a parallel system based primarily on landscape features and vegetation. Both systems have been used extensively for specific applications. For the purpose of this paper, information from both systems was generalized to divide Alberta into six major ecological zones (Figure 1).

The **grassland** ecological zone accounts for 14% of provincial area and occupies the southeastern part of the province. It is mainly composed of flat to rolling plains occasionally dissected by deep river valleys. These valleys often support extensive riparian poplar stands which, in the southern portion of the zone, are the only forest communities. Most of the land in the zone is under private ownership and is heavily impacted by agricultural cultivation and grazing (Posey 1992).

The **aspen parkland** ecological zone occupies approximately 8% of provincial area and forms an ecotone between the grasslands and the boreal and cordilleran forests. Topographically it is similar to the grassland zone except that, along the foothills, it is more rolling. Historically, this zone was maintained by frequent fires which confined trembling aspen to groves in a matrix of fescue grassland. Pothole sloughs and their unique communities are common throughout the zone. Due to its fertility and attractiveness to man, the aspen parkland is primarily held under private ownership and has been significantly impacted by urbanization and agriculture.

The **montane** ecological zone is a small zone occupying only 1% of provincial area. It is a foothills zone characterized by open forests and grasslands at lower elevations and closed canopy forests along its upper boundary with the subalpine zone. In southwestern Alberta it forms a continuous band along the foothills but, to the north, it becomes discontinuous and is found only in areas of broad river valleys associated with mountain passes (Figure 1). Cypress Hills in the southwestern corner of the province represents an outlier area of the montane. Montane forests are characterized by early successional stands of either pure or mixed lodgepole pine, trembling aspen, and Douglas-fir with an occasional component of limber pine. Secondary succession is generally to white spruce and occasionally to Douglas-fir (Strong 1992). Most of the montane zone is held as public land but it is impacted significantly by transportation corridors, domestic grazing, forestry, and recreation.

The **boreal forest** ecolological zone is the largest in the province and occupies approximately 52% of provincial area. The topography is largely subdued with locally extensive hill systems. Deciduous forests of trembling aspen and balsam poplar occupy upland sites in early succession. Secondary succession on upland sites is to white spruce and balsam fir. Wetland bogs, fens, swamps, and organic soils are extensive in this zone. Balsam poplar, black spruce, and tamarack are the major tree species occupying these sites. On coarse textured soils and dunes, jack pine is the most frequent colonizer. Previously the boreal forest was not intensively used. However, this is changing with increased timber harvesting, oil exploration, and agriculture activity. The majority of this ecological zone is managed as public land.

The **boreal foothills** ecological zone represents about 19% of provincial area. This zone forms the ecotone between the boreal forests of northeastern Alberta and cordilleran forests of western Alberta. The topography varies from undulating and rolling to rugged. Early successional stands at lower elevations are dominated by aspen and black poplar mixedwood. This gives way with increasing elevation to aspen and lodgepole pine mixedwood. At higher elevations, poplars are outcompeted by lodgepole pine which commonly forms extensive closed canopy stands. Secondary succession is to white and black spruce and balsam fir. Black spruce, tamarack, and paper birch, as well as other boreal elements, separate this zone from the montane which occupies the lower foothills to the south. Most of this region is managed as public forest lands. It has some of Alberta's most productive forests and timber harvesting occurs throughout the zone.

The **alpine/subalpine** ecological zone exists in the Rocky Mountains above the montane, parkland, and boreal foothills zones. It represents about 6% of provincial area and is an altitudinally controlled vegetation zone which reflects orographic climatic effects.

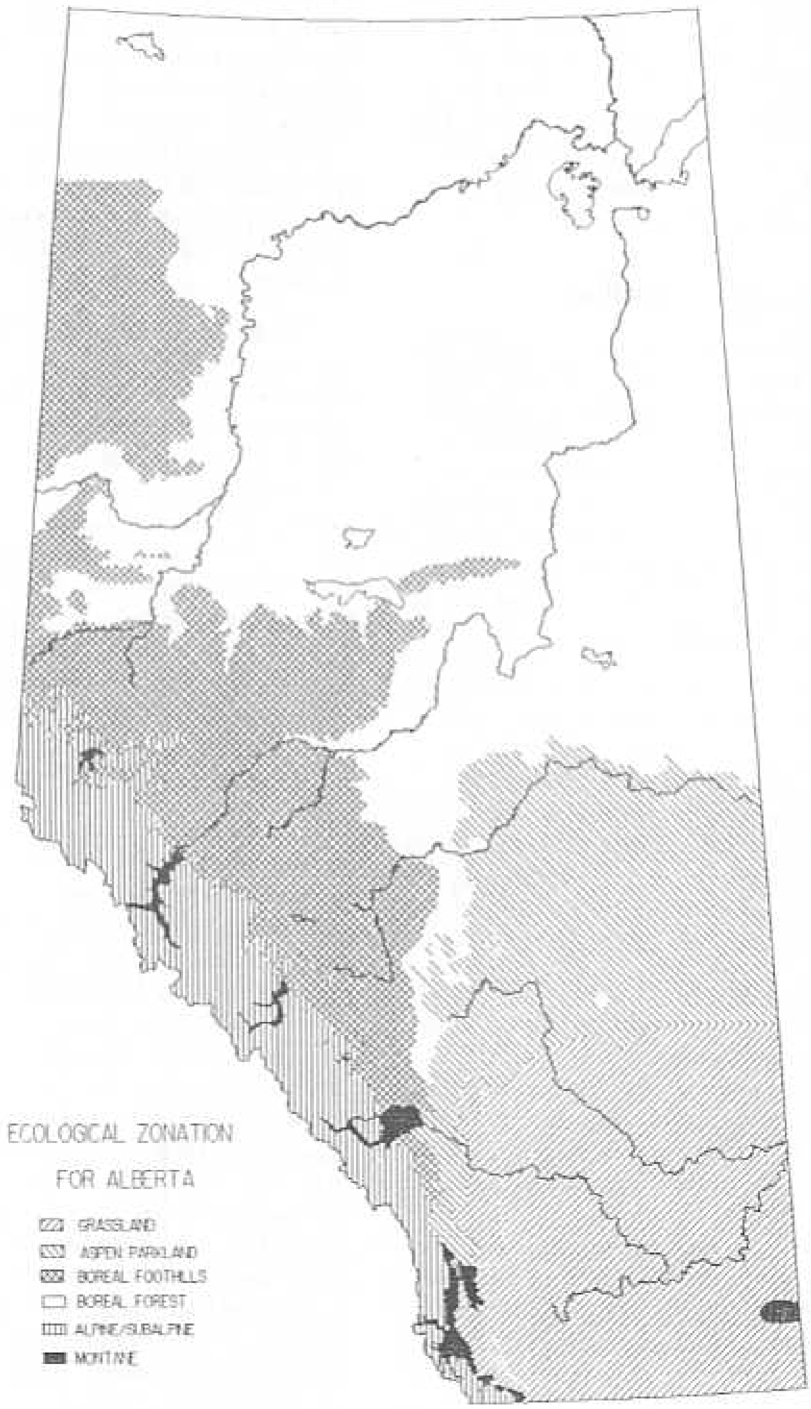

Figure 1. Produced by Forest Resource Information Branch, Edmonton. Adapted from Alberta Recreation and Parks (1990).

The alpine portion is generally treeless and consists of alpine meadows inhabited by hardy alpine and tundra mosses, herbs, and shrubs. The upper subalpine is typified by a discontinuous and stunted conifer tree cover of Engelmann spruce, subalpine fir, white-bark pine, and alpine larch. At lower elevations of the subalpine, closed-canopy lodgepole pine and spruce-fir forests occur. This ecological zone is managed as public forest land and large portions remain undeveloped or are protected areas. Lower elevations are managed for timber production and management for watershed and recreation are the predominant land uses.

In Situ Conservation

In the past, federal and provincial *in situ* conservation initiatives in Alberta were largely driven by heritage and scenic resource protection concerns. More recently, the issues of habitat protection for rare and endangered species and protection of genetic resources have increasingly influenced *in situ* conservation efforts.

Parks

In Alberta, five national parks encompass a total of 54 084 km^2 or 8.2% of provincial area and are covered under the 1930 National Parks Act. These five national parks vary widely in size from the small Elk Island National Park (194 km^2), to the extensive Wood Buffalo National Park (35 866 km^2). The three mountain national parks (Waterton Lakes, Banff and Jasper) collectively cover 2.7% of provincial area in the montane and alpine/subalpine ecological zones. The two boreal forest national parks (Elk Island and Wood Buffalo) account for the remaining 5.5%. The national park system covers a significant portion of the alpine/subalpine, montane, and northern boreal forest ecological zones with a relatively high level of protection.

The Alberta provincial parks system provides a moderate level of protection to some additional forested areas. These parks are protected under the Provincial Parks Act and Wilderness Parks Act. Their intent is the integration and protection of outstanding recreational landscapes and provincially significant natural, historical, and cultural landscapes and features for quality recreation and educational experiences. Depending on management objectives, they may or may not be heavily developed and intensively used. There are 63 provincial parks covering 1424 km^2 (0.22% of provincial area) and one wilderness park (Willmore) covering 4597 km^2 (0.77%). These parks tend to be in and adjacent to populated areas of the southern foothills, aspen parkland, and southern boreal forest zones.

Wilderness Areas

The Alberta Wilderness Areas program has reserved three areas covering 1010 km^2 (0.15%) of provincial land in the alpine/subalpine ecological zones of the Rocky Mountains. These areas were established in the 1960s for the purpose of protecting for future generations the beauty of Alberta's wildland resources. They have a relatively high level of protection and allow foot traffic only. Any disturbance harmful to plants or animals is prohibited.

Ecological Reserves

The Ecological Reserves program has reserved 14 areas totalling 271 km^2 (0.04%) of provincial area. Their size varies from the small 0.36 ha Egg Island Ecological Reserve to the 3770 ha Athabasca Sand Dunes Ecological Reserve. They are protected under the Wilderness Areas, Ecological Reserves, and Natural Areas Acts. Their intent is to maintain biological diversity through protection of unique and representative ecosystems in each of Alberta's ecological zones. Management plans for activities on the reserves are flexible and based on conservation objectives. The level of protection is second to that for wilderness areas. Ecoregion representation among ecological reserves is described in Table 1.

Natural Areas

The Natural Areas Program has reserved 123 areas totalling 378 km^2 (0.05%) of provincial area. Their size varies from less than 1 ha to 5490 ha. They are generally selected to represent one or more aspects of biological or physical diversity and to provide opportunity for nature studies and recreation. They provide varying degrees of protection depending on classification for research, education, or recreation. Use is generally restricted to low impact activities. A breakdown of Natural Areas by ecological zone is given in Table 2.

Special Places 2000 is a proposed program with broadbased support. It is an area-based systematic

Table 1. Summary of Ecological Reserves in Alberta by Ecological Zone

Ecological Zone	No. Reserves	Area (ha)
Boreal Forest	4	5,574
Boreal Foothills	2	2,076
Aspen Parkland	3	8,060
Grasslands	2	3,297
Alpine/Subalpine	1	2,288
Montane	2	5,805
TOTAL	14	27,000

Table 2. Summary of Natural Areas in Alberta by Ecological Zone

Ecological Zone	No. Reserves	Area (ha)
Boreal Forest	56	15,498
Boreal Foothills	34	6,612
Aspen Parkland	26	2,809
Grasslands	2	5,500
Alpine/Subalpine	3	6,520
Montane	2	934
TOTAL	123	37,873

network approach to the problem of conservation. Its objectives are to be achieved through inventorying and reviewing existing protected areas and then supplementing them with additional areas where deficiencies exist. The goals of the program, in addition to protection of the full range of provincial natural environmental diversity, are opportunities for heritage appreciation, outdoor adventure travel, ecotourism, and the expansion of total protected lands by 2% to 3%.

Gene Pool Reserves

The Rare and Exceptional Stand program implemented in 1986 as a joint project under the Canada Alberta Resource Development Agreement is specifically concerned with conservation of forest genetic resources. As part of the provincial tree improvement program, it is directed at *in situ* conservation of wild stands exhibiting exceptional phenotypic traits or rare characteristics. Under this project, five exceptional white spruce stands, one rare black spruce stand and one rare tamarack stand have been identified and reserved in the boreal forest ecological zone. Three exceptional and one rare Douglas-fir stands have been identified and reserved in the montane zone. Recently, efforts to identify and reserve stands have been less ambitious due to lack of resources.

Additional provincial legislated and unlegislated zoning on public lands provides some degree of protection and a framework for conservation management on public lands. An example of this is the prime protection zone in the Eastern slopes of the Rocky Mountains which limits timber harvest above 1800 m. Table 3 gives an area summary of legislated and unlegislated sites and zoning for Alberta.

Rare and Endangered Plant Species

Alberta has 1755 known native vascular plant species of which 360 have been identified as rare (Moss 1983, Packer and Bradley 1984). Generally, there is insufficient knowledge of species distributions, population structure and biology of these identified rare plant species to permit formal review and recognition by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Packer and Bradley 1984, Posey 1992). Recently, however, background work on three prairie species has been completed and application has been made for formal COSEWIC threatened or endangered status (Posey 1992).

Alberta Department of Environmental Protection recognizes four additional grassland and four montane species as endangered in Alberta. These include big sagebrush (*Artemisia tridentata* Nutt.) which is a woody shrub of the southwestern Rocky Mountains. No tree species is recognized to be endangered or threatened. Table 4 lists Alberta's twenty four native tree species (Moss 1983).

Three species (western white pine, western larch, and western hemlock) have been designated as rare in Alberta (Packer and Bradley 1984). All three are common western trees at the northern and eastern limit of their natural range in Alberta. There is some uncertainty about the exact status of western white pine. Western larch, in addition to being designated as rare in

Table 3. Summary of Protected Crown Lands in Alberta

Protected Crown Land	Sites (#)	Area (km^2)	Provincial Area (%)
Legislated - Federal Sites (*federal parks & wildlife areas*)	10	54651	8.26
Legislated - Provincial Sites (*ecologica reserves etc.*)	527	15537	2.34
Unlegislated Designated Areas (*designated areas*)	511	4286	0.64
Unlegislated Protective Zoning (*mainly east slopes Rocky Mtns.*)	-	15850	2.40
TOTAL	1048	90324	13.64

Table 4. Native trees of Alberta, their abundance status, and zonal distribution

Common Name	Species Name	Status and Ecological Zone
Balsam fir	*Abies balsamea*	Common/Boreal
Subalpine fir	*Abies lasiocarpa*	Common/Subalpine
Alaska birch	*Betula neoalaskana*	Occasional/Boreal
Water birch	*Betula occidentalis*	Occasional/Foothills
Paper birch	*Betula papyrifera*	Common/Boreal
Tamarack	*Larix laricina*	Common/Boreal
Alpine larch	*Larix lyallii*	Occasional/Subalpine
Western larch	*Larix occidentalis*	Rare/Subalpine
Engelmann spruce	*Picea engelmannii*	Common/Subalpine
White spruce	*Picea glauca*	Abundant/Boreal
Black spruce	*Picea mariana*	Common/Boreal
Whitebark pine	*Pinus albicaulis*	Occasional/Subalpine
Jack pine	*Pinus banksiana*	Common/Boreal
Lodgepole pine	*Pinus contorta*	Abundant/Foothills
Limber pine	*Pinus flexilis*	Occasional/Subalpine
Westen white pine	*Pinus monticola*	Rare/Montane
Narrow-leaf cottonwood	*Populus angustifolia*	Occasional/Grassland
Balsam poplar	*Populus balsamifera*	Abundant/Boreal
Western cottonwood	*Populus deltoides*	Occasional/Grassland
Trembling aspen	*Populus tremuloides*	Abundant/Boreal
Manitoba maple	*Acer negundo*	Uncommon/Grassland
Douglas-fir	*Pseudotsuga menziesii*	Common/Montane
Western redcedar	*Thuja plicata*	Uncommon/Subalpine
Western hemlock	*Tsuga heterophylla*	Rare/Montane

* Status Explaination
Abundant → Dominant in zone and common in more than one zone
Common → Common in zone occasional in other zones
Occasional → Occurring occasionally in one zone seldom in others
Uncommon → Occurring rarely
Rare → Reported from five or fewer locations in the province

Alberta, is also considered an endemic species of limited range outside the province (Fairbarns et al 1987).

Tree Improvement and *Ex Situ* Conservation

Tree improvement in Alberta is mainly focused on commercially important conifer tree species. White spruce and lodgepole pine are by far the most important reforestation species and presently account for almost all of the nursery seedling production in the province. Black spruce, Douglas-fir, and tamarack are the other species of interest and are slowly gaining prominence in provincial reforestation plans. Two exotic conifer species, Siberian larch (*Larix sibirica*) and Scots pine (*Pinus sylvesteris*), have also shown considerable promise in initial research testing. Small genetic improvement projects for these two species have also been established to develop the necessary research information and produce small amounts of improved seed each year for operational testing in large blocks.

Among the deciduous tree species only trembling aspen and balsam poplar are commercially important. Minor tree improvement efforts were spent on these two species over the past few years, but this work has been recently cut back substantially and is now limited to conservation maintenance of genetic stock already collected or established in field experiments.

Alberta's seed orchards program is relatively new. The oldest seed orchard in the province was started in 1982. To date, a total of 16 seed orchards have been established. Pertinent information on these is summarized in Table 5. All seed orchards mentioned are first generation orchards. Most of these were established as part of cooperative tree improvement programs with industry and only five of the orchards have reached the seed production stage. Total seed harvest from these seed orchards in 1993 amounted to 6.4 kg, which is sufficient for only about 2% of the total nursery seedling production requirement for one year.

Table 5. Description of seed orchards in Alberta

Species	No. of Orchards	Total Area (ha)	No. of Clones/Families per Orchard
White spruce	5	11.4	48 - 149
Lodgepole pine	5	17.6	35 - 150
Douglas-fir	1	0.6	34
Black spruce	1	0.3	19
Misc. Species *	4	1.5	6 - 14
TOTAL	16	31.4	823

* tamarack, Siberian larch, Scots pine and western larch

A total of 1727 parent tree selections have been made for various research and applied breeding projects in Alberta since the start of the provincial tree improvement program in 1976. Nearly all (1696) of the selections were made in wild stands located in Alberta. Until now only a small proportion of these selections have been established in the clone bank (Table 6) although a much larger number of these are represented in respective clonal seed orchards. Work is currently in progress to make additional grafts of the ortets not represented in the clone bank to complete it so that it contains and conserves, as much as possible, all vegetatively propagated genetic stock assembled for genetic tree improvement in Alberta. Each clone in the clone bank is typically represented by four ramets.

A separate research seedbank is maintained as part of the germplasm conservation function of the provincial tree improvement program. This seedbank is independent of the provincial operational seed storage which contains a total of 33 826 kg of seed from 15 species which is used for government and industry reforestation programs. The number of seedlots presently held in operational storage is 1531. The amount of seed per seedlot varies from 20 g to 1771 kg.

The tree improvement seed bank (Table 7) contains 2949 seedlots from 61 species. The amount of seed among individual seedlots varies from 0.01 g to 431 g. Since starting the seedbank in 1976, a total of 3537 accessions have been registered. Many of these have been exhausted.

Seedlots are stored at -20°C and seed quality is monitored annually by testing a set of reference seedlots representing about 2% of the total seedbank entries. New seedlots are added to the reference seedlots list every few years to replace those depleted and to sample new entries. In seedlots where sufficient seed is available, the seedlot is divided into operational and archival portions. The archival seedlots are stored at -18°C in a vault in a separate building to provide additional safety.

Table 6. Clone Bank Collection

Species	Number of Clones
White spruce	206
Lodgepole/Jack pine	65
Douglas-fir	25
Western larch	5
Aspen/Poplars	19
TOTAL	320

Table 7. *Ex Situ* Conservation of Seed Germplasm in the Tree Improvement Seed Bank

Species	Number of Entries	Total Amount (kg)
White spruce	827	33.16
Lodgepole pine	1379	23.58
Black spruce	81	0.32
Larches	199	1.60
Misc. Conifers	200	10.97
Aspen/Poplars	228	1.52
Misc. Hardwoods	35	0.57
TOTAL	2,949	71.72

Storage of archival seedlots at -80°C was experimentally tested but it was concluded that it did not offer any significant advantage over -20°C storage.

Conclusion

Provincial *in situ* conservation efforts, although not specifically guided by forest genetic resource conservation concerns, have provided good coverage for these resources in the alpine/subalpine and northern portions of the boreal forest (Posey 1992, Alberta Parks Service 1993). Gaps in coverage of other ecological zones are being addressed by the proposed Special Places 2000 project. This program is intended to systematically set aside designated land in underrepresented zones and subzones by landform and physical environment type. Present zones with poor protection area coverage are the grassland, parkland, boreal foothills zones and portions of the boreal forest ecological zones (Alberta Parks Service 1993).

There is also a considerable lack of knowledge about biological diversity at both regional and local levels. Coordination of conservation efforts by agencies with diverse concerns is also lacking. It is clear that *in situ* conservation efforts need to be strengthened by a more comprehensive and integrated approach to planning and implementing projects.

The forest gene pool reserves program already started has made some progress in identifying and protecting rare and exceptional stands for germplasm collection and future tree improvement needs. Additional efforts and resources are required to continue and expand this program.

A strong program of *ex situ* conservation of valuable forest genetic resources is already well developed as part of the provincial tree improvement program. However, it is limited in scope and does not adequately address non-commercial forest species eg. birch, balsam fir, etc.

At present, a comprehensive program for conservation of forest genetic resources in Alberta is lacking and there is a need to develop and systematically implement such a program. Hopefully, the recent initiative by the Environmental Council of Alberta and its Public Advisory Committees to develop a comprehensive conservation and sustainable development strategy for Alberta will more fully address the issue of forest genetic resource conservation.

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Forest Genetic Conservation in Saskatchewan under Weyerhaeuser's FMLA

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Abstract

A description is given of Weyerhaeuser's Saskatchewan operations as well as the diversity of the Forest Management License Agreement (FMLA) that supports those operations. Harvesting plans take into account non-timber forest uses, a silviculture program for both natural and planted regeneration carried out with the objective of maintaining the natural species balance, and a tree improvement program aimed at getting genetically diverse seed material for reforestation. Economically important trees are being conserved *ex situ* through the tree improvement program and vast areas of natural forests are being conserved *in situ*, as shown by placing the area harvested in the perspective of the whole FMLA. There are no readily apparent gaps in the conservation of forst genetics under the FMLA, but what is being done should be reevaluated if this situation is changed by factors such as increased harvesting levels or more intensive silviculture and tree improvement programs.

Résumé

La présente communication décrit les activités d'exploitation de la société Weyerhaeuser en Saskatchewan ainsi que les divers volets de l'Entente relative aux licences d'aménagement forestier qui appuient ces activités. Les plans d'exploitation tiennent compte également d'autres utilisations de la forêt. Un programme de traitements sylvicoles de régénération naturelle et de plantation est mené afin de maintenir l'équilibre naturel entre les essences. Il existe un programme d'amélioration des arbres destiné à assurer, en vue du reboisement, un approvisionnement en semences diversifiées sur le plan génétique. Dans le cadre de ce programme, les essences d'intérêt commercial font l'objet de mesures de conservation *ex situ*. Par ailleurs, de vastes aires forestières naturelles sont conservées *in situ*, comme le montre la superficie exploitée par rapport au territoire visé par l'Entente relative aux licences d'aménagement forestier. Cette entente ne comporte aucune lacune évidente en matière de conservation des ressources génétiques forestières, mais les activités actuelles devront être réévaluées si la situation est modifiée par certains facteurs, comme un niveau d'exploitation plus élevé, ou des programmes plus intensifs de sylviculture ou d'amélioration des arbres.

Introduction

In Saskatchewan, Weyerhaeuser Canada operates a sawmill, pulpmill, papermill, and a chemical plant. There are three sources for the supply of wood to the sawmill and pulpmill. Typically about 55% of the wood required comes from contractors harvesting trees on a Forest Management License Agreement (FMLA) area — forested crown lands leased from the Saskatchewan government and managed under a long term contract. Sawmill residues in the form of chips provide about 25% of the wood needed, and wood purchased from private operators and farm woodlots typically provides about 20%.

Weyerhaeuser's FMLA area is 3.4 million hectares in extent and lies within Canada's northern boreal forest. Just under half of that area, 1.5 million hectares, is land capable of producing commercial wood products. The most abundant tree species is trembling aspen, followed by jack pine, black spruce, and white spruce. The sawmill uses all softwood trees, but primarily white spruce. On average the pulpmill uses 60% softwood (mainly jack pine, black spruce and white spruce) and 40% hardwood most of which is trembling aspen. The average area harvested on our FMLA since the pulpmill began operations in 1967 has been about 5300 ha./yr, or one third of 1% of the productive forest[1] per year.

Ecological Diversity in our FMLA

The boreal forest region has few tree species compared to other forest regions in Canada. Within this relatively simple forest the ecological diversity is variable. There are forest types that are naturally low in

[1] "Productive forest", as it is used in this paper, refers to land capable of producing commercial wood products.

diversity, such as the many square kilometers of continuous jack pine forests found on expanses of level, rapidly drained sands. There are also some areas with irregular topography, more site variation, and more diverse vegetation types. For example, on an esker ridge or a moraine there might be aspen on the drier upper slopes and black spruce on the moist lower slopes.

Most stands are of fire origin; on the average the forest has burnt every 50 to 100 years. Typically, there have been a few very large fires and many smaller ones, which has resulted in many large and small patches of even aged forest. In the summer of 1993 Saskatchewan experienced one large fire that burnt over 3000 square kilometers, or 300 000 ha. Since 1969 fires have burnt an average of 9040 ha/yr on Weyerhaeuser's FMLA.

Past harvesting practices, which included some large clear-cuts, also created large and small patches of even aged forest. Today clear-cuts are smaller, usually limited to 40 ha. in size, in response to public concern over harvesting practices. This will not produce the large patches of even-aged forest that fires would have naturally created, which is a change from the natural pattern that will likely not be good for some species of wildlife such as caribou. However, although fire suppression is practiced it is not always successful and, for now, some large patches are still being created by wildfire.

Only native tree species, jack pine and white spruce, are planted to reforest cutover areas, and many areas are naturally regenerated rather than planted (see the section of *Intensive Management/ Tree Improvement Programs* below). In plantations, plants and trees grow up naturally from seed left on the ground or, in the case of poplar trees, sprout up from root suckers, so there is usually always a component of natural regeneration in plantations.

Intensive Management/Tree Improvement Programs

The forests in our FMLA are being managed to sustain their natural levels of biological diversity, as Canada as a whole has committed to doing, and we are aiming for a variety of ecosystems in a variety of successional stages. Forests are constantly going through successional changes, making it more appropriate to aim for the levels that would occur naturally, taking succession into account, rather than the levels that are there currently. Our harvesting plan takes other forest uses into consideration, including wildlife, trapping, recreation, cottage industries for special forest products, and archeological sites. This is a major task which counts the use of a Geographical Information System (GIS) to map the locations and to predict the most probable locations where those other uses occur.

Our silviculture objective is to maintain natural species balance. Areas which were predominantly hardwood (poplar) before harvesting are regenerated to hardwood, and those which were predominantly softwood (pine, spruce) are usually regenerated to softwood. No herbicides are used, but manual pre-commercial thinning and weeding is carried out on some of our older plantations.

Operations undertaken to regenerate or enhance softwood growth in 1993 are shown below. These figures are presented in hectares rather than as a percent of the harvested area, because not all of these activities were undertaken on *current* harvest areas, and harvest areas are calculated for a fiscal year whereas silviculture operations are summarized for a calendar year.

• **Scarification** to assist natural regeneration	1436 ha	
• **Tree Planting** (6.44 million trees)	3690 ha	
FMLA harvests (for comparison)	1992/93	4139 ha.
	1993/94	5100 ha
NOTE: Areas previously harvested that are not being scarified or planted are coming back naturally to aspen.		
• Site preparation for 1994 planting		3592 ha
• **Stand Tending** (pre-commercial thinning and weeding)		1023 ha.

Silviculture research is ongoing to try out new methods of site preparation and scarification as well as new products and ideas. Some small trials of other species which are non-native to our FMLA have also been planted (see *Provenance Tests* below).

Advanced generation tree improvement programs are being carried out for our two most important conifers — jack pine and white spruce. This includes selecting, testing, and breeding trees, establishing seed orchards, and carrying out supportive research.

All jack pine seed needed for planting could now come from an unrogued, first generation orchard. Not all trees planted are improved ones yet because there are still some issues with respect to the growing and planting of improved seed which need to be worked out. The oldest set of pine progeny tests are now 10-13 years old, and trees are being selected from them for inclusion in the future program. Data analysis is showing that the objective of selecting for growth and form in the program is being achieved.

An unrogued white spruce seed orchard is now producing some seed for operational planting. Interim seed is being collected from selected stands and an established Seed Production Area until the orchard can supply all the seed needed.

A limited, low key aspen program is also underway, and we are currently members of the North Central Experiment Station's Aspen/Larch Co-operative. We will be establishing a provenance test that includes our own local selections, as well as improved aspen material supplied by the Co-operative, in order to get information needed to be ready to move into an active aspen planting program in future. Currently there is no incentive to plant aspen, as it readily suckers from the roots left in the ground after harvest.

Seed material resulting from the tree improvement program will be kept genetically diverse. In our seed orchards, there is intermating between totally unrelated parents from different areas (many populations), and the resulting offspring will have a far greater diversity than seedlings which naturally seed in under a stand (one population). There are no plans to use clonal reforestation material, where concerns over genetic diversity are greater, instead of seed.

Genetic Conservation

In Situ

Trees

Figure 1 shows our current harvest level, puts it in the perspective of our whole FMLA area, and demonstrates the disturbance caused by natural wildfire.

Typically 0.3 or 0.4% of the total productive forest is harvested per year, which is 0.15 or 0.2% of our total FMLA area and .03% of the timbered area in Saskatchewan. In the 26 years since the pulpmill has been in operation, and the 19 years since the sawmill has operated, we have only cut 8.7 % of the productive forest area, and those areas are regenerated and growing back. There is actually a huge, unharvested area remaining in our FMLA which contains whole forest ecosystems being preserved *in situ* because they have not yet been disturbed by people. At the current harvest rates it would take about 292 years before all the productive forest would be logged once but, in actual practice, some more intensively managed areas would likely be harvested for a second or third time before all of the productive areas were harvested once. As well there would still be over half of the total FMLA that is non-productive from a commercial wood products point of view left undisturbed.

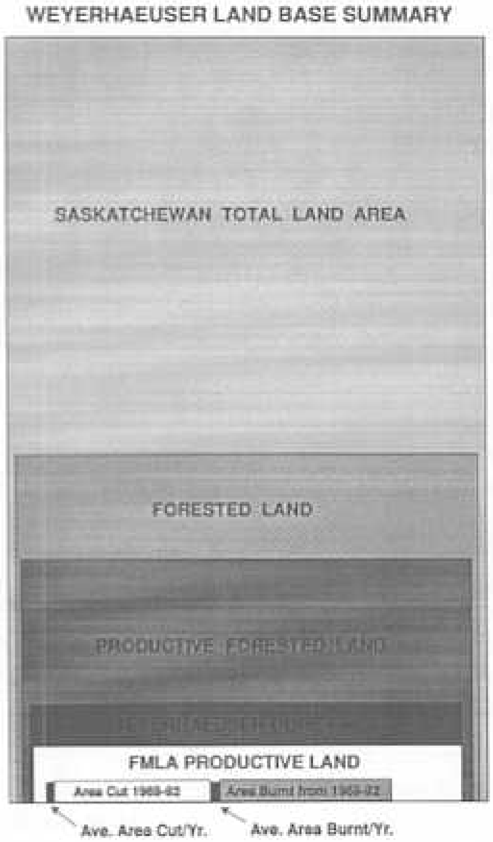

Figure 1. FMLA area, current harvest level and the disturbance that natural wildfire has.

In situ conservation of trees is also being carried out in a 4 ha stand of white spruce that has been established as a Seed Production Area. The stand is being used for the collection of interim seed until the seed orchard can supply all seed needs.

Plants

We are currently working towards a strategy for conserving the natural species diversity of forest plants. The plants of Saskatchewan's forests have been catalogued, and Harms et al. (1992) have assessed which naturally occurring species are rare or endangered. Our planning staff have come up with a list of these rare plants which occur on or near our FMLA and have looked at factors such as whether it is also rare or endangered in Canada as a whole, the plant's habitat requirements, and the types of habitats we are likely to be harvesting in. The GIS will be used to predict areas in our FMLA with suitable habitat where plants with particular conservation concern are likely to be found, and we will be taking those "likely areas" into consideration in future planning and harvesting plans. The plants that are of the greatest concern right now are some of the orchids, sedges, and rushes.

Wildlife

A Forest Wildlife Habitat Project is also underway, in co-operation with several other organizations, in an effort to ensure that a rich variety of wildlife communities always exists. Six "indicator" species of animals have been chosen for the project, because each is believed to require a certain type of habitat and therefore represent the general needs of a larger group of animals and plants. The effect of different types of forest harvesting on each indicator species is being studied, and the end result will be knowledge that can be used in planning harvesting operations consonant with wildlife needs.

Several wildlife studies are also being carried as part of Saskatchewan's Model Forest project and, since 45% of the Model Forest lies within our FMLA, the results will be applicable to many of our operations. Mammal and vegetation surveys are being carried in the Model Forest. The Canadian Wildlife Service is conducting research on birds within the area looking at the difference in populations between cutover, regenerated, and forested areas versus natural areas. The barred owl (*Strix varia*), which may be a threatened species, is being tracked and used as an indicator species, both inside and outside of a protected area — the Prince Albert National Park.

Ex Situ

As reported in *Forest Tree Genetic Conservation Activities in Canada* and updated to the present, Table 1 summarizes the forest trees we currently have conserved *ex situ* outside of their natural source.

Summary and Identified Gaps

Economically important trees are being conserved *ex situ* through our tree improvement programs and

Table 1. Trees Conserved *Ex Situ*

Seed Orchards				
jack pine	clonal	7.2 ha	31 clones	established 1979 - 1983 trees selected from a broad range of sites & geographic areas
white spruce	clonal	8 ha	40 clones	established 1984 - 1988 trees selected from a broad range of sites & geographic areas
Clonal Archives				
jack pine		0.1 ha	31 clones	insurance clone bank for seed orchard trees established in 1983 with 3 grafts of each clone
			0.1 ha	31 clones insurance clone bank for seed orchard trees established in 1989 with 3 grafts of each clone
jack pine		1.2 ha	450 clones	contains 5 and 10 year selections from progeny tests grafted at orchard site for breeding purposes
white spruce		0.1 ha	40 clones	insurance clone bank for seed orchard trees established in 1983 with 3 grafts of each clone
			0.1 ha	40 clones insurance clone bank for seed orchard trees established in 1989 with 3 grafts of each clone
Provenance Tests				
	Sources	Size	Yr. planted	
hybrid aspen	7	2 ha	1990	material from Aspen/Larch Co-opperative
hybrid aspen & poplar	10	.5 ha	1989	material from Aspen/Larch Co-op & Indian Head Nursery
hybrid poplar	16	~2 ha	1987	material from Indian Head Nursery, Sk.
lodgepole pine	11	4 ha	1989	88 families from BC, Alta, & Cypress Hills, Sask.
Scots pine	1	3 ha	1982	seed from plantation of unknown origin at MacDowall Sk.
red pine	1	1 ha	1985	material from Black Island on Lake Winnipeg, Man.
Siberian larch	1	3 ha	1982	was 4+0 bareroot stock grown at Sk. government nursery
Seed Banks				
jack pine	3 g. seed from ~200 wild selections, archived from the establishment of progeny tests			
white spruce	3 g. seed from ~130 wild selections, archived from the establishment of progeny tests			

propagated in the resulting plantations of improved seedlings. Trees not selected to be carried into advanced generations of the tree improvement program will remain in progeny tests where they can be re-sourced, if need be.

Vast areas of natural forests, not necessarily represented in the tree improvement program, exist *in situ* and will not be harvested for several hundred years, if ever. Conservation of the natural diversity of plants and animals is also being targeted in our harvesting plans and through some in-depth studies.

In general we are in a good position as far as the conservation of forest genetic diversity goes. The issue will continue to be addressed and techniques refined as we learn more from the work that is already underway and as new developments occur. There are no readily apparent gaps in the conservation of forest genetics in our FMLA, but what is being done should be reevaluated should our situation described here be changed by factors such as increased harvesting levels or more intensive silviculture and tree improvement programs.

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Forest Genetic Resources in the Northwest Region, Canadian Forest Service

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Abstract

Forest genetic resources controlled by Northwest Region consist of family test plantations, clonal archives, and stored seed for a jack pine improvement program and test plantations for a range-wide black spruce provenance experiment. The family test plantations include an aggregate of more than 600 open-pollinated progenies of wild trees collected in a latitudinal band about 2 degrees wide from southeastern Manitoba to eastern Alberta. Parent clones of about 450 of these families were planted from 1977 to 1985 in a clonal archive in Alberta. Seed of most of the families is being maintained in long-term frozen storage at Pineland Forest Nursery. Northwest Region maintains three range-wide black spruce provenance study plantations planted in 1975 in Manitoba, Saskatchewan, and Alberta. As of May 1994, Northwest Region does not have any in-house project or study to investigate forest genetic resources.

Résumé

Les ressources génétiques forestières régies par la Région du Nord-Ouest sont constituées de plantations comparatives de familles, de banques de clones, et de semences entreposées pour un programme d'amélioration du pin gris, ainsi que d'une plantation expérimentale pour une étude de provenance de l'épinette noire appliquée à toute l'aire de distribution. Les plantations comparatives de familles comprennent un agrégat de plus de 600 descendance d'arbres indigènes librement pollinisés, recueillis sur une bande latitudinale d'environ deux degrés, du sud-ouest du Manitoba à l'est de l'Alberta. Les clones à l'origine d'environ 450 de ces familles ont été plantés de 1977 à 1985 dans une zone de banques de clones de l'Alberta. Des semences de la plupart des familles sont conservées par entreposage à long terme à l'état congelé dans la pépinière forestière de Pineland. La région du Nord-Ouest maintient trois plantations pour l'étude de provenance de l'épinette noire appliquée à toute l'aire de distribution; elles ont été établies en 1975 au Manitoba, en Saskatchewan et en Alberta. À compter de mai 1994, la région du Nord-Ouest ne disposera plus d'aucun projet ou étude internes pour l'étude des ressources génétiques forestières.

Forest genetic resources controlled by Northwest Region consist of family test plantations, clonal archives, and stored seed for a jack pine improvement program, and test plantations for a range-wide black spruce provenance experiment.

The family test plantations include an aggregate of more than 600 open-pollinated progenies of wild trees collected in a latitudinal band about 2 degrees wide from southeastern Manitoba to eastern Alberta. Four plantations in central and western Saskatchewan include 214 families from central Saskatchewan westward into Alberta. Two plantations in eastern Saskatchewan and one in western Manitoba include 214 progenies of trees selected in and around the uplands of the Manitoba escarpment. Four plantations in eastern Manitoba include 209 eastern Manitoba progenies.

Parent clones of about 450 of these families, along with grafts of progeny ortets of other families were planted from 1977 to 1985 in a clonal archive in Alberta. Filling and tending were discontinued in 1985 owing to funding constraints. Grafts of 60 clones from eastern Saskatchewan and western Manitoba, having above-average performance at 10 years from planting, are being maintained in Pineland Forest Nursery, Manitoba, with funding from the Canada-Manitoba Partnership Agreement in Forestry.

Seed of most of the families in the jack pine breeding program is being maintained in long-term frozen storage at Pineland Forest Nursery. There is an inventory of these seedlots, but it is not in a computer file and is not up-to-date.

Northwest Region maintains three range-wide black spruce provenance study plantations planted in

1975 in Manitoba, Saskatchewan, and Alberta. These plantations may constitute a forest genetic resource as well as a potential genetic challenge to neighboring natural black spruce populations. The plantations have been in need of tending, but resources have not been available for this purpose.

Northwest Region does not have any in-house project or study to investigate forest genetic resources. Management of Northwest Region have no plans to initiate a program in this area, but will give serious consideration to any recommendation from this workshop.

Green Plan funds administered by Canadian Forest Service were granted to Dr. F.C. Yeh, University of Alberta, for a study entitled "Empirical and Theoretical Investigation of Gene Co-adaptation in Forest Trees". This study is intended to detect, by persistence of gametic disequilibrium, any fitness advantage of multilocus allelic combinations. Verification of this phenomenon in forest tree populations will indicate a need for conservative strategies in tree breeding to preserve co-adapted gene complexes.

Genetic Resource Management Principles and Their Application in the Forests of Ontario

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Abstract

Traditionally, timber production has been the pre-eminent goal of forest management. However, rising environmental awareness has led to a clear message that economic development must be practiced within the ethic of environmental protection. Canada's national forest strategy, "Sustainable Forests: A Canadian Commitment", reflects these evolving societal values and identifies a fundamental shift in the approach to forest management. The strategy includes the requirement that forest management planning explicitly address concerns for biodiversity and genetic diversity.

Since the 1950s, the science of forest genetics has been strongly linked to tree improvement, because of the traditional emphasis of forest management on timber production. While the application of genetic principles to improve timber production continues to be important, the science of forest genetics is also evolving to explicitly address concerns for genetic diversity, gene conservation, and the ability of tree species to adapt to climate change. Similarly, the traditional tree improvement program in Ontario is evolving into a genetic resource management program that recognizes the need to integrate genetic diversity and gene conservation goals into program priorities.

Résumé

Traditionnellement, la production de bois d'œuvre était le but manifeste de la gestion forestière. Toutefois, dans la foulée de la sensibilisation croissante aux besoins de l'environnement, on s'est rendu compte que ce développement devait respecter l'éthique de la protection environnementale. La stratégie forestière nationale du Canada, «Durabilité des forêts : un engagement canadien», reflète l'évolution des valeurs sociales et dénote un changement fondamental dans l'approche utilisée pour la gestion des forêts. Cette stratégie comporte une nouvelle exigence : que la planification de la gestion forestière tienne compte de façon explicite des préoccupations ayant trait à la biodiversité et à la diversité génétique.

Depuis les années 50, la science de la génétique forestière est fortement liée à l'amélioration des arbres forestiers, parce que traditionnellement, la gestion forestière mettait l'accent sur la production de bois d'œuvre. Alors que l'application des principes génétiques pour l'amélioration de la production de bois d'œuvre continue à jouer un rôle important, la science de la génétique forestière connaît également une évolution qui la porte à s'occuper explicitement des préoccupations ayant trait à la diversité génétique, la conservation des gènes et l'aptitude des essences à s'adapter au changement climatique. De même, le programme traditionnel d'amélioration des arbres forestiers de l'Ontario est en train de devenir un programme de gestion des ressources génétiques qui reconnaît la nécessité d'intégrer les objectifs de la diversité génétique et de la conservation des ressources génétiques dans les priorités du programme.

Background

The geographic limits of Ontario include more than 15 degrees of latitude and 20 degrees of longitude. Lake Superior and Lake Huron are at approximately 200 metres above sea level. Elevations increase rapidly to as much as 500 metres along the north shore of these two lakes, and to a lesser extent, to the east of Lake Huron. Elevations then drop in two increments to sea level, 300 meters in the Great Clay Belt, and less than 100 meters in the Hudson Bay lowlands.

The major forest regions of Ontario include the Carolinian zone in the extreme south, the Great Lakes/St. Lawrence, and the Boreal Forest that stretches from the "Height of Land" north of the Great Lakes to timber line in the Hudson Bay lowlands. These three forest zones have been further subdivided into 13 ecoregions based on physiography-vegetation relationships.

The ecological concerns are as varied as the forest cover. Southern Ontario can be characterized as forest land that was converted to agriculture which, in turn, has given way to substantial urbanization. The remaining forests occurs as highly fragmented wood lots. Historically, the Great Lakes/St. Lawrence forest supported a logging industry based on red and, especially, white pine. Protection of the remaining old growth red and white pine forests are the most visible environmental concern in this forest zone. However, professional foresters are also concerned about the reduced occurrence of species such as eastern hemlock and red spruce. Perhaps the primary ecological concern for the Boreal Zone forests centres on the impacts of harvesting. For example, a recently completed independent audit of forest regeneration found that hardwoods (primarily poplar) have increased in occurrence while the occurrence of conifers (especially spruce) has dropped dramatically in the second forest. And, of course, the potential effects of climate change on forests is a concern across the entire land base of Ontario.

Genetic Principles

Managing genetic diversity is more complex than identifying and preventing loss of rare alleles. Genetic variation occurs in an hierarchial structure. Adaptive variation occurs across environmental gradients. Genetic variation among and within local populations can be the result of adaptation to pests, etc., or the result of stochastic events that lead to genetic drift. Genetic variation within individuals is largely the result of mating systems within the population. The generation length and fecundity of populations are also determinants of genetic variation within species.

When the hierarchial structure of genetic variation is recognized, it is clear that "genetic diversity" is a property of populations. As a result, genetic resource management can be viewed as population management, and the scientific disciplines of population genetics and population ecology provide the theoretical base for developing genetic resource management strategies.

The goals for genetic resource management in Ontario include conserving adaptive gene complexes across populations, managing for a broad genetic base within populations, and the prevention of species extinction. Although the relative weighting of these goals will undoubtedly vary among species and geographic locations, management strategies should integrate all of these goals regardless of whether the population in question is the last one of a rare species or one constructed for tree improvement purposes.

Ontario's genetic resource management strategy is not fully developed yet, but there are several key theoretical concepts from forest genetics, quantitative genetics, population ecology, population genetics and conservation biology, that are being used to implement the practice of genetic resource management. These concepts include;

Terminology. As a first step to effective management of genetic resources, some terminology is needed. The terms "genetic diversity" and "gene conservation" are frequently used interchangeably. However, genetic resource management concerns occur at multiple scales, and there is value in a rigorous use of these two terms in reference to concerns at different scales. The concept of "Genetic diversity" is associated with perpetuating the evolutionary potential of a species. As a result, genetic diversity concerns are oriented toward conservation of adaptive gene complexes that occur at a landscape scale. For example, such questions as "is a given population genetically (read adaptively) unique?" tend to occur when populations are isolated, such as on the edge of a species range. Conversely, the concept of "gene conservation" is associated with the loss of genetic variation and/or rare alleles within populations, that is, the effects of small population sizes on genetic variability. Questions are related to the issues of, bottleneck/founder effects, inbreeding depression, and the risk of population extinction.

Seed Zones/Breeding Zones. The concept of seed zones and breeding zones were originally developed to limit genotype by environment interactions. Phrased a little differently, it is to limit stock deployment to ensure the use of adapted stock. As a result, seed zones and/or breeding zones provide the key to conserving adaptive gene complexes. Such zones could be viewed as "genetic resource management units" within which the multiple goals of genetic resource management can be integrated.

Recurrent Mutation. The loss of rare alleles is one of the issues frequently raised as a gene conservation concern. By definition, a single mutation that generates a new allele results in the occurrence of a rare allele in a population. However, population genetic theory leads to the expectation that the fate of a single mutation is to be purged from the population. Rare alleles are only maintained in populations as a result of strong selection pressure in favour of the new allele (an unlikely occurrence), or as a result of recurrent mutation. As a result, at least part of the key to conserving rare alleles is to maintain populations large enough for the recurrent mutation rate to balance the effects of genetic drift.

Minimum Viable Population Sizes. Minimum viable population size (MVP) is a concept that refers to the genetic minima required to meet a specific genetic resource management goal. Namely, either managing inbreeding depression or perpetuating evolutionary potential. The calculation of a minimum viable population size is based on theory and several variables such as ecological niche, generation time, and fecundity can modify the estimate. The estimates are calculated in terms of "effective population size" (Ne) that refers to the size of an "ideal" population that is subject to the same degree of genetic drift as the actual population being considered. "Ideal" refers to a population that has random mating, a 1:1 sex ratio, and the number of progeny per family is randomly distributed.

While MVP estimates are best viewed as ballpark figures, the theoretical work that has been done suggests that the minimum viable population size for managing inbreeding is approximately 50 to 100. However, as discussed above, the conservation of evolutionary potential requires a population size large enough to balance the effects of genetic drift with recurrent mutation. Published MVP estimates range between 500 and 1000. It should be noted, however, that both these figures are calculations of effective population sizes. The actual number of individuals required to maintain these effective population sizes may be much larger, depending on the mating system. (See Soulé (1987) and Frankel and Soulé (1981) for a detailed treatment of this theory).

Bottlenecks, Allele Frequencies, and Genetic Variation. Genetic bottlenecks occur when a population "crashes" or is greatly reduced in number such that the subsequent generation is produced by limited number of parents. (Note the concept of effective population size rather than an actual tally of individuals applies here.) The effects of bottlenecks on the genetic base are a function of whether it is a single-or multiple-generation bottleneck, and whether the focus is on quality (number of alleles) or quantity (genetic variance) of the genetic base. Theoretical work in this area indicates that a single-generation bottleneck is more likely to result in the loss of rare alleles than it is to reduce genetic variance substantially. This is because rare alleles add little to the genetic variance. (See Frankel and Soulé (1981), Chapter 3 for a detailed treatment of this theory).

Extinction. Extinction is to a population what death is to an individual, an inherently probabilistic event. Given enough time, it is a certainty that any given population will go extinct. There are several factors that increase the probability of extinction, but the primary one is decreasing population size. However, even when populations are large, factors that will eventually lead to extinction include threats that contribute to the loss of habitat and catastrophic events. Because localized extinction is a certainty over long time frames, long-term persistence of a species requires a balance between localized extinction and recolonization.

Metapopulations. Conceptually, a metapopulation is a network of populations linked by migration. When a metapopulation exists, the species is able to persist in the landscape by recolonizing habitat patches after localized extinction occurs. It should be noted that population genetic theory indicates that the effects of genetic drift within populations are neutralized with the occurrence of as little as one migrant per generation. Realistic models of metapopulation dynamics are being developed. Metapopulation theory and models will provide the base for developing restoration strategies for tree species that occur in disjunct patches.

Conservation Goals. In order to monitor the success of a conservation program, clearly defined realistic goals must be established at the beginning. For example, defining a minimum viable population size requires a goal such as "conserving 95 percent of the original genetic variation after 200 years, assuming a generation interval of 50 years". Setting appropriate goals is a judgment call tempered by existing theory. Short term goals such as protecting an existing population from habitat destruction due to human development are reasonably easy goals to achieve (albeit potentially expensive). However, while this may be the first step in triage for an endangered species, it does not fully address the conservation goal of perpetuating evolutionary potential. Conversely, setting ambitious goals, such as "conserving 99 percent of genetic variation over 100 generation" can be impractical.

Program Implementation

The traditional tree improvement program in Ontario includes breeding programs primarily in jack pine, black spruce, and white pine. The tree improvement program mandate also includes seed source control of reforestation stock. While these efforts have traditionally emphasized economic or habitat-creation goals, they form the base for developing operational programs for managing genetic diversity.

Beginning in 1991, the government of Ontario funded a 5-year Sustainable Forestry Initiative to start addressing environmental concerns. The goals of the Genetic Heritage Program under the Sustainable Forestry Initiative include: 1) developing gene conservation strategies for species that are vulnerable to extinction forces; 2) developing genetic resource management policy and management guidelines for forest management planning; and, 3) conducting research directed at identifying spatial patterns of adaptive variation in some of Ontario's keystone species. There are several interconnected projects underway to address these goals.

1. *Climatic Modelling Project*

On behalf of the Ontario Forest Research Institute, the Genetic Resource Management Program (GRM) has taken the lead on collaborative research with the Forest Resource Economics Section, Canadian Forest Service - Ontario Region, to develop a high quality climatic model of the province. The Ontario Climate Model is nearing completion and will be used in the near future to ensure seed zones reflect climatic gradients.

2. *Genecology Project*

The natural range of most forest tree species includes diverse environmental conditions. When environmental heterogeneity is substantial, differential natural selection pressures alter gene frequencies to produce adaptively differentiated populations. As a result, each natural population of trees has an adaptive profile, that is, a genetic constitution that conveys adaptation to a limited range of the environments occupied by the species as a whole. Because the primary goal of genetic resource management is to perpetuate the evolutionary potential of a species, conservation of adaptive gene complexes is viewed as the cornerstone of managing genetic diversity within species.

Over the last 15 years, short-term testing techniques have been developed that assay how closely populations are adapted to local environmental conditions. When these techniques are applied to a sampling of a large number of populations representing the ecological amplitude in a geographic region, models describing the pattern of adaptive variation can also be developed. These models can be used to build biologically sound seed zones and to identify the most appropriate seed sources for reforesting specific locations for timber production and/or species restoration efforts. Should natural populations become grossly maladapted as a result of rapid climate change, these models can also provide the base for guiding human intervention.

Ontario has ongoing genecology studies of black spruce, jack pine, and white spruce. Studies of red oak and white pine are in the planning stages.

3. *Genetic Diversity Project*

The Genetic Diversity Project is an operational program responsible for developing gene conservation strategies for species vulnerable to extirpation forces. In practice, these strategies are referred to as recovery plans but, in a general context, some species may not require restoration. So, as the program expands beyond endangered species, the strategies will be considered as species management plans rather than recovery plans.

Two national committees have developed a process for listing species as "rare, threatened, or endangered" (Committee On the Status of Endangered Wildlife In Canada, or COSEWIC) and for developing management plans for endangered species (Recovery of Nationally Endangered Wildlife, or RENEW). The procedures and report formats that these committees have developed have been adopted by the Genetic Heritage Program and the reports will be passed on to the national committees for their use at the national level.

The basic process for developing individual species recovery plans include: 1) a survey of field staff to establish a prioritized list of vulnerable species; 2) collecting existing information and writing individual species status reports; 3) developing a prognosis for the species in the absence of intervention; and 4) identify a prioritized of management actions required to restore and/or perpetuate the evolutionary potential of the identified species.

Developing a prognosis will involve two primary steps. First, describing the rarity of each species on the basis of three dimensions; geographic range, habitat specificity, and population sizes. And second, use the genetic principles identified above to identify and prioritize threats to populations within seed zones.

Developing the actions needed in a recovery plan will be based on estimates of the effective population size within seed zones and applying minimum viable population size theory. That is, when the estimated effective population size within a seed zone is 100 or less, protecting existing individuals becomes the priority and developing a plan to manage inbreeding is the next step. When the estimated effective population size approaches 1000, identifying a plan to develop a functional metapopulation will be the goal.

A number of status reports on Carolinian Forest species have been written and the first recovery plan is scheduled for development over the next six months. Priorities in northern Ontario are primarily those species with a truncated occurrence resulting from selective harvesting (e.g., red pine, white pine, eastern hemlock, yellow birch, and white spruce) and hardwoods (e.g., white elm, black ash) that may be important for biodiversity purposes.

4. *Tree Atlas Project*

Initial efforts to implement the recovery plan process have been limited by the lack of readily available information on species occurrence and population sizes. The relative abundance and distribution of Ontario's native trees has never been catalogued. The goal of the Ontario Tree Atlas Project is to design and implement a systematic survey of the occurrence of native trees in Ontario and to develop a database system for storing this information. Ontario's Breeding Bird Atlas, the Mammal Atlas, and the Herptofaunal Survey methodology will be used as the template for the tree atlas. A five-year timeframe is envisioned for completing and publishing this survey.

Ex Situ Conservation

The role of *ex situ* conservation efforts has not been fully developed, but there are two likely roles. First, the metapopulation approach to species conservation is based on balancing localized population extinctions with recolonization. Seed storage, when practical, could play an important role for human mediated "recolonization." And second, when a species is on the brink of extinction, i.e., effective population sizes less than 50, *ex situ* conservation of genotypes may be warranted to facilitate controlled mating and to protect against additional losses in the wild. The University of Guelph Arboretum has established an *ex situ* collection of rare Carolinian Forest species.

Summary

The tree improvement program in Ontario is broadening its goals to include genetic diversity and gene conservation. The provincial government is funding a five-year program to develop gene conservation strategies, and policy guidelines for managing genetic diversity. Theoretical principles from the fields of forest genetics, quantitative genetics, population genetics, population ecology and conservation biology are being used in building a genetic resource management program. However, it must be emphasized that the program described is still in the early stages of implementation. Substantial development, both in integrating theoretical principles and developing a practical operational program, is still required.

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Conservation of Forest Genetic Resources at the Petawawa National Forestry Institute

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Abstract

Research and development activities within the Forest Genetics and Biotechnology Program and the National Forest Genetic Resources Centre at the Petawawa National Forestry Institute emphasize the complementary goals of conservation of genetic resources and the genetic improvement in the growth, quality, and health of the trees in Canada's forests. Brief descriptions are given of research on topics such as genetic diversity, physiological genetics, the genetics of growth and yield, tree seed, and molecular genetics and tissue culture. Practical *ex situ* conservation activities are also outlined.

Résumé

Les activités de recherche et de développement effectuées dans le cadre du Programme de génétique forestière et de biotechnologie, ainsi qu'au Centre national des ressources génétiques forestières à l'Institut forestier national de Petawawa, soulignent les objectifs complémentaires de la conservation des ressources génétiques et de l'amélioration génétique pour la croissance, la qualité et la santé des arbres des forêts canadiennes. On donne de brèves descriptions des travaux de recherche effectués dans plusieurs domaines, notamment en diversité génétique, en génétique physiologique, en génétique de la croissance et du rendement, ainsi qu'en génétique moléculaire et en culture de tissus. On présente également les grandes lignes d'activités pratiques de conservation *ex situ*.

The Petawawa National Forestry Institute (PNFI) has a long history of involvement in research and development related to two complementary goals: the conservation of genetic resources and the genetic improvement in the growth, quality, and health of the trees that will be harvested in future to fuel growth in the Canadian economy. In the past 50 years there have been significant changes in the specific studies being undertaken at PNFI, but the basic goals remain as valid today as they were at the outset, and are reflected in activities that are currently concentrated within the Forest Genetics and Biotechnology Program at PNFI.

The objective of this Program is:

> To generate knowledge and technology that can be applied to achieve improvements in the quality, productivity , and health of Canada's forests within genetically and environmentally sound programs of forest management.

Each component of the Forest Genetics and Biotechnology Program involves activities that have the potential to make a significant contribution to the conservation of vitally important genetic resources, but additional prominence was given to this aspect of Program's activities in 1992 with the establishment of the National Forest Genetic Resources Centre at PNFI.

The establishment of the Centre, encompassing many of the facilities and activities within the Forest Genetics and Biotechnology Program, met Green Plan and Departmental Strategic Plan commitments to provide facilities and expertise for the long-term storage of tree seed and other tree germplasm. The Centre also obtained Green Plan support for activities directed at promoting the understanding and maintenance of the genetic components of the rich and complex biological diversity in our forest ecosystems.

Staff at the National Forest Genetic Resources Centre have also made significant contributions to conservation of forest genetic resources in Asia and Africa through their work on two Canadian International Development Agency projects supporting the establishment of the ASEAN Forest Tree Seed Centre and the Southern African Development Community (SADC) Tree Seed Centre Network.

The research and other activities in the Forest Genetics and Biotechnology Program are conducted within the framework of Projects/Studies outlined below.

Genetics of Growth and Yield

This Project's objectives include developing an understanding of the genetic control of forest productivity, improving the assessment of genetic resources in tree improvement programs, and designing and evaluating strategies for advanced generation breeding and deployment of genetic resources.

Although the Genetics of Growth and Yield Project is more concerned with the wise use of genetic resources than with conservation, any application of genetics that succeeds in improving productivity on intensively managed forest lands presents an opportunity to take the pressure off other areas in which priority may be given to maintaining genetic and biological diversity.

Physiological Genetics and Plasticity

This Project involves ecophysiological studies of genetic variation in traits related to productivity, adaptation, and accuracy of selection. Current activities include investigation of genetic variation in responses to increased carbon dioxide, drought, photoperiod, and temperature changes.

An understanding of the physiological basis for variations in growth and adaptation offers an opportunity to make more informed decisions related to the selection and deployment of trees used in forestry practice. It also provides a basis for evaluating the risks that selection favouring superior performance under current climatic conditions could lead to in reducing the genetic potential for adaptation to meet the unprecedented challenges presented by predicted changes in our climate.

Genetic Diversity and Reproductive Success

Project objectives include determining the effects of land use and forestry practices on genetic diversity and reproductive success of forest species, and developing and promoting strategies to maintain genetic diversity and ensure mating success in native tree populations. Part of the current activity focuses attention on the status of rare and threatened populations and the determination of minimum population sizes required to ensure their survival.

Seed Science and Reproductive Development

This Project's objectives include developing an understanding of the roles of ecological, environmental and physiological factors in the development, storage, and germination of tree seed, and the generation of prescriptions to achieve improved seed quality and more efficient use of seed.

In addition to promoting and supporting the efficient use of tree seed in forestry practice, the knowledge generated in this Project finds application in the development of seed storage protocols which could form part of *ex situ* conservation strategies. Current studies include the investigation of the value of cryogenic storage for orthodox tree seed and the development of protocols to deal with species with recalcitrant seeds.

In response to the recommendations of an FAO Panel of Experts on Forest Gene Resources, the leader of the Project recently completed a review of *ex situ* storage of seeds, pollen, and *in vitro* cultures of perennial woody plant species (Wang et al. 1993).

Molecular Genetics and Tissue Culture

The objectives of this Project include developing cell and tissue culture technologies with potential application in the mass propagation of selected genotypes, the development of genetic transformation protocols to take advantage of genes of potential value in forestry practice, and the use of molecular techniques to achieve an understanding of gene function and regulation in trees.

Under specific circumstances the protocols developed in this Project have potential application in *ex situ* conservation through the cryogenic storage of tree germplasm generated by cell and tissue culture.

Awareness of the importance of genetic conservation is reflected in research directed at ensuring that products of biotechnology, such as genetically transformed materials, will pose no threat to the integrity of natural gene pools when planted in the forest.

Genetic Resources Services

This Project essentially looks after practical *ex situ* conservation activities at PNFI through management of the National Tree Seed Bank, supervision of numerous research plantations and gene banks of native and exotic tree species in the Petawawa Research Forest, and the development, coordination, and management of an information system of genetic resources in Canada, representing materials and associated information identified through genetic research, tree improvement, and conservation activities.

Conclusion

The above descriptions show that most of the activities within the Forest Genetics and Biotechnology

Program and the National Forest Genetic Resources Centre at the Petawawa National Forestry Institute have some linkage to conservation of forest genetic resources. Conservation issues have high priority within PNFI's research programs, and are driven by an overall objective of ensuring that Canada's forest genetic resources will be adequately conserved within programs that also address sustainable development and maintenance of biological diversity at all levels.

Reference

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A Canadian Database of Forest Genetic Resources

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Abstract

The National Forest Genetic Resources Centre at the Petawawa National Forestry Institute is developing a national database to inventory forest genetic resources in Canada, including information identified through genetic research, tree improvement, and conservation activities. This paper is intended to provide an overview of the system and its potential role in supporting conservation activities at both the national and international levels.

Résumé

Le Centre national des ressources génétiques de l'Institut forestier national de Petawawa établit actuellement une base de données nationale pour inventorier les ressources génétiques des forêts au Canada. Elle comprendra des données provenant de la recherche génétique, de l'amélioration des arbres et de la conservation. Ce texte donne un aperçu du système et du rôle que celui-ci peut jourer dans les activités de conservation, tant au niveau national qu'international.

Introduction

Most forestry agencies in Canada undertake initiatives to address both *in situ* and *ex situ* conservation of forest genetic resources. For example, the federal government has set a target of 12% of the land area to be placed under legal protection. Such protected land, representing *in situ* conservation, falls under several categories including national parks, national wildlife areas, provincial/territorial parks and wildlife areas, provincial/territorial wilderness areas, and ecological reserves (Boyle 1992).

Ex situ conservation activities vary from the establishment of seed banks, arboreta, clonal archives, provenance and progeny trials, seed orchards, and seed production areas. Although in most instances these activities did not see *ex situ* conservation as a primary objective, they do provide a means of conserving valuable gene pools. To reflect the magnitude of *ex situ* resources in Canada, 9000 provenance samples, 28 000 families in seedling seed orchards, 15 000 clones in clonal seed orchards, and 44 000 clones in archives have been planted in approximately 4500 hectares across the country (Boyle 1992). This material has been established by federal and provincial governments, industry, and universities. However, there is currently no formal coordinated strategy for conservation of forest genetic resources among these agencies. The independence of each agency's activities has resulted in gaps in the conservation effort, inconsistent approaches to conservation, and inadvertent duplication.

Although it is recognized that provincial agencies will assume primary responsibility for the practice of conservation, the establishment of the National Forest Genetic Resources Centre (NFGRC) at the Petawawa National Forestry Institute (PNFI) represents, for the first time in Canada, an agency with a recognized mandate to promote the conservation of forest genetic resources. As part of this mandate, it is proposed that the NFGRC coordinate and develop a national database that will identify the location, extent, and quantity of forest genetic resources to support research and operational conservation activities in Canada.

Database Function/Objective

The database will be developed for the following purposes:

1) to provide an up-to-date national overview of *in situ* and *ex situ* conservation activities;
2) to promote collaboration among Canadian forestry agencies regarding conservation activities;
3) to support strategies for the preservation of endangered species or commercially valuable material;
4) to provide easy access to distribution and the availability of genetic resources in Canada with a view of supporting research objectives and preventing duplication of scientific effort;
5) to serve as a centralized, national archive of Canadian forest genetic resources;
6) to provide a coordinated Canadian input into a report on the state of the world's plant genetic

resources for use in developing a global action plan for plant genetic resources being coordinated by the Food and Agriculture Organization of the United Nations (FAO).

Database Development

To determine the feasibility, cost, and timeframe of developing and maintaining a national database of forest genetic resources, a Pilot Project was initiated in mid-1993 involving the Ontario Forest Research Institute (OFRI) of the Ontario Ministry of Natural Resources (OMNR) and PNFI. Programming of the database, using dBASE IV Version 2.0, was completed in December 1993. Information provided by OFRI on the status of Ontario's progeny trials, seed orchards, and breeding archives, as well as provenance trials established by PNFI were entered into the system. During 1994 the database was evaluated and modifications completed. Throughout the latter part of 1994 and early 1995, the database was demonstrated to various forestry agencies across Canada for further evaluation.

Future Development

Following evaluation of the Pilot Project and demonstration of the database within Canada, it will be necessary to establish a national network for the system. It is anticipated that many of the participants of this workshop would comprise the core of the network. Once the network is set up, the database software will be installed throughout Canada. Individual forestry agencies will be responsible for entering and updating forest genetic resources information under their jurisdiction. Annually, or semi–annually, data would be sent to PNFI where the information would be updated to the national level. The national database information would then be returned to respective agencies. During 1995 it is planned to enhance the database by incorporating a Geographic Information System (GIS) that would facilitate forest genetic resources information retrieval combined with mapping capabilities.

Summary

In Canada, an immense amount of genetic diversity is conserved under a variety of *in situ* and *ex situ* conservation activities. The National Forest Genetic Resources Centre (NFGRC) was established at the Petawawa National Forestry Institute to provide assistance in improving coordination and cooperation in research and operational conservation efforts of forest genetic resources. In support of this mandate, one goal of the NFGRC is to develop a national database to inventory all Canadian forest genetic resources, information which is currently under the jurisdiction of numerous forestry agencies. Such a database would serve as a valuable tool to researchers and forest managers in developing conservation strategies. In addition, with the focus on the development of a global action plan for plant genetic resources, this database would provide a coordinated up-to-date national status of Canada's forest genetic resources.

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Forest Tree Genetic Conservation Activities at the Laurentian Forestry Centre

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Abstract

Forest genetic studies were initiated about 40 years ago in Quebec. The oldest provenance trial became the first *ex situ* conservation site. Our research activities did not have *ex situ* conservation as a primary objective, but genetic conservation is a result nonetheless. Although facilities for long-term seed storage are available, most of our activities were directed towards operational conservation. However we intend, as long as the level of funding allows it, to enlarge our seed collection for white spruce and white pine in order to protect our gene pool from erosion. Genetic diversity studies must be pursued to correctly direct forest genetic conservation activities in Quebec.

Résumé

Au Québec, le début de la recherche en génétique forestière date d'une quarantaine d'années. Le site du plus vieux test de provenance est devenu le premier site de conservation *ex situ*. Notre recherche n'avait pas pour objectif principal la protection de ressources *ex situ*, mais la protection de ressources génétiques est néanmoins un des résultats obtenus. Malgré l'existence d'installations d'entreposage à long terme des semences, la plupart de nos activités étaient orientées vers la protection opérationnelle des ressources. Toutefois, nous avons l'intention d'élargir notre collection de semences d'épinette blanche et de pin blanc afin de prévenir l'érosion des pools génétiques de ces essences, aussi longtemps que notre financement le permettra. Il faut poursuivre les études sur la diversité génétique si l'on entend orienter correctement les activités de protection des ressources génétiques forestières au Québec.

History of Forest Tree Genetic Conservation Activities

Forest genetic studies were initiated in 1954 in the province of Quebec. From then on up to 1967, efforts in forest genetics were directed towards designing and establishing provenance trials for important tree species. These research activities were under the leadership of the (then) Petawawa Forest Experiment Station with the collaboration of the Laurentian Forest Research Centre (now called Canadian Forest Service - Québec Region) and the pulp and paper industry.

In 1967 the first geneticist was hired in Quebec by the Laurentian Forest Research Centre to take over responsibilities for conducting tree improvement programs. Two years later the Quebec Lands and Forests Department initiated its own improvement programs. Research and breeding responsibilities in Quebec were then divided among four institutions according to Corriveau and Vallée (1981) (Table 1). Since the beginning of the 80s, the two governmental organizations agreed on dividing responsibilities in order to avoid duplication. Thereby, CFS-Québec Region conducts genetic studies and breeding programs on white spruce and white pine. The organizations share responsibilities on Norway spruce, with the federal research centre conducting genetic studies and the Ministère des Forêts du Quebec being responsible for the improvement program. The Ministère des Forêts du Quebec also conducts genetics and tree improvement programs on all other tree species of interest to the province.

As such, our research activities did not have *ex situ* conservation as a primary objective, but genetic conservation is a result nonetheless. Efforts have always been made to use samples from across the range of the species in the province of Quebec and sometimes over its complete range. We also intend to maintain and preserve all provenance trials beyond the age of final data collection as they constitute one important form of *ex situ* conservation. Table 2 presents the list of the genetic trials under our responsibility. Therefore, as tree breeders, we hold an important gene pool, as representative as possible of the "natural" gene pool, that complements *in situ* conservation.

Table 1. Forest genetics and improvement projects in Quebec

Projects	Year of initiation	Organizations involved*
Provenance research on economic forest species	1955	CFS-Q, SR, CIP, UL
Genetics and improvement of high quality hardwoods	1965	UL, SR
Introduction of exotic species	1969	SR, CFS-Q, UL
Genetics research and improvement of poplars	1968	SR
Genetics research and improvement of larchs	1970	SR
Genetics research and improvement of jack pine	1974	SR
Genetics research and improvement of white spruce	1975	CFS-Q
Genetics research and improvement of white pine	1976	CFS-Q
Establishment of seed production areas	1968	RA, SRes, CIP
Establishment and development of the arboreta network	1969	SR, RA
Selection of plus-trees and seed orchard establishment	1975	RA, SRes, SR, CFS-Q, UL, CIP
Revival and enlargement of hardwood breeding programs	1989	SR

* CFS-Q: Canadian Forest Service-Québec Region; SR: Service de la recherche, Ministère des Forêts du Québec; CIP: Canadian International Paper Company; UL: Université Laval; RA: Régions administratives, Ministère des Forêts du Québec; SRes: Service de la restauration forestière, Ministère des Forêts du Québec.

Table 2. *Ex situ* conservation: species and number of provenances/families per species in provenance trials and genecological tests

Species	No. provenances/ families	Age (year)	No. sites
Picea glauca	220/671	10-35	18
Pinus strobus	235/514	4-7	7
Picea abies	165/345	2-38	18
Picea mariana	100	18-19	6
Picea rubens	16	34	3
P. mariana × *P. rubens*	3	21	1
P. glauca × *sitchiensis*	-/5	34	2
P. glauca var. *albertiana*	28	21	1
Pinus resinosa	12	35-37	2
Abies spp.	8	22	1
Abies balsamea	-/23	21	1
Pseudotsuga menziesii	10	22	2

Current Status of Forest Genetic Resources

In Situ

In the province of Quebec, *in situ* conservation is under the jurisdiction of the provincial government. Our participation is therefore limited to conducting related studies, identifying sites of special interest, and supporting any action aimed at long-term genetic conservation.

Ex Situ

The current status of *ex situ* conservation will be reported only on the species under our responsibilities. Tables 3, 4, and 5 present the number of provenances/ families under field testing. Data are given on the geographic origin of the seedlots.

For *Picea glauca*, over 200 provenances and 600 families have been sampled and have been or are currently being field tested (Table 3). This species has been quite well sampled over its range in Quebec in easily accessible areas (southern to the 49th parallel).

The genecological tests of *Pinus strobus* include nearly 600 seedlots, with half from Quebec and the other half from the complete range of the species in North America (Table 4). Our seed bank contains 1000 family seedlots. Forty percent of this seed collection has not been field tested so far. Sampling of the natural white pine population in Quebec has been completed in the Outaouais and southwestern regions. Few samples have been collected elsewhere. Sampling should be completed in the future.

Norway spruce is an exotic species of high potential for reforestation. An improvement program was

Table 3. Ex situ conservation of white spruce: number of provenances/families under field testing and in the seedbank

	Under field testing		In seedbank	
Origin	No. of provenances	No. of families	No. of provenances	No. of families
CANADA				
Quebec	93	368	164	924
Ontario	98	246	2	10
Maritimes	11	0	0	0
Western Canada	8	5	0	0
U.S.A.	3	0	1	5
Total	213	619	167	939

Table 4. Ex situ conservation of white pine: number of provenances/families under field testing and in the seedbank

	Under field testing		In seedbank	
Origin	No. of provenances	No. of families	No. of provenances	No. of families
CANADA				
Quebec	128	315	188	700
Newfoundland	2	0	2	0
New Brunswick	3	5	3	5
Nova Scotia	2	5	2	5
Ontario	37	58	39	58
USA				
Maine	5	5	6	5
New Hampshire	1	5	1	6
Vermont	1	15	1	20
New York	2	1	3	3
Pennsylvania	9	5	9	7
Connecticut	2	0	2	0
West Virginia	2	8	2	8
Ohio	2	5	2	5
North Carolina	8	7	7	7
Tennessee	5	8	5	8
Georgia	2	0	2	0
Michigan	9	19	12	23
Illinois	1	1	1	1
Wisconsin	8	27	12	35
Minnesota	7	24	15	30
Total	235	514	314	926

initiated in the early 70s. As shown in Table 5, seedlots of various geographic origins have been used to establish genetic trials in order to enlarge the genetic base of our breeding population.

Part of this material and additional genotypes can be found in the 180 ha of seed orchards that have been established in the province for these three species. Clonal archives and arboreta are also sites of *ex situ* conservation. Detailed information on the numbers of clones or families maintained on those sites can be found in Boyle (1992).

Table 5. Ex situ conservation of Norway spruce: number of provenances/families under field testing and in the seedbank

Geographic origin	Under field testing		In seedbank	
	No. of provenances	No. of families	No. of provenances	No. of families
Bulgaria	5	30	-	-
Czechoslovakia	5	-	3	-
Finland	13	-	-	-
Germany	10	-	-	-
Lithuania	1	-	-	-
Latvia	5	-	-	-
Poland	56	140	9	193
Romania	6	-	-	-
Russia	18	-	-	-
Yugoslavia	4	-	-	-
Ontario	1	5	1	15
Quebec (known origin)	23	115	50	341
Quebec (unknown origin)	18	55	37	118
Total	165	345	100	667

Current and Planned Programs for Genetic Conservation

Under the Green Plan NFGRC initiative, we are currently completing a study on the genetic diversity and structure of white pine populations in Quebec. The study was initiated by Dr. Jean Beaulieu who completed a PhD degree on this subject. Six additional populations will be sampled and analyzed. The expected output of this research includes knowledge of the genetic diversity of the species over its range in Quebec, identification of populations of special interest for which *in situ* conservation should be considered, and seed collection of great value for improvement purposes. Study on the genetic diversity of natural white spruce populations in Quebec is also part of our research proposal under the Green Plan initiative.

Ex situ tree genetic conservation remains an underlying objective of our tree improvement programs. Storage of representative seed samples, studies on the impact of selection on genetic diversity, and cryopreservation of cell lines will continue to be part of our activities.

Special Projects or Opportunities

Important problems may arise as new pathogens or insects are found or introduced in our forests. In some cases, it may even lead to a possible eradication of the host species, making gene conservation a priority. An example of such a problem is the discovery of a new, highly virulent race of *Sirococcus clavigignenti-juglandacearum* (butternut canker) that seriously threatens the survival of butternut in North America. The epidemic appears to be so widespread that this species may be the first tree considered for addition to the Endangered Species List. This situation has raised the question of genetic conservation of the species for future generations. The urgency of sampling the living butternut population and setting up a seedbank is dependent on the pace of the epidemic. Little is known on the extent of the epidemic but it is severe enough and the butternut population has declined so steeply in some parts of the United States that some states like Minnesota have decided to ban cutting the trees on state lands.

The disease has reached the border with Ontario and Quebec. As Quebec is at the limit of the species distribution, concerns may be raised on the genetic diversity of the Quebec butternut population and its level of resistance to the disease. The probability of its extinction is, therefore, possibly higher than in the States.

Given these facts, actions should be undertaken to:

- Survey the butternut populations in Quebec and Ontario
- Determine the frequency of infected trees in the population in order to evaluate the urgency of undertaking conservation procedures
- Determine sampling and storage strategies
- Initiate laboratory research for *in vitro* culture of the species for cryopreservation purposes because long-term conservation cannot be insured through seed storage.

Funding opportunities are being evaluated.

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La Conservation des Ressources génétiques dans les Forêts du Québec

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Résumé

Pour mettre en œuvre la convention sur la biodiversité, le gouvernment du Québec a créé un comité interministériel. Dans ce cadre, le ministère des Forêts (MFO) réalise un bilan sur la biodiversité en milieu forestier. Ce bilan comporte quatre sections : le cadre territorial de référence, les espèces menacées, les zones protégées et les pratiques d'aménagement.

Pour gérer les ressources en fonction de la biodiversité, le MFO élabore une carte des écosystèmes qui intègre les régions écologiques et les unités physiographiques. Une loi a été adoptée pour la protection des espèces menacées. Le réseau de zones protégées, d'une superficie de 1 million d'hectares, regroupe 178 sites des catégories I, II, IV et IX de l'U.I.C.N (Union internationale pour la conservation de la nature et des ressources naturelles). L'aménagement forestier, encadré par divers programmes, stratégies ou lois, favorise la conservation de la diversité biologique. Des activités de conservation des ressources génétiques (*ex situ* et *in situ*) ont été réalisées pour les programmes d'amélioration génétique et de reboisement.

Plusieurs éléments essentiels à la conservation de la biodiversité sont déjà en place. Le processus d'élaboration d'une stratégie de conservation est amorcé.

Abstract

The Quebec government has formed an interdepartmental committee to implement the Biodiversity Convention. As part of the committee, the Quebec Department of Forests is preparing a report on biodiversity in the forest sector. The report has four parts: the territorial frame of reference, threatened species, protected zones, and development practices.

To manage resources with the objective of biodiversity conservation, the Department of Forests is developing an ecosystems map which integrates ecological regions and physiographic units. An Act has been adopted to protect threatened species. The network of protected areas, totalling one million hectares, is composed of 178 sites in IUCN (International Union for the Conservation of Nature) categories I, II, IV, and IX. Forest management, backed by legislative authority, promotes the conservation of biological diversity. Genetic resources conservation activities (*ex situ* and *in situ*) have been carried out for genetic improvement and reforestation programs. A number of initiatives essential to biodiversity conserva-tion are already in place. The process of developing a conservation strategy has been initiated.

Introduction

Le gouvernement du Québec a déclaré son adhésion aux principes et aux objectifs de la convention sur la biodiversité. Pour assurer la mise en œuvre de la convention, il a créé en novembre 1992 un Comité interministériel sur la biodiversité. Ce comité est composé des sous-ministres des ministères suivants : Affaires internationales (MAI), Loisirs, Chasse et Pêche (MLCP), Agriculture, Pêcheries et Alimentation (MAPAQ), Environnement (MENVIQ), Énergie et Ressources (MER) et Forêts (MFO) et du Secrétariat aux affaires intergouvernementales canadiennes (SAIC). Un groupe de travail (MFO, MENVIQ, MLCP et MAPAQ) a été formé par le Comité interministériel; son mandat est d'analyser l'état de la biodiversité au Québec et de suggérer au comité des moyens pour assurer la conservation de cette biodiversité.

Comme membre du groupe de travail sur la biodiversité, le MFO a notamment la responsabilité d'analyser la situation en milieu forestier. En avril 1993, le Ministère publiait un document exploratoire intitulé «Biodiversité et aménagement des forêts : contexte québécois» (Bouchard et coll. 1993). Les recommandations des auteurs étaient :

1- de réaliser un bilan sur l'état de la biodiversité en milieu forestier;
2- de mettre au point, selon les résultats du bilan, des mesures spécifiques de conservation de la biodiversité;
3- de participer au processus prévu par la Loi sur les espèces menacées ou vulnérables;
4- de participer aux travaux du Comité interministériel sur la biodiversité en vue d'élaborer la stratégie québécoise de conservation de la biodiversité.

Le MFO a donc entrepris en septembre 1993 de réaliser la première étape, soit le bilan sur l'état de la biodiversité en milieu forestier. Le plan de travail préliminaire pour réaliser ce bilan comporte quatre grandes sections :

- un cadre territorial de référence pour la gestion des ressources en fonction de la diversité biologique;
- les espèces menacées ou vulnérables;
- les zones protégées;
- les pratiques d'aménagement.

Ce plan de travail n'est pas statique; il sera amélioré au fur et à mesure de la progression des travaux. Chacune des sections prévues pour dresser le bilan sur la biodiversité en milieu forestier a *un rapport direct ou indirect avec la conservation des ressources génétiques forestières*.

Le Cadre Territorial de Référence

Pour gérer les ressources forestières, le ministère des Forêts du Québec a mis au point un programme d'inventaire et de classification écologique (végétation, sols...) des forêts (Bergeron et coll. 1993). Ce programme pourrait servir de base à la définition du cadre territorial de référence pour la gestion des ressources en fonction de la diversité biologique.

L'inventaire écologique permet de décrire la diversité des peuplements forestiers du Québec. L'objectif du programme est de compléter la classification écologique des forêts sur tout le territoire au sud du 52e parallèle. Des méthodes d'analyses multifactorielles sont utilisées pour décrire la diversité des types forestiers et les séries évolutives. Par la suite, les analyses de croissance et de contraintes à l'aménagement mènent à la définition des stations forestières. La description des stations forestières ainsi que des propositions d'aménagement, regroupées selon un scénario sylvicole, forment l'essence du guide sylvicole.

Un système hiérarchique de classification écologique est utilisé. Les régions écologiques (fig. 1) sont au sommet de la pyramide. Ces régions sont des portions de territoire caractérisées par un climat régional distinct, exprimé par la végétation. Elles sont subdivisées successivement en districts écologiques (ensembles physiographiques), en types écologiques et en phases écologiques. Un exemple de ce système est donné à la figure 2. Pour la gestion en fonction de la diversité biologique, le MFO procède à la mise au point d'une carte des écosystèmes (à l'échelle 1 : 2 500 000) qui intégrera les régions écologiques et les unités physiographiques.

Les fiches descriptives (figure 3) de chaque type forestier (au niveau de la phase écologique) renferment des informations qui fournissent une description partielle de plusieurs types de diversité biologique (pour une discussion de chaque type de diversité mentionné ici, voir Kimmins 1992). Chaque fiche décrit partiellement la diversité «alpha» des espèces (variété dans un écosystème) et la diversité structurale de l'écosystème (stratification verticale du couvert, pourcentage de recouvrement des strates). Les séquences associées à chaque série évolutive (regroupement de phases écologiques évoluant vers une même végétation stable) permettent de décrire la diversité temporelle des écosystèmes (changement de la variété des espèces dans le temps). La cartographie des types écologiques (carte écoforestière) illustre la diversité biologique à l'échelle du paysage, ainsi que la variation des espèces selon un transect (diversité «beta» des espèces). Finalement, l'interprétation des données physiques spécifiques aux types forestiers (dépôt, drainage, indices de croissance) nous renseigne sur la variabilité de la productivité des écosystèmes (diversité biologique fonctionnelle).

L'efficacité des mesures de conservation de la diversité biologique sera d'autant plus grande que ces mesures seront intégrées entre différentes échelles géographiques, du peuplement à la région écologique (Salwasser 1990). La classification hiérarchique utilisée au Québec répond à cet impératif de gestion. Elle permet de visualiser, par la cartographie, les différents niveaux d'intégration.

L'inventaire écologique par rapport à la diversité génétique

L'inventaire écologique permet notamment d'identifier les populations marginales. Ces populations sont souvent hautement spécialisées du point de vue génétique (Stern et Roche 1974). Elles sont exposées à des conditions de croissance différentes de celles des populations du corps principal. La distribution d'une espèce est généralement limitée par des facteurs climatiques extrêmes, par des barrières géographiques

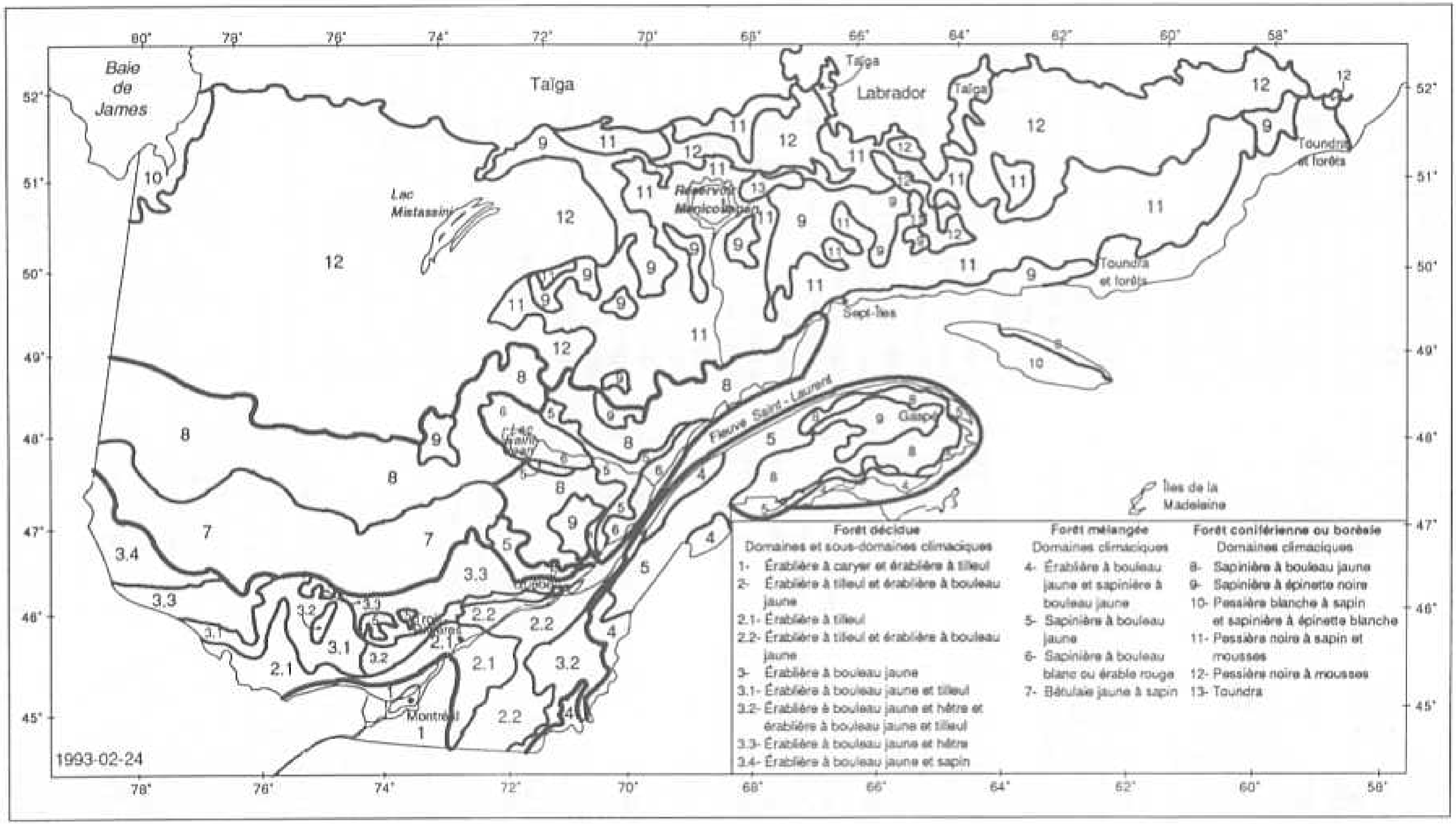
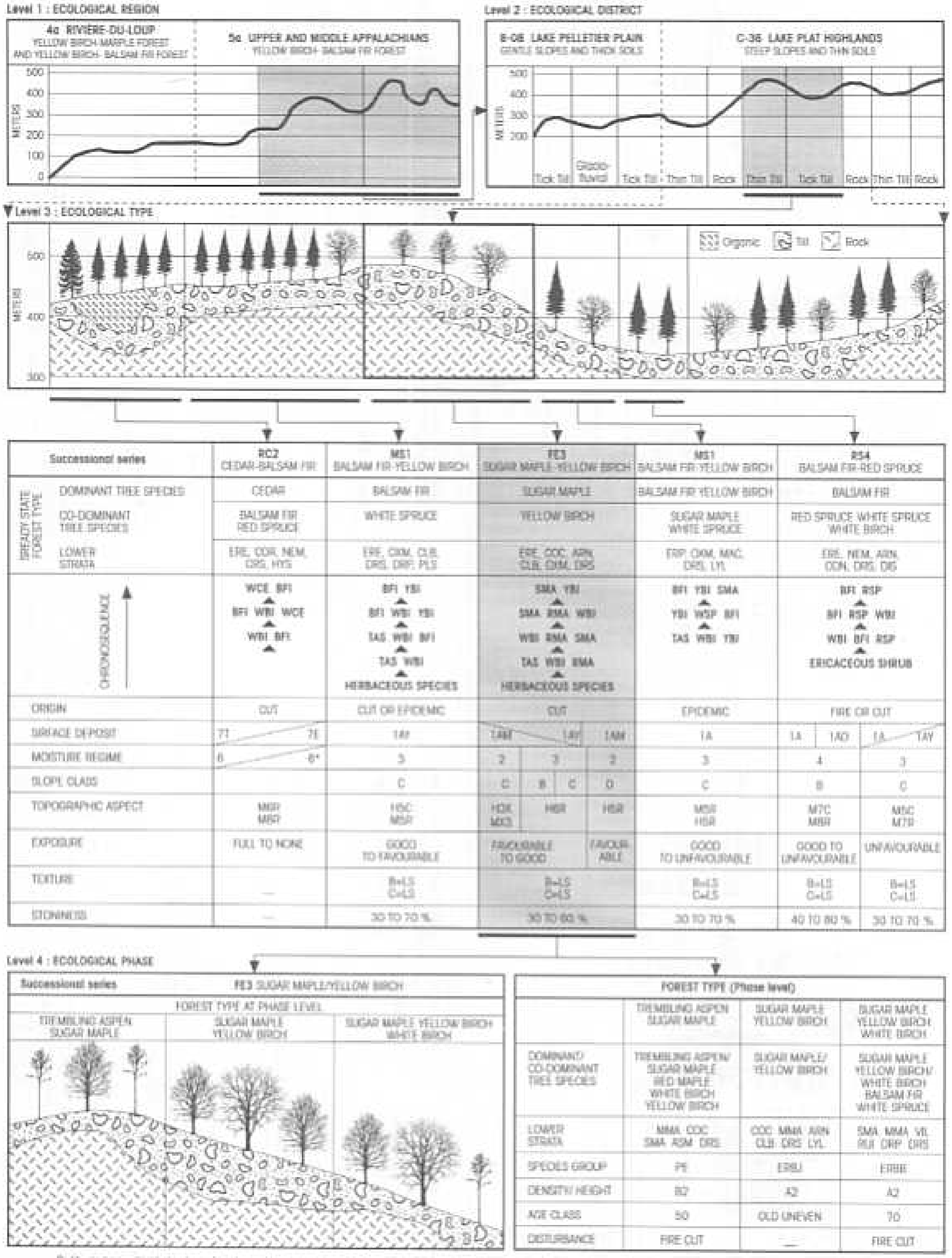


Figure 1. Les régions écologiques du Québec méridional (Thibault 1985)

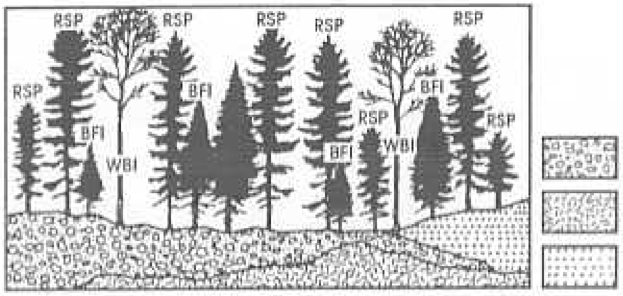


Québec's hierarchical structure of ecological land classification. Four classification levels have been defined and a equivalent number of mapping scales correspond to these levels : region, district, type and phase. A synthetic example of toposequence is provided at the level 3. The level 4 describes the species composition and the stand characteristics of forest types of the phase level.

Figure 2. Structure hiérarchique de la classification écologique au Québec. (Adapté de Bergeron et coll. 1993)

4A-RS42-5.3 RSP / PLS VAM
Red spruce / mosses, Vaccinium

Ecological region:	4A	Collines de Mégantic — Lac Etchemin
Successional series:	RS42	Typical balsam fir — red spruce
Successional stage:	5.3	Steady state
Number of sampling plots:	35	



Species composition

Tree layer (70 - 95 %)
Dominant: Picea rubens[3]
Co-dominant: Abies balsamea[1]
Occasional: Betula papyrifera[+]

Shrub layer
Regeneration (30 %)
Dominant: Abies balsamea[3]
Co-dominant: Picea rubens[1]
Occasional: Betula papyrifera[+] Acer rubrum[+]

Understory shrub (30 %)
Dominant: **Vaccinium myrtilloides**[2] Kalmia angustifolia[1]
Co-dominant: Nemopanthus mucronata[1] Viburnum cassinoides[1]
Occasional: Amelanchier sp.[+]

Herbaceous layer (25 %)
Dominant: Cornus canadensis[1]
Co-dominant: Pteridium aquilinum[1], Clintonia borealis[1], Chiogenes hispidula[1] Trillium undulatum[1], Epigea repens[1]
Occasional: Maianthemum canadensis[1], Gaultheria procumbens[+], Pyrola secunda[+]

Moss layer (40 - 75 %)
Dominant: **Pleurozium schreberi**[4], Dicranum sp.[+]
Co-dominant: Ptilium crista-castrensis[1], Bazzania trilobata[1]
Occasional: Sphagnum girgensohnii[1], Hylocomium splendens[+], Polytrichum sp.[+], Cladina rangiferina[+]

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Forest type **4A-RS42-5.3 RSP / PLS VAM** — Physical Environment

Abundance codes
+ = 1 - 5 %
1 = 6 - 15 %
2 = 16 - 25 %
3 = 26 - 35 %
4 = 36 - 45 %
5 = 46 - 55 %
6 = 56 - 65 %
7 = 66 - 75 %
8 = 76 - 85 %
9 = 86 - 100 %

Features / Surface deposit	Moisture regime							Texture	Stonines (%)	Roughness classes 1 to 5
	0	1	2	3	4	5	6			
R		+						—	50 - 60	3 - 4
M1A		+						B : LS		
1AM			+					C : LS	30 - 60	3
1AY				1				B : LS / C : LS		
1A				2	3	2				
1AD						1			> 70	3 - 4
2A				1	1			B : SL / C : S	30	2
3AN						+		B : LS / C : LS	10	1

Exposure:

		N		
		2		
W	3	[2]	2	E
		1		
		S		

Topographic Aspect

Site position on slope / Meso-relief	Crest / Upper slope	Lower slope	Mid-slope	Level
Upper				
Middle	2		2	6
Lower	2	2	1	6

Altitude: 260 to 410 m
Slope class: B^3, A^3, C^2
Soil type: PHFGL[1], PHFO[1], GO[1]
Humus type: Mor[8] (10±4 cm), peat[1] (20±5 cm)
Distribution: Frequently found in physiographic assemblage U-Collines des Basses Appalaches

Succession: Steady state forest type which is capable of maintaining itself after forest fire. Following harvesting or without a major disturbance, this forest type can evolve towards a Balsam fir - red spruce, Pleurozium, Vaccinium type. Usually originating from fire or harvesting, the type described here could stem from the post-epidimic degradation of a Balsam fir - red spruce forest type. This aformentioned forest type is often vulnerable to spruce budworm attacks.

Stratum: E E

Remark: In the tree layer, the black spruce is occasionaly replacing the red spruce

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Fact sheet describing the red spruce, Pleurozium, Vaccinium forest type. This example is adapted from the FEC field guide prototype developed for the Appalachian region, ecological region 3e.4a.5b (Grondin et al. 1991); the forest type number contains the following information: ecological region, 4A; sucessional series and sucessional stage RS42-5.3; overstory dominant species and indicator species, EPR/PLS-VAM. Acronyms and codes used in this figure are described in Robert and Saucier (1988).

Figure 3. Exemple de fiche descriptive d'une phase écologique (Adapté de Bergeron et coll. 1993)

ou par la supériorité compétitive d'autres espèces (Stern et Roche 1974). Des gènes ou des groupes de gènes uniques ou rares peuvent se développer dans les populations marginales.

Pour la délimitation des zones de transfert de semences, la cartographie écologique est aussi très utile. Elle peut servir, dans un premier temps, à délimiter des zones préliminaires en attendant les résultats des tests génécologiques. Lorsque les résultats de ces tests seront connus, les zones de transfert pourront être modifiées. Mais de grands blocs de territoire seront attribués à une zone ou à l'autre en fonction de leur seule appartenance à une région écologique ou à un district écologique. Il est en effet impensable d'établir un réseau de tests assez dense pour faire fi des informations que nous donne la végétation naturelle. Au Québec, les régions écologiques sont déjà utilisées pour contrôler les transferts de semences. Dans les programmes d'amélioration, elles servent à délimiter des zones d'amélioration et des zones de testage.

Les Espèces menacées ou vulnérables

La Loi sur les espèces menacées ou vulnérables a été adoptée afin de protéger les espèces. Il existe au Québec méridional 2 550 espèces de plantes vasculaires dont près de 1 850 sont indigènes. Parmi celles-ci, une liste de 374 espèces susceptibles d'être désignées comme menacées ou vulnérables a été produite récemment (Lavoie 1992). Selon la loi adoptée au Québec, une espèce est menacée lorsque sa disparition est appréhendée; elle est vulnérable lorsque sa survie est précaire même si sa disparition n'est pas appréhendée. Le mot espèce a ici un sens très large, englobant une sous-espèce, une race, une variété ou une population isolée.

Douze espèces d'arbres (tableau 1), dont aucune n'a une importance commerciale au Québec, figurent sur cette liste. Ce sont toutes des espèces à la périphérie nord de leur distribution naturelle. Au Québec, elles se retrouvent toutes dans le sud-ouest du Québec, (particulièrement dans le domaine de l'érablière à caryer) là où la menace de disparition des habitats est la plus importante en raison de l'urbanisation et du développement agricole. À l'exception des aubépines (*Crataegus* spp.), dont la taxonomie est assez compliquée, on peut affirmer que ce sont toutes des espèces largement répandues à l'extérieur de nos frontières.

Aucune sous-espèce, race, variété ou population isolée d'autres espèces arborescentes n'a été identifiée comme étant potentiellement menacée ou vulnérable.

Tableau 1. Liste des espèces d'arbres susceptibles d'être désignées comme menacées ou vulnérables

Acer nigrum Michx. f. - érable noir
Celtis occidentalis L. - micocoulier occidental
Crataegus brainerdii Sarg. - aubépine de Brainerd
Crataegus crus-galli L. - aubépine ergot-de-coq
Crataegus dilatata Sarg. - aubépine dilatée
Crataegus pruinosa (Wendl) K. Koch var. *pruinosa* - aubépine pruineuse
Crataegus suborbiculata Sarg. - aubépine suborbiculaire
Juniperus virginiana L. var. *crebra* Fern. - genévrier de Virginie
Pinus rigida Ait. - pin rigide
Quercus alba L. - chêne blanc
Quercus bicolor Willd. - chêne bicolore
Ulmus thomasii Sarg. - orme liège

Toutefois, la préservation de certaines populations méridionales d'espèces boréales devrait être envisagée. Des différences génétiques liées à l'origine géographique ont déjà été identifiées, chez le sapin baumier par exemple (Beaulieu et coll. 1990). Des adaptations climatiques particulières aux populations méridionales pourraient devenir déterminantes en regard d'un réchauffement climatique.

Les Zones protégées

En plus de se préoccuper des espèces menacées ou vulnérables (mesure corrective), le Québec a aussi établi un réseau de zones protégées (mesure préventive). Ce réseau, d'une superficie totale de plus de 1 million d'hectares, regroupe 178 sites variant de 1 à 457 000 hectares (tableau 2). Ces sites peuvent être classés dans les catégories I, II, IV et IX de l'Union internationale pour la Conservation de la Nature et des Ressources naturelles (UICN). Les aires de catégories I (réserve naturelle intégrale ou réserve scientifique), II (parc national ou réserve équivalente) et IV (réserve naturelle dirigée ou réserve faunique) sont considérées comme des aires naturelles protégées. Les réserves de la biosphère (catégorie IX) sont des sites aménagés en vue de la recherche, de l'éducation ou de la formation; elles ont aussi pour but de sauvegarder la diversité génétique des espèces. Ce ne sont pas toutes des aires forestières. Cependant, elles sont toutes localisées au sud du 52e parallèle, là où se trouvent la presque totalité des habitants du Québec et là où se trouve la forêt dite commerciale. Puisque la méthode la plus efficace pour protéger la diversité biologique consiste à protéger les habitats, le réseau devra donc être examiné pour évaluer son efficacité à préserver la biodiversité. Cette évaluation sera fondée sur le pourcentage de territoire protégé, mais aussi sur des facteurs tels que la

Tableau 2. Résumé[1] des zones de préservation et des zones de conservation au Québec, selon les catégories de l'UICN

Catégorie U.I.C.N.	Désignation	Nbre	Superficie (ha) Tot.	Min.	Max.
I	Réserve écologique	43	43 003	4	23 540
II	Parc national	3	94 430	15 000	54 390
	Parc historique national	1	190	–	–
	Parc de la Commission de la capitale nationale	1	35 700	–	–
	Parc provincial	16	419 410	60	149 000
IV	Autre parc	9	1 351	1	600
	Réserve nationale de la faune	8	5 314	20	2 398
	Refuge d'oiseaux migrateurs	33	50 683	4	11 200
	Refuge faunique	1	145	-	-
	Centre éducatif forestier	9	12 829	182	3 424
	Station forestière	1	9 000	-	-
	Forêt d'enseignement et de recherche	16	28 468	112	6 665
	Autre aire de conservation	35	4 438	2	951
IX	Réserve de la biosphère	2	458 100	1 100	457 000
Total		178	1 163 061		
Superficie totale du Québec[2]			149 640 000 approx.		
Superficie du Québec au sud du 52e parallèle			75 790 000 approx.		

[1]Tiré du *Registre des aires naturelles protégées du Québec selon la classification de l'UICN.* MENVIQ, Dir. du patrimoine écologique, juin 1993.
[2]Excluant les eaux du fleuve et du golfe Saint-Laurent, celles des échancrures des baies de James, d'Hudson et d'Ungava ainsi que celles du détroit d'Hudson.

représentativité, la configuration et les interrelations avec les territoires adjacents (Cimon 1993).

Une expansion de ce réseau est déjà prévue par le gouvernement du Québec. Plusieurs territoires sont déjà réservés à cette fin et bénéficient d'une protection absolue dans l'attente d'une décision finale.

Au Québec, environ 90 p. 100 de la superficie forestière est propriété de l'État (Cimon 1993). L'utilisation durable de l'ensemble des ressources est préconisée sur ces terres. La conservation de la biodiversité peut donc y être encouragée par la gestion des pratiques d'aménagement qui y sont autorisées.

La Conservation *Ex Situ* et *In Situ* des Ressources Génétiques

Des activités de conservation des ressources génétiques au Québec ont été réalisées dans le cadre de l'amélioration génétique et du reboisement. Les organismes impliqués dans ces activités sont le Service canadien des forêts, et le ministère des Forêts du Québec. Quelques compagnies forestières ont réalisé ou collaboré à la réalisation des travaux d'amélioration génétique.

Par le biais des programmes d'amélioration génétique, on a mis en place des arboretums, des tests de provenances, des tests de descendances, des vergers à graines et des banques de clones, de semences et de pollen pour plusieurs espèces. Plusieurs lots de semences et de pollen de diverses espèces sont conservés en congélation après lyophilisation. D'ici peu, la cryoconservation des cals embryogènes sera expérimentée. Le programme de reboisement, pour sa part, a nécessité la création d'une banque de semences à des fins opérationnelles, la sélection de peuplements pour la récolte de semences et, tout récemment, la création de quartiers de pieds-mères de peupliers hybrides. La majorité de ces activités a déjà été décrite en détail par Boyle (1992). Un résumé est présenté au tableau 3, qui comprend aussi quelques renseignements provenant d'autres sources (Beaudoin et coll. 1993; S. Mercier, comm. pers.).

Les peuplements sélectionnés bénéficient tous d'une certaine forme de protection dans le sens que rien ne peut y être fait sans l'accord du MFO. D'autres mesures seront suggérées pour assurer une protection à plus long terme de ces peuplements.

Les Pratiques d'Aménagement

L'aménagement des forêts québécoises est encadré par divers programmes, plans, stratégies ou lois qui sont favorables, à divers degrés, à la conservation de la diversité biologique. Citons, à titre d'exemples, la Loi sur les forêts, les plans d'aménagement exigés en vertu de celle-ci, la Stratégie de protection des forêts, le Programme de connaissance de la ressource forestière (inventaires, cartographie forestière, classification des écosystèmes, etc.) et le Règlement sur les normes d'intervention en milieu forestier. Le MFO procède à l'évaluation de certaines pratiques d'aménagement forestier. L'efficacité de celles-ci en vue du maintien de la diversité biologique en forêt aménagée et dans les zones protégées adjacentes sera déterminée et des ajustements seront proposés.

L'Amélioration Génétique des Espèces Commerciales

Au Québec, le MFO et le Service canadien des forêts se partagent la tâche de réaliser l'amélioration génétique des espèces forestières commerciales. Le MFO gère des programmes pour le pin gris (*Pinus banksiana*), l'épinette noire (*Picea mariana*), les mélèzes (*Larix* spp.), les peupliers (*Populus* spp.) et certains feuillus nobles [bouleau jaune (*Betula alleghaniensis*), chêne rouge (*Quercus rubra*), frêne blanc (*Fraxinus americana*)]. Pour les peupliers et les feuillus nobles, un projet de recherche particulier, visant à mettre au point des méthodes de sélection pour la résistance aux maladies, est en cours. Le MFO a aussi la responsabilité d'installer tous les vergers à graines. Pour sa part, le Service canadien des forêts est responsable des programmes d'amélioration pour l'épinette blanche (*Picea glauca*) et le pin blanc (*Pinus strobus*). Ensemble, les deux organismes travaillent à l'amélioration génétique de l'épinette de Norvège (*Picea abies*). Finalement, le MFO subventionne une équipe du Centre de recherche en biologie forestière de l'Université Laval pour réaliser la transformation génétique de l'épinette blanche en insérant dans son génome le gène de la toxine de *Bacillus thuringiensis*. Des équipes de l'Université du Québec à Montréal et en Abitibi-Témiscamingue s'intéressant à la sélection précoce et à

Tableau 3. Résumé des activités de conservation des ressources génétiques forestières au Québec

Type Activité	Commentaires*
In situ	
Peuplements sélectionnés	16 espèces, 136 peuplements, 2 975 ha
Ex situ	
Tests de provenances	29 espèces ou hybrides, 3 876 provenances, 337 ha, 327 tests
Tests de descendances	25 espèces ou hybrides, 142 tests, > 16 000 descendances
Tests clonaux	Plusieurs espèces de peuplier et de saule
Vergers à graines	
- de semis	13 204 familles, 877 ha, 42 vergers, 6 espèces
- clonaux	7 101 clones, 193 ha, 39 vergers, 8 espèces
Banques de clones	17 espèces, 18 077 clones, 185 ha, > 170 000 arbres
Banque de semences	
- recherche	52 espèces, 14 455 lots
- opérationnelle	16 espèces, 1 019 lots, > 40 110 kg
Banque de pollen	17 espèces, 568 lots
Arboretums	21 sites, 124 espèces
Quartiers de pieds-mères	5 sites, > 300 clones de peupliers

* Le nombre d'espèces mentionné comprend, dans tous les cas, des espèces exotiques

la multiplication *in vitro* du pin gris. Une brève description des projets réalisés au MFO est présentée ici. La description de chaque projet est détaillée chaque année dans un rapport interne disponible à la Direction de la recherche du MFO.

Pin gris

Des tests de provenances ont montré qu'en général, les provenances locales sont plus fiables. Les vergers à graines ont été conçus en conséquence. Des tests de descendances ont été établis pour permettre une éclaircie génétique dans les vergers. La sélection d'arbres parmi les provenances les moins sensibles au chancre scléroderrien (*Gremmeniella abietina*) est un critère important pour les endroits où les conditions de croissance sont plus favorables au développement de cette maladie. On porte aussi attention à la rouille-tumeur globuleuse (*Endocronartium harknesii*), au charançon du pin blanc (*Pissodes strobi*) et au nodulier du pin gris (*Vespamima pini*). Le pin gris est la seule espèce pour laquelle l'industrie québécoise a proposé des critères technologiques à améliorer génétiquement. Ainsi, on cherche à accroître la production (volume) et la rectitude du tronc et à maintenir la densité du bois à sa valeur actuelle. On commence à s'intéresser à la colora-tion du bois. Si ce facteur est génétiquement régi, il pourrait devenir un critère de sélection. Des croise-ments dirigés avec les meilleures provenances de pin taxifolié (*Pinus contorta* var. *latifolia*) seront réalisés.

Épinette noire

Programme très semblable à celui qui a été établi pour le pin gris. L'essence étant reconnue et très utilisée pour ses qualités papetières et pour le sciage, on vise à améliorer la productivité (volume) et à maintenir la densité du bois à sa valeur actuelle. L'épinette noire présente une tige relativement droite et est peu affectée par les insectes et les maladies. Cette espèce se prête très bien au bouturage juvénile et à la multiplication par embryogenèse somatique. Pour la deuxième génération, des variétés multifamiliales seront constituées en choisissant les meilleures croisements pour chaque zone d'amélioration. La possibilité de cryopréservation de cals embryogènes pourrait permettre de créer des variétés multiclonales. On explore les possibilités de l'hybridation avec l'épinette de Serbie (*Picea omorika*) et l'épinette de Sitka (*Picea sitchensis*).

Mélèzes

Pour leur croissance rapide, des provenances de mélèze d'Europe (*Larix decidua*), de mélèze du Japon (*L. leptolepis*) et certains hybrides (*L. × eurolepis*) ont été sélectionnés pour le sud du Québec. Le mélèze laricin (*L. laricina*) et le mélèze de Sibérie (*L. sibirica*) seront plutôt utilisés plus au nord. Pour les espèces exotiques, on vise surtout la sélection des meilleurs clones, mais des provenances très performantes de mélèze d'Europe ont été identifiées. Chez le mélèze laricin, des vergers à graines et des tests de descendances ont été établis à partir de récolte de semences sur des arbres-plus. L'utilisation des mélèzes est restreinte par un sérieux problème d'approvisionnement en semences. Le bouturage de pieds-mères juvéniles pourrait permettre d'étendre son utilisation pour le reboisement.

Peupliers

Des essences exotiques sont introduites au Québec, dans des tests de provenances et de descendances. Des croisements interspécifiques sont réalisés pour constituer les populations de base, afin de sélectionner les meilleurs clones. La croissance, la morphologie et la résistance à certaines maladies sont les critères de sélection. Les arbres sélectionnés sont bouturés et évalués dans des tests clonaux.

Feuillus nobles

Ce programme vise surtout à identifier ou à créer, littéralement, de bonnes sources de semences pour le programme de reboisement. L'amélioration de la qualité des arbres est basée sur une sélection pour l'adaptation climatique, la croissance juvénile et, particulièrement, la dominance apicale et son incidence sur la forme des arbres. Pour le chêne rouge et le frêne blanc, des tests de provenances-descendances sont privilégiés. L'hybridation intraspécifique du bouleau jaune et l'hybridation avec le bouleau blanc (*B. papyrifera*) servent à produire des semences améliorées. Les bouleaux se bouturant relativement bien, la voie clonale pourrait servir à reproduire le meilleur matériel. Le noyer noir (*Juglans nigra*), essence introduite au Québec, fait l'objet d'une collection de noix et de greffons à des fins de préservation et de promotion du matériel adapté auprès des utilisateurs.

Résistance aux maladies

Il s'agit essentiellement de mettre au point des méthodes d'inoculation qui permettent un testage précoce. Chez les peupliers, des clones résistants ou peu sensibles au chancre septorien (*Septoria musiva*) et au chancre hypoxylonien (*Hypoxylon mammatum*) sont déjà sélectionnés. Pour le bouleau jaune, on met au point une méthode pour évaluer sa sensibilité au chancre nectrien (*Nectria galligena*).

Épinette de Norvège

L'adaptation aux conditions de croissance est l'objectif principal qui guide le choix des provenances et des descendances chez cette espèce exotique très productive. On s'intéresse en particulier à sa tolérance au froid et à sa résistance au charançon du pin blanc. Des croisements entre arbres sélectionnés sont réalisés. L'essence se prête relativement bien au bouturage juvénile. Le reboisement avec l'épinette de Norvège se fait surtout dans l'Est (Bas-Saint-Laurent et Gaspésie) en raison de l'absence du charançon dans ces régions.

Tous ces programmes d'amélioration sont encore relativement jeunes. Nos variétés améliorées ont une base génétique relativement large. La grande majorité des sélections pour les vergers à graines s'est faite sur une base régionale pour en garantir l'adaptation. Les tests de descendances sont faits dans la ou les régions prévues pour l'utilisation des semences. Le nombre de tests de descendances correspondants à un même verger à graines varie de un à quatre. Pour les familles d'un même groupe, le test de la descendance est généralement réparti sur plusieurs sites.

Lacunes à Combler[1]

La conservation génétique *in situ* revêt deux aspects : la protection de zones forestières et la gestion écologique appropriée dans les zones non protégées (Boyle 1992). Afin de réaliser une conservation *in situ* adéquate, je pense qu'on doit répondre aux questions suivantes :

- quelles espèces ont besoin d'une protection particulière, en tout ou en partie (sous-espèce, provenance, etc.)?
- en fonction de la structure génétique des espèces, quelles populations doivent être protégées pour préserver un échantillon représentatif?
- en fonction du système génétique propre à chaque espèce (mode de reproduction et dynamique des populations, en particulier), quelles superficies minimales sont nécessaires en fonction du but recherché (voir Shaffer 1981)? Quels autres organismes doivent être présents (pour la pollinisation entomophile, par exemple)?
- quels sont les effets des différentes interventions en zones non protégées et de la fragmentation des forêts sur la variabilité génétique des populations (coupe à diamètre limite, coupe de régénération, etc.)?

[1]Les idées exprimées dans cette section n'ont pas été l'objet de discussion au sein du ministère des Forêts; elles sont le fruit des réflexions de l'auteur.

Les deux premières questions doivent aussi être considérées pour préciser les priorités de conservation *ex situ*. En conséquence, j'identifie les besoins suivants :

- une synthèse de la situation des espèces, afin d'identifier les priorités et les cas-problèmes. La liste des plantes rares de Lavoie (1992) est basée sur la taxonomie, la fréquence, l'abondance, l'habitat et la répartition des espèces mais ne tient pas compte de leur structure génétique. Cette information est probablement inexistante pour la grande majorité des espèces non commerciales. Elle est parfois partielle pour les espèces ayant fait l'objet de tests de provenances ou d'analyses d'isoenzymes. La réalisation de cette synthèse pourrait nécessiter la détermination de la structure génétique de plusieurs espèces. Les priorités de recherche pourraient s'établir à partir des critères retenus par Lavoie (1992) et du statut commercial de l'espèce. Par exemple, une espèce à large distribution et abondante serait moins prioritaire qu'une autre limitée à une niche écologique particulière et observée moins fréquemment.
- la détermination du système génétique propre à chaque espèce prioritaire, afin de bien planifier et gérer la conservation *in situ*. Ces informations pourraient aussi servir à évaluer l'impact de différentes activités d'aménagement sur la variation génétique des populations dans les zones aménagées.
- le suivi des effets génétiques de l'aménagement des forêts par des analyses isoenzymatiques et des études morphologiques et physiologiques (Kitzmiller 1990).

Quelques ajustements à certaines pratiques actuelles permettraient d'améliorer l'efficacité des mesures de conservation de la variabilité génétique. Il s'agit de la gestion des peuplements sélectionnés pour la production de semences, de la récolte de semences, de la production de plants destinés au reboisement et des programmes d'amélioration génétique.

Les peuplements sélectionnés pour la production de semences ont tous une durée de vie limitée. Aucune directive n'existe pour que la régénération du site sera assurée de manière à ce que le nouveau peuplement soit génétiquement conforme à l'ancien. La gestion des peuplements sélectionnés selon le modèle des peuplements standards de Finlande (Hagman (1972) cité par Stern et Roche (1974)) servirait non seulement à la conservation génétique, mais permettrait aussi de disposer d'un réseau de peuplements de référence pour l'amélioration génétique des espèces. Il est important de noter que ce modèle n'exclut pas l'utilisation commerciale des peuplements.

La récolte de semences est planifiée selon les régions écologiques, en fonction des besoins en plants pour le reboisement et des capacités de production des vergers à graines. Éventuellement, toute la récolte destinée à la production de plants devrait provenir des vergers. On pourrait prévoir une récolte de semences destinée à la conservation génétique *ex situ*, planifiée en fonction de la structure génétique des espèces et selon un cycle de quelques années. Des récoltes à intervalles réguliers permettraient de dynamiser la banque de semences; les récoltes successives dans un même peuplement refléteraient l'évolution génétique de celui-ci.

La préservation de la variabilité génétique au cours du processus de domestication, préconisée par El Kassaby (1992), n'est pas encore une préoccupation des pépinières forestières du Québec. Cette lacune me semble très facile à combler. Des mesures préventives sont aisément applicables. Il serait possible d'évaluer la sensibilité de chaque espèce à l'appauvrissement génétique engendré par le processus de production de plants de reboisement.

Dans les programmes d'amélioration génétique, la principale lacune me semble être la faible duplication des tests de descendances. Si, face à l'incertitude engendrée par les changements climatiques, la meilleure stratégie consiste entre autres à sélectionner des «généralistes» (Ledig et Kitzmiller 1992), nous devrions établir nos tests de descendances à plus d'endroits et en placer quelques-uns à l'extérieur des zones d'utilisation prévues pour les semences.

Conclusion

Au Québec, le MFO préconise la régénération naturelle des forêts et l'aménagement des forêts est déjà orienté vers la conservation de la diversité biologique. Aucune stratégie de conservation de la diversité génétique d'espèces forestières n'a encore été mise au point mais le processus est amorcé. Un bilan sur l'état de la biodiversité en milieu forestier semble en voie d'être réalisé, bilan qui devrait tenir compte de la diversité génétique. Une classification des écosystèmes forestiers est disponible pour la majeure partie du Québec méridional. La législation nécessaire à la protection des espèces menacées ou vulnérables existe déjà et l'identification des espèces susceptibles de bénéficier de cette protection est en cours. Un réseau de zones protégées est en place et son expansion est prévue à court terme. Les programmes d'amélioration génétique et de reboisement ont eu pour conséquence la réalisation d'activités de conservation *in situ* et *ex situ* des ressources génétiques. Plusieurs éléments essentiels à la conservation de la biodiversité sont donc déjà disponibles. Des lacunes existent mais certaines peuvent facilement se corriger et à peu de frais. Il s'agit maintenant de procéder à l'évaluation complète des mesures existantes et d'élaborer une stratégie qui répondent à nos besoins en respectant les inévitables contraintes de toutes natures.

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Gene Conservation Activities at the Canadian Forest Service - Maritimes Region

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Abstract

There are a number of activities of the Canadian Forest Service, Maritimes Region that have some connection with gene conservation, although that is not the primary focus. A study was conducted recently to determine how well major forest types are represented in highly protected areas in the Acadian Forest Region. Within the Fundy Model Forest, a CFS - led Gap Analysis project seeks to identify those areas that should be protected but are currently receiving none. In addition, a study is underway to examine the effect of different disturbance types on the genetic diversity of several species. The CFS has its own small *in situ* conservation program in the form of several small ecological reserves at the Acadia Forest Experiment Station. This experiment station is also the site of a number of genetic and species tests that provide a limited degree of gene conservation. Work on embryogenesis and cryopreservation is progressing, and it is expected that the techniques will be applicable to gene conservation.

Résumé

Dans la Région des Maritimes, un certain nombre d'activités du Service canadien des forêts a un lien avec la conservation des ressources génétiques, mais ces activités n'ont pas la conservation pour but principal. Une étude récente visait à déterminer dans quelle mesure les principaux types forestiers étaient bien représentés dans les aires hautement protégées de la région forestière acadienne. Dans la Forêt modèle Fundy, le SCF dirige un projet d'analyse des carences visant à relever les secteurs qui devraient être protégés. Une autre étude permettra d'examiner l'effet des différents types de perturbation sur la diversité génétique de plusieurs essences. En outre, le Service canadien des forêts a son propre programme de conservation *in situ*, qui prend la forme de plusieurs petites réserves écologiques à la Station d'expérimentations forestières Acadia; cette station dispose d'un certain nombre de tests de descendances et de plantations comparatives essences, assurant ainsi une certaine protection du patrimoine génétique. Enfin, des travaux région sur l'embryogenèse et la cryopréservation sont en cours dans la région et devraient produire des techniques utiles à la conservation des ressources génétiques.

Status of Forest Genetic Resources *I*

A study was conducted recently to determine how well major forest types are represented in highly protected areas in the Acadian Forest Region, which covers most of the Maritime Provinces (Hundert and Loo, in prep.). Areas considered to be highly protected include national parks, ecological reserves, nature reserves, and some provincial parks. Priorities for new areas were assigned to forest types on the basis of number and size of those presently protected.

Using Loucks (1962), Rowe (1959), and Simmonds et al. (1984), sixteen major forest types in the region were identified (Fig. 1). Forest types are assumed to be associated with a given successional stage, following a predictable pattern. For example, a forest type consisting of a coniferous, deciduous mixture with a tolerant hardwood component would be expected to succeed to a late successional type of either tolerant hardwoods or tolerant mixedwood depending on the proportion and species of softwoods in the mixture.

Early successional types are very common in the Maritime forested landscape, so were not considered to have priority for establishment of new areas regardless of their representation in protected areas. All of the identified major forest types appeared at least once in an area of at least 50 hectares. This does not necessarily mean that all forest tree species in the Maritimes occur in at least one highly protected area; the forest types were assigned on the basis of dominant species, and minor species with highly localized or widely scattered low density distributions may not appear in any of the protected areas. It is unlikely that any of the areas includes bur oak, for example.

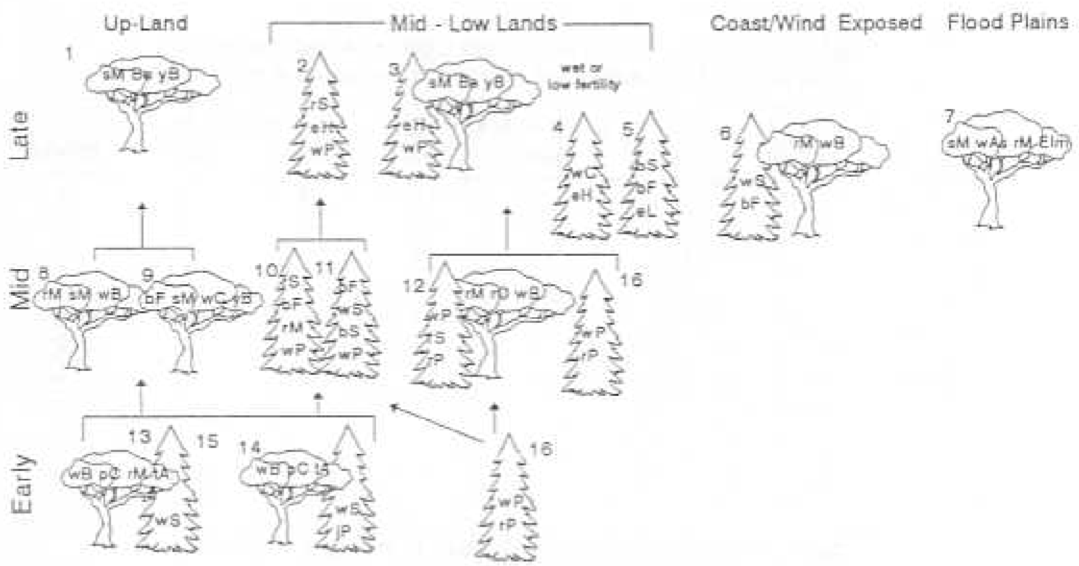

Figure 1. Successional patterns of major forest types in the Acadian Forest Region.

Highest priority was given the mixed late successional and cedar-hemlock forest types, each of which appear in only one highly protected natural area (Table 1). There are four protected areas in the region with mid-successional mixed forest types that would be expected to succeed to the late mixed type, but most are small. Both the coastal and flood plains types received a priority rating of 2. Both are in some danger of development and both are highly specific habitats, including species or populations of trees that are highly adapted to their respective habitats.

The CFS in the Maritimes has its own small *in situ* conservation program in the form of several small ecological reserves designated in the 1950s at the Acadia Forest Experiment Station near Fredericton. Unfortunately, there is no federal legislation for ecological reserves, so the sites have no official legal protection. Their locations are indicated both on maps and on the ground, however, and the whole area, by virtue of being an experiment station, has a degree of protection.

In total there are nine reserves, which have since been identified as International Biological Program sites, summing to 139 hectares. Species included in the reserves when they were inventoried almost 40 years ago are: red spruce, black spruce, and white spruce; white pine and red pine; red maple and sugar maple; tamarack; white cedar; yellow birch and white birch; black ash and white ash; balsam fir; and eastern hemlock. These ecological reserves are interesting from an ecological perspective because they were inventoried about 40 years ago and have been untouched since then within the boundaries of the reserves. The landscape around the reserves has been modified, however, including establishment of plantations of exotics and range-wide provenance trials of native species.

Ex situ Conservation

Provenance testing has received strong emphasis over the years in the Maritimes Region. In particular, the Acadia Forest Experiment Station has 130 test sites (some location duplicates) including species, provenance, progeny, and clonal trials (Table 2). Many of these tests consist entirely or in part of exotic species or exotic × native hybrids so do not contribute to gene conservation of native tree species.

The CFS has provenance tests for nine species (two exotics) scattered across the region as well (Table 3.). A total of 55 hectares of provenance tests have been planted in the Maritimes Region by the CFS at 37 locations. The ages of these plantations range from 8 to 34 years from planting. Most of these tests have been measured and, for many, results have been reported. At present, however, most of the provenance trials are considered inactive and are minimally maintained for the stated purpose of gene conservation.

Current and Planned Programs

Much of the forest genetics work at CFS-Maritimes Region is now concentrating on embryogenesis

Table 1. Areas of forest types occurring in highly protected natural areas in the Acadian Forest Region and priorities for protection of new areas

Type	% of Total	Total Area	# Sites > 50 ha Late	# Sites > 50 ha Total	# Sites > 500 ha Late	# Sites > 500 ha Total	Priority
Hardwood	23	22909	12	16	3	6	3
Softwood	27	27528	4	8	1	4	2
Mixed	13	13471	1	5	0	3	1
Ce-He	3	2826	1	1	1	1	1
Bs, Bf, El	11	11503	7	7	3	3	3
Coastal	1	1249	5	5	0	0	2
Flood Pl	1	964	2	2	1	1	1

Table 2. Summary of genetic tests at Acadia Forest Experiment Station

Type of Test	Number of Tests	Species
Species	6	Sitka spruce, black spruce, white spruce, Norway spruce, *P. shrenkiana*, *P. koyami*; native fir and exotic fir; tamarack, European larch and Japanese larch
Species Hybrids	37	Native and exotic spruces, native larch and exotic larch
Provenance	26	Red spruce, Norway spruce, Sitka, black spruce and white spruce; tamarack, European and Japanese larch; Douglas-fir; jack pine and red pine
Progeny	9	Norway spruce, white spruce, and black spruce; Japanese larch, tamarack, jack pine
Clonal	10	Spruce native and exotic hybrids, black spruce and white spruce, native larch and exotic hybrid larch, tamarack
Others	12	Red spruce, black spruce, and white spruce; balsam fir, red pine and jack pine

Table 3. Provenance tests established in the Maritime Region by the Canadian Forest Service

Species	No. Provenances	Area (ha)	No. Locations
Black spruce	99	10.0	10
White spruce	103 (3 expts.)	4.7	3
Red spruce	46 (2 expts.)	6.4	9
Norway spruce	100 (many expts.)	7.5	several
Red pine	40 (2 expts.)	6.8	3
Tamarack	75	12.0	8
Japanese larch	20	4.5	1
Yellow birch	45	1.0	1
Jack pine	73	2.2	2

and cryogenic storage of embryogenic cultures. Though the work on cryogenic storage is not presently focused on gene conservation, it is recognized as a useful tool for that purpose. Techniques developed in the tree improvement program with the purpose of storing clonal tissue until test results are available should also be applicable to gene conservation. A total of 500 white spruce clones have now been cryogenically stored as embrogenic cultures, and tests have shown that the cultures resume growth when removed from storage.

There are as-yet unfunded plans to make collections from commercially important tree species near their southern range limits in the New England states in anticipation of climate change. Some of the seed would be tested at various locations in the Maritime provinces for performance under local photoperiods, and the remainder would be stored for future use.

The projects underway in the Fundy Model Forest specifically relating to gene conservation, a gap analysis of the Fundy Model Forest and comparison of genetic diversity under different disturbance regimes, are part of the CFS program.

The genetic component of an Acadian forest restoration project at the Prince Edward Island National Park, which was initiated by the Canadian Parks Service, is being conducted at CFS-Maritimes. The objective of the genetic study is to determine, using isozyme analysis, whether there is adequate gene flow between P.E.I. and mainland populations of sugar maple, red oak, white pine, and white spruce to prevent differentiation of Island populations. Fifty individuals from each of 10 populations, including four Island and 10 mainland, of each of the four species have been sampled (Fig. 2) and isozyme analysis is underway.

Research Requirements, Species to Investigate, Issues

The issue of minimum viable populations and population viability analyses has received much attention for (large) faunal species, but very little has been done specifically on trees. There is a need for information on viable numbers for continued survival and adaptation of populations and species of trees, in designing protected areas, as well as in operational forest management plans.

Tree or shrub species with high "ecological" value, with fruit or berries providing important food for many bird and animal species, are generally insect-pollinated. The impact of fragmentation and species conversion of forests may be greater on these species than on wind pollinated species. Research on gene flow mechanisms and success rates, and genetic variability in this group of species, would allow recognition of potential problems.

Species in the Maritime Region potentially requiring attention include bur oak, which occurs in small isolated populations in the Saint John River Valley; ironwood and butternut, which are associated with rich hardwood forests and are both probably much less common now than in precolonial times; beech, which has been devastated by beech bark disease throughout most of the region although occasionally trees appear untouched by the disease; and hemlock, which is probably much less frequent than in precolonial times and has isolated, very old populations in parts of the region.

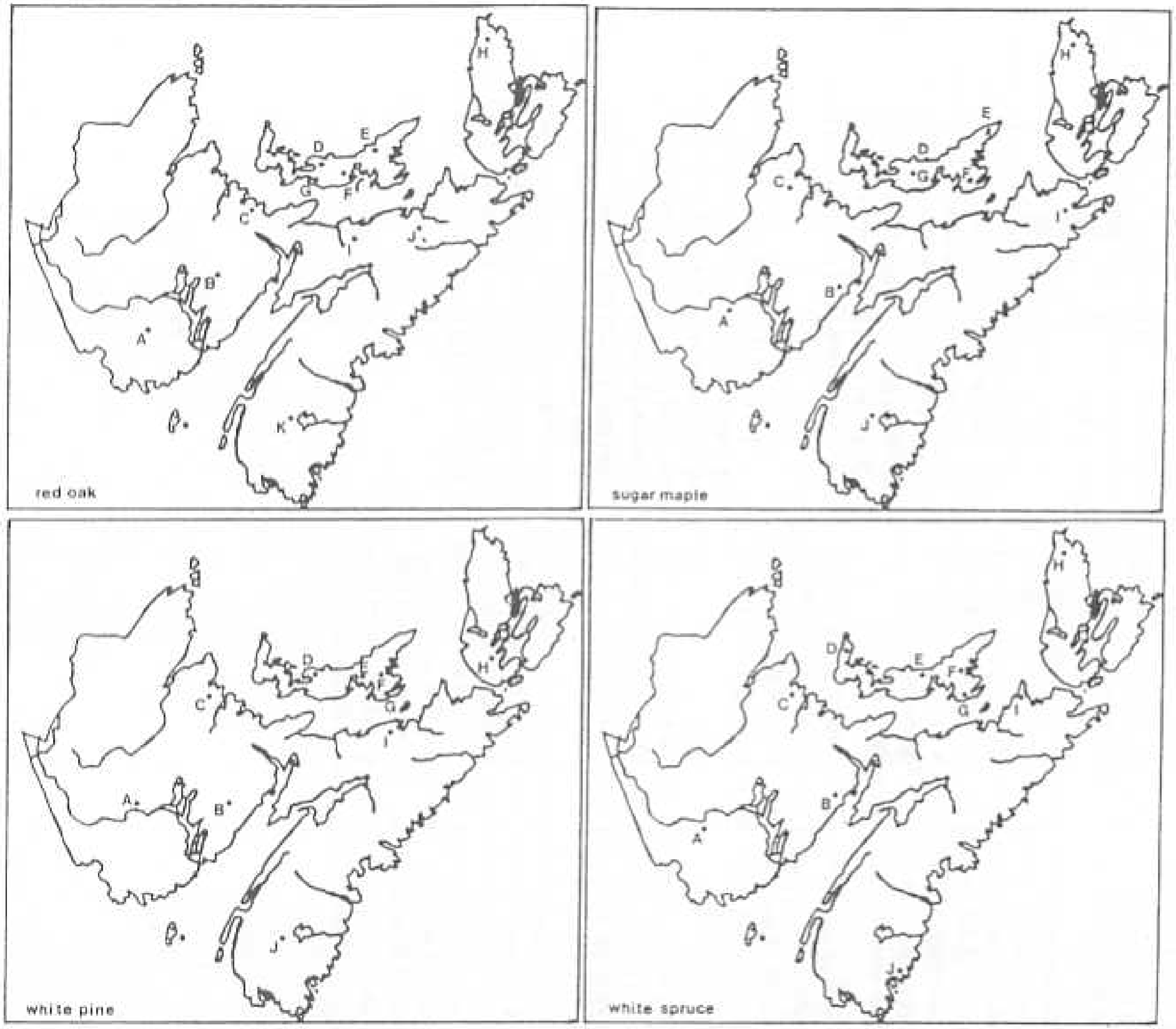

Figure 2. Distribution of sampled populations in Prince Edward Island, New Brunswick, and Nova Scotia.

Gene Conservation in New Brunswick

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Abstract

There is currently no explicit forest gene conservation strategy or program for the province of New Brunswick. As well, there are no tree species presently in the province that are on the rare or endangered list. Gene conservation is, however, only one purpose of protected areas and of managing for biodiversity. The parks group of the New Brunswick Provincial Recreation and Environment Branch are presently in the process of developing a new provincial parks plan which will increase its focus on conservation. The provincial ecological reserves program is in a state of change as well, though only a few small areas currently receive protection. Plans are being developed for a system of representative protected areas for the future. Tree improvement activities have focused on the four species most used for reforestation, and tests, seed orchards, and seed storage all provide some degree of gene conservation for these species.

Résumé

Il n'existe en ce moment aucune stratégie ni aucun programme précis de conservation des ressources génétiques forestières du Nouveau-Brunswick. De plus, aucune essence ne figure sur la liste des espèces rares ou menacées d'extinction. Pourtant, la conservation des ressources génétiques est un des buts de l'aménagement des aires protégées et de la gestion de la biodiversité. Les responsables des parcs, à la Direction de l'environnement et des loisirs de la province, sont en train d'élaborer un nouveau plan provincial des parcs qui accordera plus d'importance à la conservation. Le programme provincial de réserves écologiques est lui aussi en mutation, bien que seulement quelques aires de petite taille soient protégées pour le moment. Les plans d'un futur système d'aires représentatives sont en cours d'élaboration. Par ailleurs, les activités d'amélioration des arbres ont surtout porté sur les quatre essences les plus utilisées pour le reboisement, et la conservation des ressources génétiques de ces essences est assurée dans une certaine mesure par des plantations comparatives, des vergers à graines et des banques de semences.

Ecological Diversity of Forested Ecosystems in the Province

New Brunswick has a diverse array of forested ecosystems. Loucks (1962) identified six forest zones in New Brunswick which consisted of 16 species associations (Table 1). On the basis of the tree species associations, he divided the province into eight ecoregions which more or less followed the major geologic (Fig. 1) and climatic delineations in the province. Other significant early work on forest ecosystem classification in New Brunswick includes that of Rowe (1959). By his designation New Brunswick included parts of three Forest Regions: Acadian (most of the area), Great Lakes - St. Lawrence, and Boreal. The Forest Regions are divided into Sections, of which New Brunswick has eight, with boundaries similar to Louck's ecoregions though they are not exact.

There has been much recent work on ecological classification undertaken by the N.B. Department of Natural Resources and Energy. The province is in a good position to conduct a rigorous forest ecosystem classification because of the availability of detailed forest cover and soils data, digitized in the province-wide GIS, and extensive ground-truthed data. The present eco-classification system is depicted by Fig. 2. The heavy dark lines delineate ecoregions, based entirely on climate, intermediate lines delineate the 26 ecodistricts based on soils, topography, and climate, and ecosections are defined by the fine lines. Ecosections must be considered provisional at present; they are in the process of being described and boundaries are being validated. In the process of validating the boundaries, forest communities are being described for each ecosection using tree species, site richness, and moisture data.

An additional project recently undertaken by the ecological classification group at N.B. Department of Natural Resources and Energy (DNRE) aims to estimate the potential species and age class constitution of the forest landscape under natural disturbance regimes for comparison with the present situation. They plan to evaluate the effect of projected future harvesting cycles

Table 1. Forest zones and ecoregions with associated major tree species in New Brunswick (From Loucks 1962).

Zone	Ecoregion	Characteristic species	Associated climate
Sugar maple-Ash		sM, Be, wAs*	Warm, dry
	(1) St. John River	sM, Be, I, wAs, Bu, Ba	" "
Sugar maple-Hemlock-Pine		sM, Be, wP, eH, yB	Mod. warm, mod. dry
	(2) Restigouche-Bras d'Or	sM, Be, bF, yB, wP, wS	Mod. cool, mod. dry
	(3) Magaguadavic-Hillsborough	sM, Be, wP, eH, bF, rS	Mod. warm, mod. dry
Sugar maple-Yellow birch-Fir		sM, yB, bF, Be	Cool, moist
	(4) Maritime Uplands	sM, yB, bF, Be, wS, rS, rM	" "
Red spruce-Hemlock-Pine		rS, bF, eH, wP, rM	Mod. warm, mod. dry
	(5) Clyde River-Halifax	rS, wP, eH, rO, rM, bS, Be	Warm, dry
	(6) Maritime Lowlands	bF, rS, bS, eH, wP, rM, jP, wS, Be	Mod. cool, mod. dry
Spruce-Fir Coast		wS, bF, wB	Cool, wet
	(7) Fundy Bay	rS, bF, wB, wS, bS, yB, Mo	" "
	(8) Atlantic Shore	wS, bF, bS, wB	" "
Fir-Pine-Birch		bF, wB, wS, wP	Cold, moist
	(9) New Brunswick Highlands	bF, wB, wP, tA, wS, bS, jP, rS	Cold, mod. dry
	(10) Gaspé-Cape Breton	bF, wB, wS, bS	Cold, wet

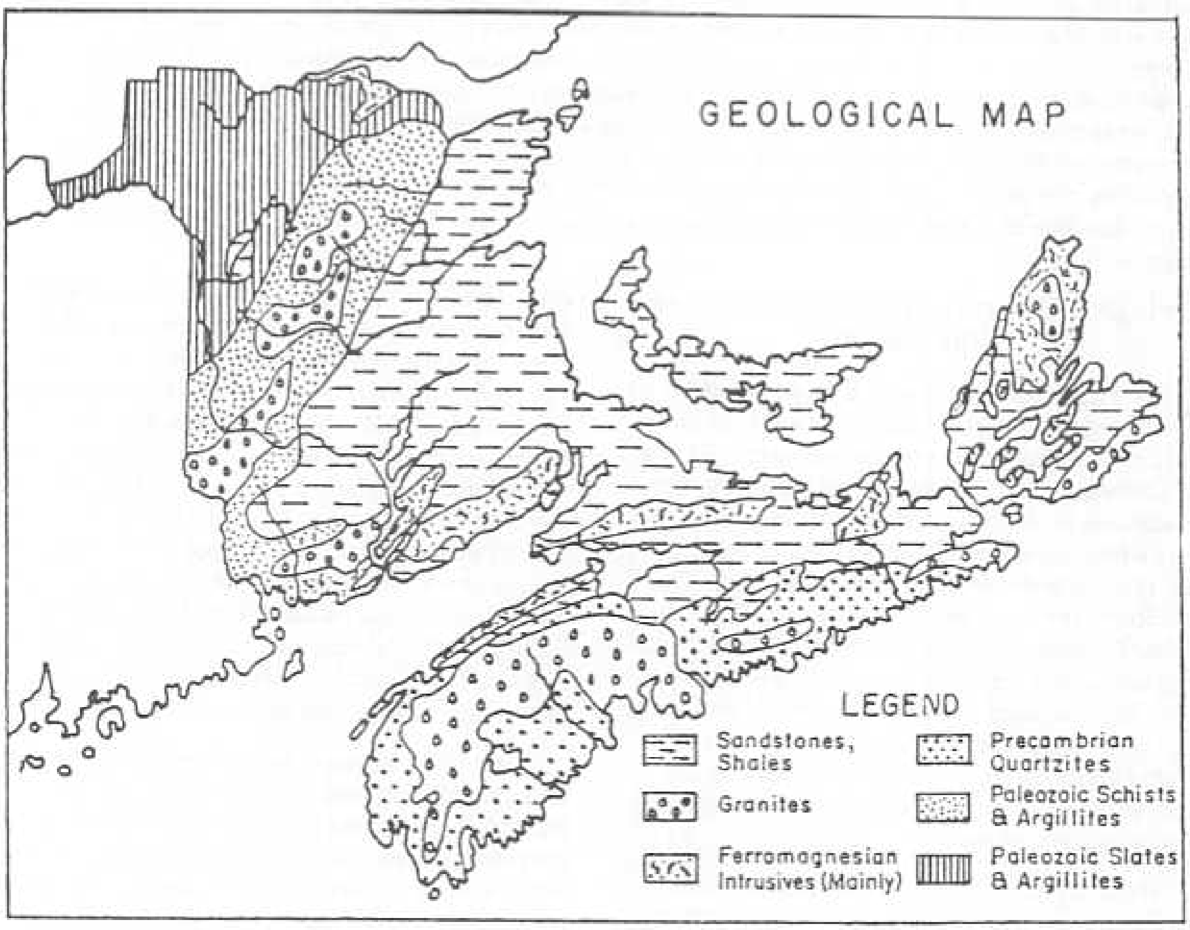

Figure 1. Geological map of the Maritime Provinces

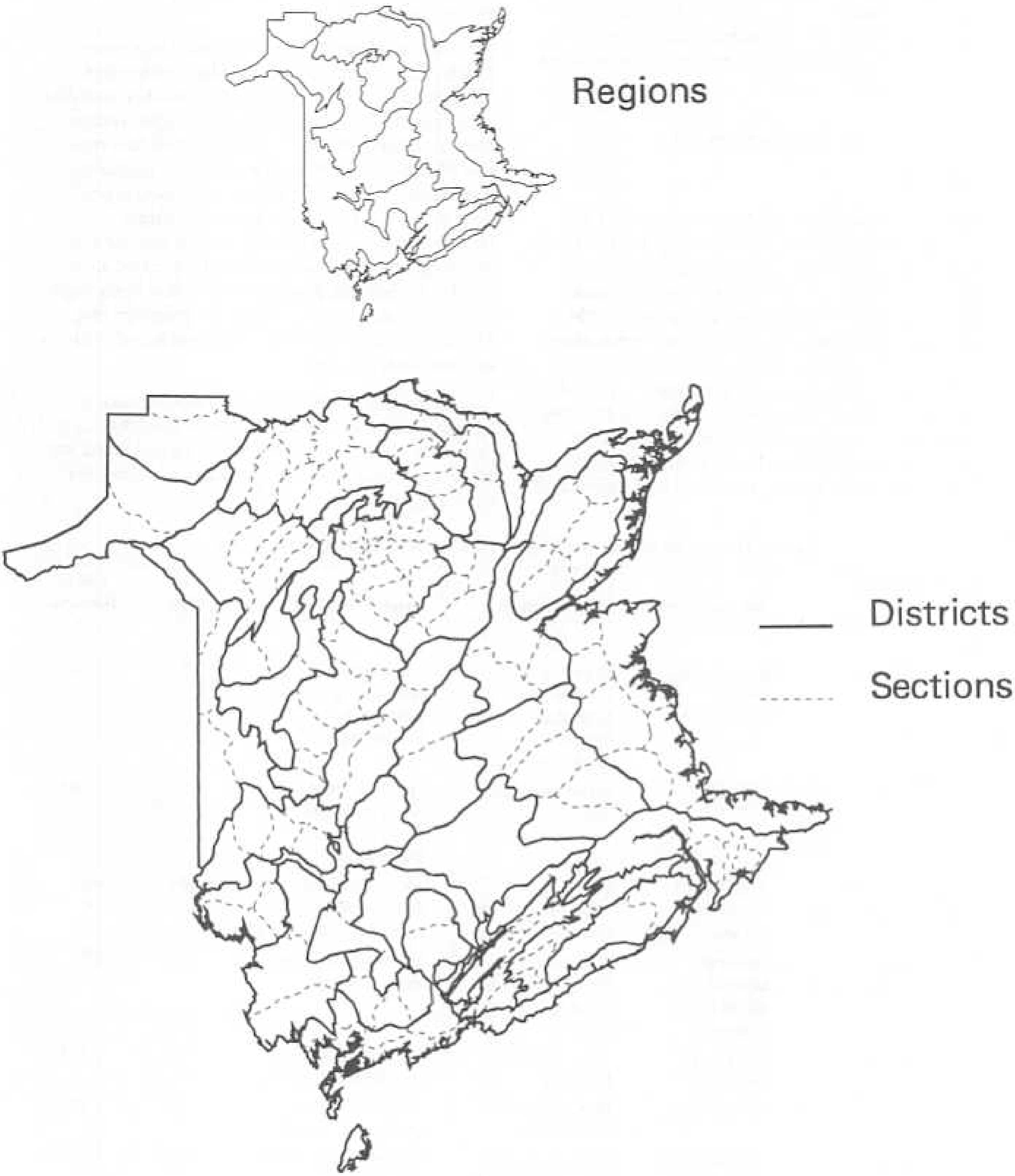

Figure 2. Draft Ecoregions (top), Ecodistricts (———) and Ecosections (- - - - - - - - -) of New Brunswick.

on the species and age class distributions across the forested landscape of the province to allow identification of deviations from that expected if the landscape dynamics were driven by natural disturbances. This process would be expected to flag tree species in danger of serious decline.

In Situ Conservation

National Parks

New Brunswick has two national parks, both primarily forested with a coastal component and both heavily impacted by logging and agriculture prior to their designation as national parks. Fundy National Park, with a total area of 20 590 hectares, is about 94% forested (Table 2). More than half of this consists of mid-successional mixedwood forest, including white birch, and yellow birch, red spruce, and balsam fir. About 40% of the forested area in the park is classified as disturbed forest, consisting primarily of a patchy remnant red spruce overstorey that survived a severe budworm infestation in the 70s with a well developed mixedwood understorey. About 5% of the forested area consists of tolerant hardwoods including sugar maple, beech, and yellow birch.

Kouchibouguac National Park has a total area of 23 880 hectares, with about 50% of the area forested (Table 3). Little of the area of the park could be classified as late successional forest, but the overall tree species diversity is high. About 65% of the forested area consists of softwood forest types with species including black spruce, white cedar, balsam fir, tamarack, jack pine, red spruce, white spruce, and white pine. Deciduous forest types cover 23% of the forested area including trembling aspen, red maple, speckled alder, grey birch, black ash, American elm, yellow birch, sugar maple, red oak, largetooth aspen, and mountain maple. About 6% of the forested area consists of mixed, mid-successional forest types.

There are no current plans for a new national park or a park extension in New Brunswick, though a Fundy Park extension has been discussed in the past and is still considered highly desirable by some nongovernment organizations.

Table 2. Forest types with dominant species composition in Fundy National Park

Major Vegetation Types	Dominant Trees	Plant Association	Lower Vegetation	# of Park	Area in Hectares
Forest:					
Hardwood Forest	sugar maple, beech, yellow birch	*Dryopterietum violetosum* (rich hardwoods - Birch - Maple) Maple-Beech-Birch	spinulose wood fern, *Viola* spp., bristly club moss, *Trillium* spp.	5.4	1002
	red maple	*Aceretum* (red maple stands)	spinulose wood fern, wood sorrel, wild lily of the valley, red maple shoots	0.1	8.5
Mixed Wood Forest - Hardwood Predominant	white birch, yellow birch, red spruce	*Dryopterietum* (mixed wood birch-spruce)	striped maple, fly honeysuckle, spinulose wood fern, wood sorrell	18.6	3641
Mixed Wood Forest - Softwood Predominant	red spruce, balsam fir, yellow birch, white birch	*Dryopterieto - Cornetum* (mixed wood spruce-fir-birch)	spinulose wood fern, asters, moss spp.	30.0	5875
Softwood Forest	red spruce, balsam fir	*Cornetum* (spruce - fir forest)	spinulose wood fern, bunchberry, moss spp.	0.7	50.8
	black spruce	*Piceetum* (black spruce bogs)	kalmia, blueberry, goldthread, *Sphagnum* spp.	1.7	80.0
Disturbed Forest	dead and dying spruce and fir (from budworm)	*Rubetum strigosae* (budworm-killed forest)	raspberry, balsam fir, red spruce, white birch and yellow birch regeneration; *Cladina* spp.	37.4	7166.3

Table 3. Forest community types with major tree species composition in Kouchibouguac National Park

Forest Community Types	Area (ha)	% forest land	% Park area
Coniferous			
1. Black spruce with *Nemopanthus aucronata* and sphagnum moss	1111	8.5	4.7
2. Black spruce with *Nemopanthus* sphagnum moss and *Pleurozium schreberi*	1619	12.4	6.8
3. White cedar and balsam fir	1815	13.9	7.6
4. White cedar and black spruce	957	7.3	4.0
5. Jack pine with sphagnum moss	132	1.0	0.6
6. Jack pine with *Pteridium aquilinua*	388	3.0	1.6
7. Eastern larch with *Sphagnum recurvua*	196	1.5	0.8
8. Eastern larch	130	1.0	0.5
9. Red spruce and balsam fir with *Pleurosium schreberi*	1946	14.9	8.2
10. White spruce	63	0.5	0.3
11. Balsam fir and white pine	85	0.7	0.4
12. White pine and white spruce	25	0.2	0.1
Subtotal	8467	64.9	35.5
Mixed Forests			
13. Balsam fir, white birch and white pine	53	0.4	0.2
14. Balsam fir, yellow birch and black ash	3	<0.1	<0.1
15. Balsam fir and yellow birch	253	1.9	1.1
16. Balsam fir and red maple	424	3.3	1.8
17. American elm	<1	<0.1	<0.1
18. American elm and balsam fir with *Carex intumescens*	<1	<0.1	<0.1
19. White birch and balsam fir	28	0.2	0.1
Subtotal	762	6.1	3.2

Forest Community Types	Area (ha)	% forest land	% Park area
Deciduous Forests			
20. Trembling aspen and speckled alder	99	0.8	0.4
21. Tembling aspen with *Pteridium aquilinua*	1023	7.8	4.3
22. Grey birch and sphagnum moss	555	4.3	2.3
23. Grey birch with *Pteridium aquilinua*	237	1.8	1.0
24. Grey birch and white pine	1	<0.1	<0.1
25. Red maple and black ash	<1	<0.1	<0.1
26. Red maple and white cedar	309	2.4	1.3
27. Red maple and grey birch with sphagnum moss	172	1.3	0.7
28. Red maple and american elm	29	0.2	0.1
29. Red maple and balsam fir	41	0.3	0.2
30. Red maple and yellow birch	10	0.1	<0.1
31. Red maple, sugar maple and beech	10	0.1	<0.1
32. Sugar maple and yellow birch	1	<0.1	<0.1
33. Speckled alder with carey and	147	1.1	0.6
Impatiens capensis	147	1.1	0.6
34. Yellow birch and red maple	1	<0.1	<0.1
35. Red oak	109	0.8	0.5
36. Largetooth aspen with *Pteridium aquilinua*	200	1.5	0.8
37. White birch with mountain maple	15	0.1	0.1
Subtotals	2960	23.0	12.9
Old Fields	846	6.5	3.6

Provincial Parks

In New Brunswick provincial parks fall under the jurisdiction of the DNRE. The parks group within the Recreation and Environment Branch are presently in the process of developing a new provincial parks system plan which they hope will become DNRE policy by early 1994, and will provide an underlying framework for the provincial parks.

At present the province has 43 provincial parks, 10 of which are considered to have conservation value in terms of representativeness of natural regions. The focus of the new systems planning process is on conservation to a much greater extent than previously, as evidenced by the stated goals of the provincial parks system. The goals are to 1) conserve and protect representative examples of natural landscapes, 2) to provide quality recreational and ecotourism opportunities, and 3) to promote environmental and natural awareness.

As part of the system planning process, eight provincial park classifications have been identified, as listed below.

1. Nature Reserve Parks - Areas which protect natural or natural/cultural features because of their special interest, unique or representative characteristics, and to the extent consistent with this, provide opportunities for education and public appreciation.

2. Wilderness Parks - Substantial areas of land where the forces of nature are permitted to function freely and where visitors travel by non-mechanized means and experience expansive solitude, challenge, and personal integration with nature.

3. Natural Environment Parks - Incorporate outstanding recreational landscapes with representative natural features (which may include historical resources) to provide high quality recreational and educational experiences.

4. Linear waterway - including public access and having protected status.
5. Recreational Parks - Highly serviced parks capable of supporting a variety of outdoor recreation opportunities for large numbers of visitors in an attractive outdoor setting.
6. Campground Parks - Provide overnight accommodations ranging from rustic to fully serviced (water, electricity, sewage) camping sites in a natural outdoor environment.
7. Day-Use Areas - Provide recreational, historical, interpretive/educational points of interest for residents and non-residents (beaches, picnic areas, heritage sites)
8. Roadside Rest Areas - Provide scenic/interpretive rest areas to the travelling public, while also including an element of safety.

At present the following exist: one provincial park — classified as a nature reserve park; two natural environment parks; nine recreation parks; 18 campground parks; eight day-use areas; and five roadside rest areas. There are no wilderness park's or linear parks.

Ecological Reserves

The provincial ecological reserves program is also in a state of substantial change. Presently there are three small ecological reserves, with five more awaiting proclamation (Table 4). Many other areas have been proposed as ecological reserves (Fig. 3) and those on provincial crown land are identified in management plans, conferring a limited degree of protection. Most of these areas were identified in the early 70s as IBP sites, many are very small, and some may no longer contain the feature of interest.

The Ecological Reserves program is now taking a systems approach, attempting to ensure that major ecosystems in the province will be adequately represented by a network of protected areas. This system may not include many of the previously identified sites if they are judged to be inadequate in size or other criteria. A Natural Areas System Plan should be completed in early 1994. The Plan will establish evaluation criteria, particularly pertaining to representivity, in addition to elaborating on the recently approved N.B. policy on protected areas.

At present, the ecological reserves project is beginning to identify study areas which are representative of recurrent land form patterns, hopefully also representative of major ecosystems. The areas are intended to have proportional representivity, reflecting natural disturbance patterns to the extent possible, and will be undeveloped to the extent possible. Representivity will be at the ecodistrict level, but the intention is to capture the diversity of the sections included within the district boundaries.

Other Designations

Approximately 20% of the productive forest land in New Brunswick has been given a form of reserve status under provincial legislation. This includes watercourse buffers, deer wintering areas, and mature coniferous forest habitat. Timber harvest is not absolutely prohibited in any of these areas, but they all receive special treatment with the goal of providing clean water, and a continuous supply of deer wintering and pine martin habitat. The reserved areas will very likely move to new locations as forest succession changes the nature of the areas and as new areas become suitable habitat.

Genetic Conservation Strategies, Rare or Endangered Tree Species

There is currently no explicit gene conservation strategy for the province of New Brunswick. In addition, there are no tree species or populations listed as rare or as endangered.

Table 4. Areas and species represented in New Brunswick's Ecological Reserves

Name	Area (ha)	Major Tree Species
Cranberry Lake	47	rO
Phillipstown	8	wS
Oak Mountain	100	sM, yB, Be
Loch Alva	38	rS, yB, rM, bF
Glasier Lake	72	bF, tA, sM, wB
McCoy Brook	45	sM, Be, yB
Blue Mountain	60	rP, rS, bS, bF
South Keswick River	54	bS, Bf

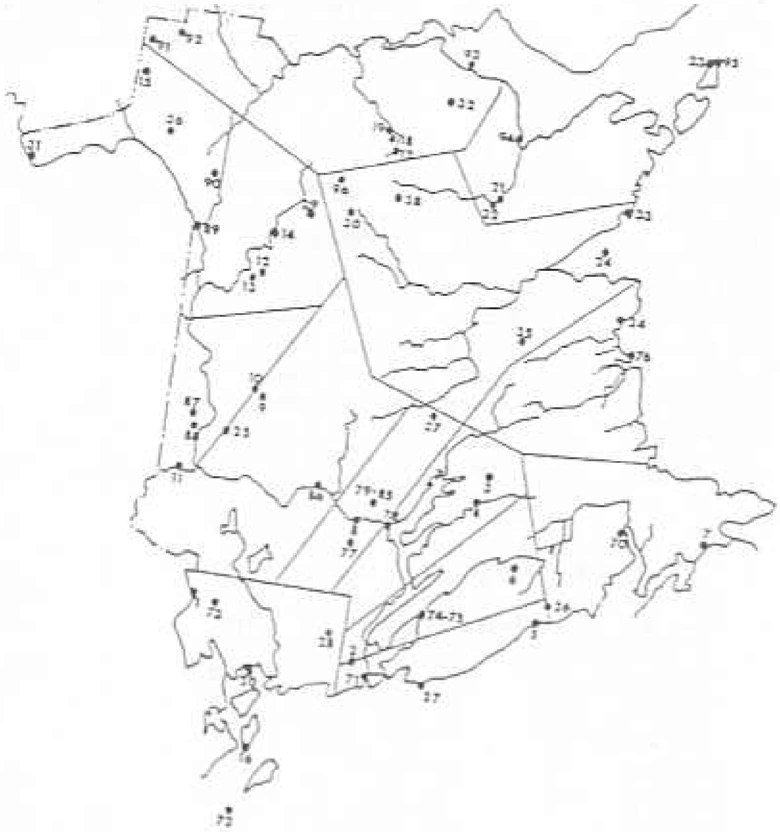

Figure 3. Locations of exisitng and proposed ecological reserves in New Brunswick.

Tree Improvement Programs

Tree improvement activities have been focused on the four major reforestation species, black spruce, jack pine, white spruce, and tamarack. There is also a limited amount of work on balsam fir, Norway spruce, and white pine. Although gene conservation has not been an explicit goal of the provincial tree improvement program, clone banks, seed orchards, genetic test plantations and operational seed storage all contribute to *de facto* gene conservation, at least for those species that have been of commercial importance.

Over the years there have been a total of 44 selected stands for each of two species, black spruce and jack pine, reserved for seed collection. Some of the stands have been tested in "stand tests". Most of these stands have now been cut and the sites have been planted with seed from the original stand. Two reserved stands remain: a black spruce stand of 111 ha, and a jack pine stand, 160 ha. in size. New stands are not being selected.

The province has a total of 134.5 hectares of seed orchards for the four major reforestation species (Table 5). This total includes seed orchards established by forest industry with the exception of the orchards on J.D. Irving Ltd. land. Most of the black spruce and jack pine seed orchards are of seedling origin, including 1240 half-sib families between the two species. Because of the high level of genetic diversity within half-sib families, these orchards contain a greater array of genetic material than do clonal orchards of similar size.

About 1880 clones have been established in clonal archives. In addition to the four species most important for reforestation, balsam fir, and Norway spruce are also represented in the clone banks (Table 6). The black spruce and jack pine entries are second generation selections. The province has established 17 stand tests, testing jack pine, black spruce and Ottawa Valley white spruce. In addition, there are 116 family tests for jack pine and black spruce and a total of 51 jack pine, balsam fir, tamarack, and white spruce progeny tests. Recently

15 realized gain tests have been established for jack pine, black spruce, and white spruce.

The province operates a seed bank for commercial planting, with 18 species presently in storage (Table 7). Only two of the species in storage are deciduous and seven of the conifers are exotic species.

Table 5. New Brunswick seed orchards by species, type, number of entries and size

Species	Type	No. of Entries	Area (ha)
Black spruce	seedling	800 families	68
Black spruce	clonal	35 clones	3
Jack pine	seedling	440 families	29
Jack pine	clonal	40 clones	3
White spruce	seedling	58 families	8
White spruce	clonal	122 clones	10.5
Tamarack	clonal	157 clones	13

Table 6. Clonal Archives in New Brunswick

Species	Number of Clones	Area
White spruce	415	13,000 m^2
Tamarack	270	9,400 m^2
Black spruce	157	300 m^2
Jack pine	189	400 m^2
Balsam fir	48	260 m^2
Spruce/larch	>600	1.2 ha
Norway spruce	200	0.2 ha

Table 7. Forest tree seed stored by the New Brunswick Department of Natural Resources and Energy

Species	Number of Lots	Weight (kg)
black spruce	53	404.2
Norway spruce	19	152.9
red spruce	7	46.8
white spruce	35	284.7
Austrian pine	2	12.6
jack pine	39	370.0
loblolly pine	1	3.8
mugo pine	1	1.7
red pine	6	58.8
Scots pine	4	14.6
white pine	20	172.1
European larch	1	1.7
Japanese larch	1	7.7
tamarack	16	56.9
balsam fir	50	841.8
eastern cedar	4	6.0
ash	4	7.3
yellow birch	2	2.1

Tree Improvement and Consideration of Forest Genetic Resources on Lands Managed by J.D. Irving, Limited

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Abstract

J.D. Irving, Limited is a diversified forest products company which manages 1.0 and 0.9 million hectares of Crown License and freehold land respectively across New Brunswick, Nova Scotia, and the State of Maine. These lands cross five ecoregions mainly in the Acadian forest type. The management of forest genetic resources for commercially important species are discussed in relation to tree improvement efforts. Specific aspects addressed are selection and *ex situ* conservation, seed production, and deployment as well as long-term management of diversity.

Résumé

La firme J.D. Irving, Limited est une entreprise forestière qui aménage 0,9 million d'hectares de terre franche et qui détient des permis d'exploitation d'un million d'hectares de terres gouvernementales au Nouveau-Brunswick, en Nouvelle-Écosse et dans l'État du Maine. Ces terres chevauchent cinq écorégions appartenant principalement à la région forestière acadienne. L'aménagement des ressources génétiques des essences forestières qui ont une valeur économique est examiné dans le contexte des travaux d'amélioration générale des arbres forestiers. Dans cet article, il est spécifiquement question de la sélection et de la protection *ex situ* de la production et de l'utilisation des semences ainsi que de la gestion à long terme de la diversité.

Introduction

J.D. Irving, Limited is a diversified forest products company with headquarters in Saint John, New Brunswick. The company produces pulp, newsprint and related products, tissues and paper towel as well as lumber (softwood and hardwood) and high-quality veneers. Forest management is conducted on approximately 900 000 ha of privately owned land (freehold) ranging from northern Maine through New Brunswick to western Nova Scotia and 1 000 000 ha of J.D. Irving Crown License land in New Brunswick. These lands are mainly part of the Acadian Forest Region (Rowe, 1959) and are located across five ecoregions described by Loucks (1962) for the Maritimes. These include Maritime Uplands through Maritime Lowlands and Coast Zones. Stand types range from Spruce-Fir, Mixed-Woods, Tolerant Hardwoods (maples, yellow birch and beech) and Intolerant Hardwoods (birches, maples, poplar and aspens). Stand composition in many areas, particularly in the southern half of New Brunswick, has been greatly influenced by the long history of settlement and forest use from the 18th century to present. Other major factors that have shaped the present forests are spruce budworm epidemics and forest fires.

Harvesting is conducted primarily using even-aged management techniques such as clear-cutting (less than 60 ha) and multiple-pass entries. In some forest types, selection harvesting is used, such as in some white pine and tolerant hardwood or mixed-wood stands. On average, 16 000 ha of freehold and 11 000 ha of J.D. Irving Crown License land is harvested annually. J.D. Irving, Limited has been involved in reforestation since the late 1950s and since that time, approximately 300 million trees have been grown in Irving nurseries and planted on freehold land. Within several months of harvest, a decision is made whether to site prepare and plant or whether to accept natural regeneration. On average, 15 million trees are planted on freehold land annually with an additional 5 million on Crown land. The five main species planted are black spruce, white spruce, Norway spruce, red spruce, and jack pine as well as several minor species including white pine, red pine, eastern larch, and birches. Stand tending is conducted as required including herbicide application and pre-commercial thinning to insure plantations and natural regeneration areas are 'free to grow'.

Selection and *Ex Situ* Conservation

The J.D. Irving, Limited tree improvement program began in 1980 and initially included four species; black spruce, white spruce, jack pine, and eastern larch. Since that time, Norway spruce and red spruce have also been included. The other species planted are not used on a large enough scale to economically justify a full-scale breeding program however seed is collected from high-quality natural stands. The company is a member of two regional tree improvement cooperatives which cover two breeding zones (Fowler 1986); the New Brunswick Tree Improvement Council (NBTIC) and the Nova Scotia Tree Improvement Working Group (NSTIWG). Breeding strategies are described by Fowler (1986). Plans generally call for family testing and seedling seed orchards for jack pine and black spruce in contrast to white spruce, red spruce, Norway spruce, and larch where clonal seed orchards and complementary mating schemes are employed (polycrosses to determine general combining ability and pair-matings for second generation selection). Programs are at the stage of selecting and breeding the second generation populations for black spruce and jack pine. For white spruce, red spruce, and eastern larch, first generation breeding and test establishment is nearing completion. First generation breeding has only just started for Norway spruce. In some cases, J.D. Irving, Limited has developed independent programs in addition such as clonal seed orchards for jack pine and black spruce and a diallel testing scheme for white spruce. The two cooperatives have been effective in the selection of a first generation breeding population from across the area. This is illustrated in Figure 1 (Simpson 1992) which shows the distribution of over 1100 black spruce selections in New Brunswick. The involvement with cooperative programs gives the company access to in excess of 4500 families or clones which are broken down by species in Table 1 (Nitschke 1990, Simpson 1992).

Ex situ conservation is practised at three different levels by J.D. Irving, Limited. These levels are seed banks, intensively managed clone banks or seed orchards and field plantings including species tests, provenance tests and progeny or family tests. Efforts in these different areas are described as follows:

Seed Banks: The company operates seed extraction, storage and testing facilities. Seed is stored at approximately -10°C. A total of 38 tree species are currently being stored and these represent 658 seedlots covering a broad range of provenances. Total seed storage exceeds 1000 kg. Each seedlot bears a unique storage number which is maintained throughout nursery production, planting and transfer of maps onto the Geographic Information System. When a seedlot is processed for operational seedling production, a sample (usually 100 gm) is removed for long-term storage where it is reserved for research purposes only. Germination testing of operational seedlots is conducted on a three year cycle. An additional seed bank is maintained for seed originating from controlled crosses used in the tree improvement program. A total of 361 seedlots from five species are presently in storage.

Clone Banks and Orchards: The company maintains clone banks for the main species considered in the tree improvement program. In some cases, for instance red spruce, the clonal seed orchard also functions as a clone bank. The grafted trees are established on farm field sites and intensively managed until the trees are well established. A minimum of two ramets per clone are planted and the clones are replicated on at least two sites, either in a clonal seed orchard or in a provincial government clone bank. The clone banks are perceived by the company to be long-term resources to be preserved and not replaced with successive generations of tree improvement programs. There are currently over 1300 clones preserved in this manner and the number increases annually as new second generation selections are made.

Field Tests: Test plantations of various types, in addition to providing information to guide reforestation efforts, also serve as a repository of genetic resources and may be termed *ex situ* conservation areas (Boyle 1992). Tests are generally replicated over several sites to assess genotype-environment interactions but this practise also has security implications. Replication acts an excellent hedge against risks from fire, insects, or other disasters. Tests established by J.D. Irving, Limited fall into two broad categories, these being family/progeny tests and species or provenance tests. Family and various types of control-pollinated progeny tests are planted to provide information and the opportunity for advanced generation selection, mainly within the breeding zone for the species with intensive tree improvement programs. To date, the company has established approximately 112 ha of such tests. The species and provenance tests function to provide long-term information on how non-native species or non-local provenances perform in our environments. These tests may be of even greater value if changes in the environment occur (Ledig and Kitzmiller 1992). The company has established approximately 100 ha of tests that fit into this category, often in cooperation with other agencies such as the Canadian Forest Service. This is an ongoing effort, for example, in 1991 a series of stand collections of red spruce were planted in New Brunswick representing sources from a

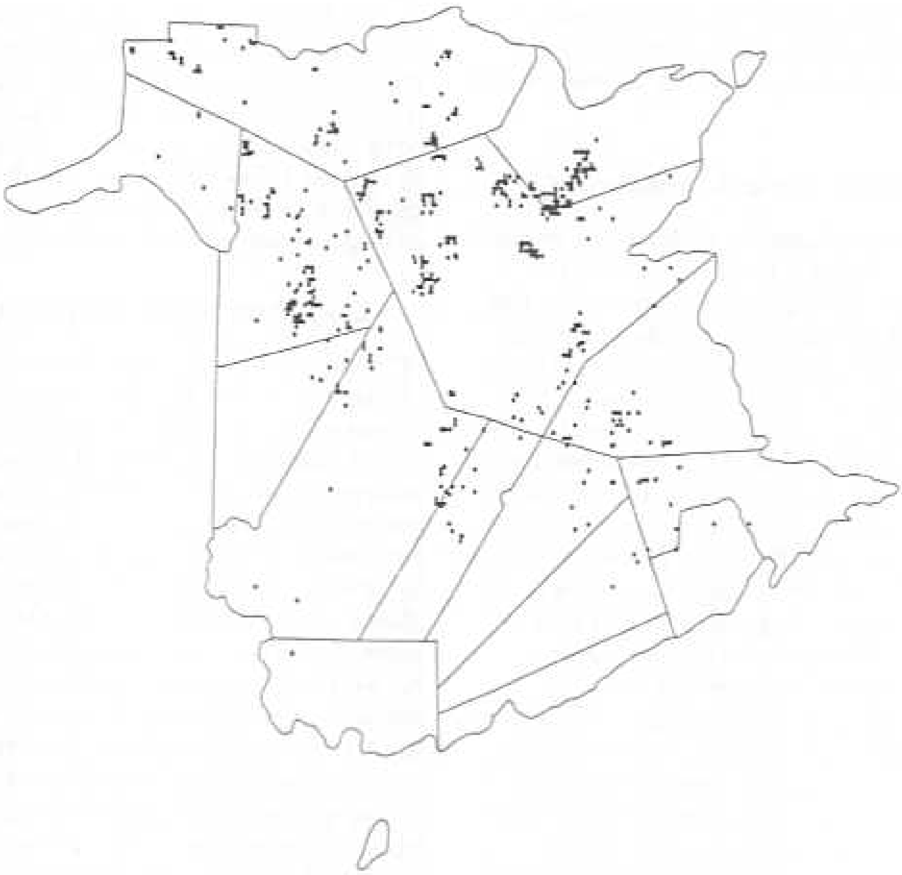

Figure 1. Location of black spruce plus trees in New Brunswick. One dot may represent several trees (total of 1144 selections) (from Simpson 1992).

Table 1. Number of plus tree selections by species for cooperative programs in New Brunswick and Nova Scotia[1]

	Number of Selections		
Species	New Brunswick (NBTIC)	Nova Scotia (NSTIWG)	Other[2]
Black Spruce	1144	791	
White Spruce	341	509	
Red Spruce		586	
Norway Spruce			250
Jack Pine	806	49	
Eastern Larch	220		
White Pine		57	
Total	2511	1992	250

[1] from Nitschke (1990) for NSTIWG and Simpson (1992) for NBTIC.
[2] Canadian Forest Service provenance trials.

transect of the Province of Nova Scotia. Seed from 50 sources for an additional provenance test of Norway spruce has recently been assembled for establishment in 1994.

Seed Production and Deployment

The establishment of seedling seed orchards for black spruce and jack pine began in 1979. Planting of clonal orchards of white spruce, black spruce, jack pine and eastern larch started in 1983, with Norway spruce and red spruce following in 1986 and 1992 respectively. A total of 33 ha of seedling seed orchards and 61 ha of first generation clonal orchards were completed by 1991 and 20 ha of second generation black spruce and jack pine orchards are nearing completion. All seed used for the first four species is supplied by the seed orchards. The clonal orchards typically contain between 50 and 80 clones with a 50% roguing intensity being anticipated. The seedling seed orchards generally contain 100 to 140 families with the intention being to remove approximately 70% of these based on family test results. Deviation from panmictic mating is one factor which influences the genetic gain captured in orchard seed and also has implications in the genetic diversity of orchard seed (El-Kassaby 1992). In our situation, this results mainly from variation in fecundity among clones. Recent advances in the control of flower production through induction treatments with gibberellic acid 4/7 (GA4/7) can greatly ameliorate this problem (Greenwood et al. 1993). This is illustrated in Table 2 for black spruce. By using growth acceleration and flower induction, 94% of clones bore female flowers and 81% of clones bore male flowers three years after grafting. The development of stem injection procedures instead of foliar sprays of GA4/7 has significantly reduced the cost of application from $2.70 to $0.40 per tree for the chemical required with additional labour and equipment reductions (Greenwood et al 1993). This makes it feasible to use flower induction in seed orchards on poor flowering clones to achieve better balance in the reproductive output of clones and increase the effective population size.

Table 2. The average number of female and male flowers per tree and percentage of clones flowering in 1992 for second generation black spruce selections grafted in 1989[1]

	Female	Male
Average number of flowers per tree	45.6	22.4
Percentage of clones flowering	94% (15/16)	81% (13/16)

Biochemical markers such as allozymes may be used to assess the genetic diversity of natural populations compared to selected populations in seed orchards (El-Kassaby 1992, Hamrick 1992). Research is currently being undertaken by Dr. J. Loo to sample heterozygosity levels and allele frequencies from all first and second generation black spruce clones in the company's seed orchards in comparison to natural stands.

Long-Term Management of Diversity

The conservation of genetic resources figures prominently in the development of long-term breeding strategies. Maintaining broad genetic diversity will allow for further improvement of reforestation stock while providing the flexibility to respond to potentially changing conditions in the environment or product goals. Fowler (1986) provided a sound basis for breeding strategies for the cooperative programs in the Maritimes and recognized that these would be adjusted as new information and technologies are implemented. In general, sublining (vanBuijtenen and Lowe 1979) will be employed for most species, however, it is still uncertain how these will be designed. As more test data becomes available, decisions will have to be made concerning whether to breed for broad adaptability or whether to develop sets of sublines for specific areas within the breeding zones (Namkoong 1991). More sophisticated production strategies employing clonal propagation are being developed for some species (Park et al. 1993) which will better accommodate the production of specially adapted planting stock than conventional seed orchards.

Other developments that will be considered with respect to genetic diversity are the use of elite populations and assortative mating schemes within sublines (Williams 1992, Weir and Todd 1993). Simulation models are being developed by Dr. T. Mullin under a contract through the Canada/Nova Scotia Forest Development Agreement to examine genetic gain and diversity implications of some of these strategies. This type of modelling exercise will be useful to J.D. Irving, Limited as the knowledge of genetic parameters for our species expands.

Summary

J.D. Irving, Limited has long considered forest genetic resources in its reforestation programs and land management goals. This is illustrated by the diversity of species and seed sources utilized as well as the level of commitment to tree improvement programs. The company has been a founding partner in the Fundy Model

Forest under Canada's Green Plan. Several projects in the Model Forest directly address issues of conserving forest genetic resources including gap analysis. Other applied research is being conducted to answer questions concerning hardwood management and mixed species management in plantations. The Model Forest will provide valuable information to assist in development of better landscape management regimes to encompass the many demands placed on the forest.

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Forest Gene Conservation in Newfoundland and Labrador

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Abstract

The flora and fauna of the island of Newfoundland may have a potential for genetic drift because of the island's geographical isolation. The stresses of a harsh and diverse climate also present unique natural selection pressures. As a result, the conservation of Newfoundland's genetic resources may be of special significance within Canada. The current status of native tree species and the conservation efforts for protecting natural populations, both *in situ* and through *ex situ* genetic archives, are reviewed. White pine (*Pinus strobus*), red pine (*P. resinosa*), and black ash (*Fraxinus nigra*) are the native tree species most vulnerable to local extinction. The need for an adequate network of protected areas to maintain each of the rare and vulnerable native species as viable populations is emphasized as the most reliable means of forest gene conservation in Newfoundland and Labrador.

Résumé

La flore et la faune de l'île de Terre-Neuve sont exposées à la dérive génétique en raison de l'isolement géographique de l'île. Le climat rigoureux et varié crée égalment des pressions particulières sur le plan de la sélection naturelle. En conséquence, la conservation des ressource génétiques de Terre-Neuve peut revêtir une importance particulière au Canada. L'auteur examine la situation des espèces indigènes d'arbres et les efforts de conservation de populations naturelles *in situ* ainsi qu'*ex situ* dans des archives génétiques. Le pin blanc (*Pinus strobus*), le pin rouge (*Pinus resinosa*) et le frêne noir (*Fraxinus nigra*) sont les essences indigènes les plus menacées d'extinction localement. Un réseau adéquat de zones protégées permettant de conserver chacune des espèces indigènes rares et vulnérables est préconisé comme moyen le plus sûr de conserver les ressources génétiques forestières de Terre-Neuve et du Labrador.

Introduction

Forest tree gene pools in Newfoundland and Labrador may be of special interest for gene conservation because of their geographic isolation from ancestral mainland populations. The combined effects of genetic isolation, inbreeding, and genetic drift within small populations, and the special natural selection pressures related to climate, may have produced unique forms of adaptive genetic variation. It is assumed that most of the forest tree populations were reintroduced to the island following retreat of the Wisconsin Glaciation around 8000 years B.P. (Macpherson 1981).

Alternatively, Newfoundland gene pools may not have been geographically isolated from ancestral mainland populations long enough to have undergone significant evolutionary (genetic) changes (Nei et al. 1975). Comparative molecular genetic studies of Newfoundland and mainland populations of white pine (*Pinus strobus*), red pine (*P. resinosa*), and black ash (*Fraxinus nigra*) are in progress to characterize the genetic status of these disjunct, island populations. These studies will determine if the island populations are of special genetic significance. Nevertheless, recent efforts have been made to provide both *in situ* and *ex situ* protection for these rare tree species through the establishment of ecological reserves and seed orchard/gene pool reserves, respectively.

Forest Regions and Ecoregions

The island of Newfoundland falls entirely within the Boreal Forest Region of Canada (Rowe 1972). The northcentral and western parts of the island are predominantly forested, whereas the eastern and southeastern parts consist of rocky barrens with scattered patches of coniferous forest. The western length of the island is dominated by the Long Range Mountains which comprise large areas of alpine barrens and open, lichen woodlands.

Despite a land mass of only 106 000 km^2, Newfoundland has a varied geology and climate (Banfield 1983, Rogerson 1983). Climatic variability is caused by the confluence of the cold Labrador Current and the warm Gulf Stream off the northeast coast. Based on vegetation, soil types and regional climate, Damman (1983) recognized nine ecoregions in insular Newfoundland.

The Western Newfoundland Ecoregion is dominated by balsam fir forests and contains the northern limit of yellow birch and black ash on the island. This ecoregion also contains a significant remnant of the island's white pine. The forest community of central Newfoundland has evolved in response to a recurring fire cycle of between 200 and 300 years and is dominated by black spruce. Natural island populations of red pine are restricted entirely to the Central Newfoundland Ecoregion (Roberts 1985) because of their ecological dependence on fire. It is here that white pine, red pine, red maple (*Acer rubrum*), and trembling aspen (*Populus tremuloides*) reach their northern limits on the island.

The white pine population of central and western Newfoundland was decimated by harvesting for the export trade at the turn of the century (Kennedy et al. 1955, Munro 1978) and subsequently, by the introduction of the white pine blister rust *Cronartium ribicola* (Mosseler and Warren 1992, Carroll 1990). Forest management policies such as fire suppression, harvesting of red pine without replacement, a preoccupation with management of spruce and fir for pulpwood production, together with inadequate protection of existing populations has resulted in serious declines in both of the native pines.

With the exception of an area of productive forest around Lake Melville and parts of the southeast coast, Labrador is dominated by scattered patches of open, lichen woodland interspersed throughout a rocky barrenland. The interior forest is dominated by black spruce (*Picea mariana*), while balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) dominate in coastal areas. Tamarack (*Larix laricina*) and white birch (*Betula papyrifera*) form a minor component. Much of Labrador forms part of the transition between subarctic forest and tundra that stretches across northern Canada (Rowe 1972). Meades (1989) recognized 10 ecoregions in Labrador.

Status of Native Tree Species

Many plants reach their northern or southern limits in Newfoundland and Labrador. There are 1406 known species of vascular plants native to Newfoundland; of these, 271 have been listed as being rare (Bouchard et al. 1991). The following tree species are native to insular Newfoundland and are listed in order of increasing rarity: *Picea mariana* (Mill.) B.S.P., *Abies balsamea* (L.) Mill., *Picea glauca* (Moench) Voss, *Larix laricina* (Du Roi) K. Koch, *Betula papyrifera* Marsh., *Populus tremuloides* Michx., *Acer rubrum* L., *Betula alleghaniensis* Britton, *Populus balsamifera* L., *Pinus strobus* L., *Pinus resinosa* Ait., and *Fraxinus nigra* Marsh. In the province of Newfoundland jack pine (*Pinus banksiana* Lamb.) is found only as a small population near the border between Quebec and Labrador; this represents one of the northernmost populations of jack pine in eastern North America. The following woody shrubs native to insular Newfoundland are listed in order of increasing rarity: *Salix* spp., *Prunus* spp., *Juniperus communis*, *Amelanchier* spp., *Sorbus* spp., *Acer spicatum*, *Taxus canadensis*, and *Cornus alternifolia*.

The rare tree species that reach their eastern and northern limits in Newfoundland, such as red pine, white pine, and black ash may have undergone significant population declines as a result of the climatic cooling that occurred after the thermal peak of the hypsithermal period 4000 to 6000 years B.P. (MacPherson 1981). However, anecdotal evidence and historical records from sawmilling activities also indicate that population declines in red pine and white pine have accelerated dramatically over the last century. Population declines in these two species have increased public awareness of the need to promote conservation of the Island's biological diversity, including the diversity of native tree gene pools (Mosseler 1992, Mosseler et al. 1993b, Mosseler and Roberts 1991a,b, 1992, Mosseler and Warren 1992). The Newfoundland Forest Service has now implemented a ban on harvesting of red pine and white pine.

In Situ Conservation of Forest Genetic Resources

Protected Areas

It is widely recognized that *in situ* protection provides the most sensible approach to ensuring the maintenance of viable populations. Newfoundland has a wide range of federal and provincial statutes and legislation for protecting natural areas. However, these mechanisms vary in their effectiveness in controlling exploitation and/or development of natural resources. In the past, areas have been set aside only to have their protected status revoked under pressure from developers. If the protected areas network is to meet the objectives of (i) representation of ecological diversity, (ii) providing sites for long-term ecological research and monitoring that can serve as natural benchmarks and scientific controls for assessing management techniques, and (iii) providing insurance against resource management policies that go awry, then legislative protection against development must be assured.

In 1980, only two percent of the island of Newfoundland comprised protected areas. To remedy this situation, the Wilderness and Ecological Reserves Act was enacted. The process enacted by the legislation is considered to be one of the best in the country because it ensures both public input into the establishment and management of the reserves and the highest level of protection from development.

Wilderness and Ecological Reserves are established by Cabinet upon the recommendation of the Wilderness and Ecological Reserves Advisory Council. The majority of the eleven member council are selected from outside government. The process is a long one that involves the technical support of the Parks Division of the Department of Tourism and Culture. Other provincial departments and agencies are consulted to identify potential conflicts through the Interdepartmental Land Use Committee. Public interests are heard through initial public meetings and final public hearings.

In the Island's 500-year history since settlement by Europeans, exploitation of natural resources has been widespread. Most recently, this has led to the collapse of the marine ecosystem and, consequently, the collapse of the cod fishery. As elsewhere in Canada, Newfoundlanders are developing a conservation ethic. In 1989, the Protected Areas Association (PAA) of Newfoundland and Labrador was formed. The PAA is the province's link with the endangered spaces campaign of the World Wildlife Fund (Canada). Through research, planning, and public education, the PAA is working towards completion of a protected areas network by the year 2000. Although anyone can suggest to the Wilderness and Ecological Reserves Advisory Council (WERAC) that an area be protected, the PAA has led this effort with the development of the most comprehensive strategy for completion of a protected areas network. A formal strategy document (Anonymous 1993) has been submitted to WERAC for their action.

The PAA strategy incorporates plans for a "core reserve system" (Component I and Component II reserves) that will include larger, ecologically representative areas within each of the nine ecoregions described by Damman (1983) for insular Newfoundland and by Meades (1989) for the 10 ecoregions of Labrador. A system of smaller (Component III) ecological reserves have been proposed to protect unique ecological features such as rare and endangered species and sites of extreme species richness. Several of these reserves include forest tree gene pools. Scientists within the Canadian Forest Service and Canadian Parks Service have assisted in the development of this strategy by documenting areas of ecological significance and by identifying rare populations of trees like red pine, white pine, and black ash (Deichmann 1989, Mosseler and Roberts 1991a,b 1992, Mosseler et al. 1993.)

At present, Newfoundland's protected areas include two large National Parks (Gros Morne Park in the west and Terra Nova Park in the east), several smaller Provincial Parks (Barachois Pond, Sir Richard Squires, Butterpot, David Smallwood, and Salmonier Nature Park), two wildlife reserves, two large wilderness reserves (the Avalon and Bay du Nord Wilderness Reserves), and 10 Ecological Reserves. While many of these areas were designed for protecting seabirds and plant communities other than trees, this network does protect forests in five of the island's ecoregions (Damman 1983).

Gaps in the Protection of Forest Genetic Resources

Populations of red pine, white pine, and black ash are the most vulnerable owing to a combination of rarity and/or introduced pest problems that threaten their survival as naturally occurring species. These species are not sufficiently protected within the present network of Ecological Reserves. Increased artificial regeneration and forest management policies favouring natural regeneration of these species could alleviate much of the current threat. Silvicultural management of naturally regenerating populations of white pine is now being carried out in central Newfoundland. The introduction of prescribed burning, mechanical scarification, and/or removal of competing tree species would also help to ensure survival of natural red pine populations presently threatened by natural succession to black spruce and balsam fir.

Considering the size (28 783 km^2) of the Central Newfoundland Ecoregion, the current level of protection of the biological diversity is inadequate. Only two to three small patches of the rare tree species (red pine, white pine, and black ash) are protected. Red pine populations near West Brook (Springdale) and at Grant's Siding have received the status of provisional reserves to protect some of the oldest red pine on the Island (Mosseler et al. 1993, Anonymous 1993). Red pine populations at Sandy Lake, Charles Arm, and Noel Paul's Brook also represent significant areas that should be considered for protection. These populations are regenerating naturally and could ensure the continued existence of self-perpetuating red pine populations in the absence of fire. The red pine population at West Brook will require some management interference in the form of either a prescribed ground fire or mechanical scarification to encourage natural regeneration.

The need to conserve the last remaining stands of red pine and white pine has been recognized and promoted for many years by individual foresters within the Newfoundland Forest Service (NFS). The NFS is moving toward a more official position of recognizing the need for conservation of these rare components of the forest and has increased forest management efforts to promote native pines through the establishment of seed orchards, genetic archives, increased planting, proposed bans on harvesting rare and vulnerable native tree species, and silvicultural management of areas where pines are regenerating naturally.

Black ash is probably the rarest native tree species. Smaller (Component III) reserves have been proposed for the protection of black ash populations along the upper Humber River and on Glide Brook. Sir Richard Squires Provincial Park could be expanded to encompass the black ash population above Big Falls. Black ash populations along the Indian River should also be considered for protection. Some protection has been provided for populations of black ash along the edge of Barachois Pond Provincial Park and in Gros Morne National Park. Barachois Pond Provincial Park could be expanded to include more of this black ash population. Other black ash stands have been identified at Glide Brook (Deer Lake) and Rocky Brook (Reidville) (Deichmann 1989).

Like the Western Newfoundland Ecoregion (10 052 km^2), the Avalon Forest Ecoregion (576 km^2) also contains yellow birch (*Betula alleghaniensis*). The birch populations of the Avalon Forest may be adapted to unique climatic conditions characterized by the high incidence of fog. These populations are partially protected within the Salmonier Nature Park and possibly within the Avalon Wilderness Reserve. An additional Ecological Reserve has been proposed for a part of this area (Anonymous 1993). The yellow birch of Western Newfoundland is not protected within an ecological reserve.

Labrador has no protected areas. Several large wilderness areas and two National Parks have been proposed and are currently under discussion. Labrador's only jack pine population at Redfir Lake has been proposed as an ecological reserve.

Current and Planned Activities

Genetic reserves are being established as artificial gene banks for red pine and white pine at Wooddale and Gander, using seed collected from islandwide samples of the gene pool. The ecological significance of natural populations of these native pines continues to be documented through studies of reproductive biology, genetic variation, and interactions with other forms of wildlife. Presently, the CFS and NFS are documenting extant populations of white pine and black ash for genetic characterization and *in situ* protection within ecological reserves.

Ex Situ Conservation and Tree Improvement Programs

Tree Improvement Programs

Forest genetics studies were initiated in Newfoundland in the 1960s by the Canadian Forest Service. Initially, exotic species were tested. Several provenance tests of Sitka spruce (*Picea sitchensis* (Bong.) (Carr.) and red spruce (*Picea rubens* Sarg.) were established, but these species were not well adapted to conditions in Newfoundland. The most promising exotic species are Norway spruce (*Picea abies* L.), Japanese larch (*Larix kaempferi* (Lamb.) (Carr.)), European larch (*Larix decidua* Mill.) and interspecific hybrids between these *Larix* species (Hall 1986a). The testing of exotics was followed by the establishment of range-wide provenance (seed source) tests for black spruce, white spruce, and tamarack, and by regional provenance tests of black spruce. Currently tree genetics research is focused on native rather than exotic species. Descriptions of tree improvement programs in Newfoundland follow, by individual tree species.

Black spruce

Black spruce is the most planted tree species in Newfoundland. Most of the artificially established gene banks on the island consist of range-wide and regional black spruce provenance tests. The range-wide black spruce provenance test initiated by Morgenstern (1978) was established at three locations (Khalil 1984). It consists of six replicated blocks containing 16 tree plots of between 64 and 72 provenances per site. A regional provenance test consisting of 32 Newfoundland and eight mainland provenances was established at six sites on the island (Nicholson and Tricco 1969, Hall 1986b).

The NFS has established two black spruce seedling seed orchards and three open-pollinated progeny tests. Seeds for these tests were collected from 213 parent trees. An orchard at Wooddale will produce seed for most of insular Newfoundland. An orchard at Pynn's Brook will produce seed for the Northern Peninsula and Labrador. The parent trees are being assessed based on open-pollinated progeny tests established at three sites (Gander, Pynn's Brook, and Goose Bay). Given the prominence of this species and the relative ease with which it regenerates itself naturally following harvesting, black spruce is not perceived as a conservation issue.

White spruce

Over the past 15 years, the white spruce component of Newfoundland's artificial regeneration program has steadily increased and now represents 50% of the province's regeneration program. Grafted clonal seed orchards of 225 selected white spruce "plus trees" are being established at Wooddale to produce seed for most of the island. A second orchard of 50 white spruce clones has been established at Pynn's Brook to supply seed for the Northern Peninsula and Labrador. Three open-pollinated progeny tests are planned for assessment of these clonal orchards.

The Canadian Forest Service (CFS) established a single white spruce provenance test in central Newfoundland at North Pond. It consists of six replications (blocks) of 40 tree plots of 32 provenances (Khalil 1985). Most of the provenances are from the Great Lakes - St. Lawrence Forest Region. Only a single Newfoundland seed source of white spruce was included in this gene bank.

White spruce predominates in coastal areas and in the more fertile valleys of western Newfoundland and the northern peninsula. The concentration of human settlement and activity in these areas has placed white spruce under intense harvesting pressure for generations. Similarly, throughout most of central Canada, the white spruce gene pool has been eroded as a result of forest harvesting, land clearing, and urbanization. White spruce is a conservation issue in central Canada and may become so in Newfoundland if representative populations are not protected from disappearance. In view of its potential commercial importance, particularly in western Newfoundland, a conservation effort for the *in situ* protection of natural white spruce populations may be warranted.

Tamarack

In 1987, the CFS established a range-wide tamarack provenance test at three locations (in central and western Newfoundland). Most of the 25 provenances originated from Ontario, Quebec, and the Maritime Provinces (Tricco 1987); three were Newfoundland provenances. Four trees per provenance were replicated in 10 blocks at each site.

The NFS is planning to establish a grafted, clonal seed orchard at Wooddale based on 200 "plus trees". The selected parents will be assessed from three open-pollinated progeny tests. While tamarack is not well represented in *ex situ* gene banks, this species regenerates well following logging disturbance and is not a conservation issue.

Balsam fir

Throughout most of Newfoundland, balsam fir will regenerate naturally and there is no need for artificial regeneration. Consequently there has been little effort to genetically characterize this species. However, there is concern for the management of balsam fir as a genetic resource because of the balsam woolly adelgid (*Adelges piceae* Ratzeburg) infestation that presents a serious threat. Balsam fir stands are now being converted to black spruce to limit the potential damage to the forest resource. If stand conversion were practised on a large scale, it could pose a threat to the balsam fir gene pool and undermine the genetic recovery of the species through natural selection for tolerance to the adelgid. Evidence of such tolerance exists in natural populations that have been infested for several decades. The removal of residual, healthy stems of balsam fir within heavily infested stands is a procedure that should be questioned in view of both its ecological and genetic implications.

Red pine

Concern over the future of red pine as a naturally occurring species in Newfoundland prompted research into the reproductive success (Mosseler 1992a, Mosseler and Roberts 1992) and genetic structure (Mosseler et al. 1992b, 1991) of Newfoundland populations. Red pine along the northeast coast of the island and in Terra Nova National Park have shown decreased reproductive success due to cone and seed insects (Mosseler and

Roberts 1992a). Cooler, wetter climatic conditions in these areas may also adversely affect pollination and seed set.

A representative sample of Newfoundland's red pine gene pool (10 open-pollinated progeny from 70 parent trees) has been established in gene banks at two locations in central Newfoundland (Wooddale and Gander). Research continues on certain population genetic parameters in an unique mutant population from western Newfoundland (Mosseler and Roberts 1991a). The emphasis of this research is on gene flow between stands. In 1993 the oldest red pine tree (350 years old) on record in North America was discovered in the Sandy Lake population (Mosseler et al. 1993b).

The NFS could ensure the continued existence of red pine as a component of the forest through increased planting. The planting of red pine on some of the dry, infertile sites that are usually occupied by unproductive, open, black spruce-lichen woodland would increase the economic potential of much of the unproductive forest cover in central Newfoundland. Red pine also faces a potentially serious threat from the scleroderris canker disease that was introduced into the Avalon Peninsula.

White pine

Excessive harvesting for the sawlog export trade at the turn of the century and the white pine blister rust have decimated Newfoundland's white pine population. The few surviving stands of uninfected younger trees remain highly susceptible to destruction by blister rust infection. White pine deserves special attention as a conservation issue in Newfoundland and warrants consideration as a species vulnerable to local extinction.

The CFS has initiated research on the effects of small population size on the genetic diversity and reproductive success in the remaining isolated stands of naturally regenerating white pine. Seedlings from populations in central Newfoundland were established in two gene banks at Wooddale and Gander in 1994. These gene banks will preserve a representative sample of Newfoundland's white pine germplasm and serve as seed orchards for the artificial regeneration program.

Black ash

Black ash is the rarest tree species in Newfoundland. Initial attempts at documenting extant populations were carried out (Deichmann 1989) and further efforts are underway to complete a full documentation of the resource. The black ash population is rare but under no specific threat at present. Two of the five known populations are protected within Gros Morne National Park and within the Barachois Provincial Park. However, the remaining three populations should be protected, either within protected areas or through a ban on harvesting. Research on the molecular genetic characterization of Newfoundland's black ash population has been initiated at the Petawawa National Forestry Institute (PNFI) to determine if these Newfoundland populations can be genetically differentiated from mainland populations.

Hardwood species

Very little genetic research has been conducted on hardwood species in Newfoundland. In 1990, a genecological study was established at two locations to test the effect of ecoregions on the genetic structure of a native willow species (*Salix discolor* Muhl.). This study may present some insights into the establishment of breeding zones for developing seed transfer guidelines for insular Newfoundland.

Seed Collection and Breeding Zone Identification

Seed shortages hampered artificial regeneration efforts in Newfoundland in the 1970s and 1980s and resulted in the importation of seed from untested mainland sources. This practice violates some of the basic principles of genetic resource management and has the potential to disrupt locally adapted gene pools. In response to these seed shortages, studies were conducted to investigate the potential for maximizing seed collections during bumper cone crops (Mosseler 1992b, Mosseler et al. 1993a).

A regional black spruce provenance test has been established to define the breeding zones of Newfoundland (Hall 1986b). Thus far, most provenances showed good survival and have appeared to be broadly adapted throughout the Island. However, growth trends suggested that seed transfers to the Northern Peninsula and Avalon Peninsula may be adversely affected. If seed transfer problems relating to maladaptation are to be identified and avoided more of this kind of genecological information will be needed. The NFS has tentatively recognized two breeding zones within its tree improvement plan: the Northern Peninsula Ecoregion and Labrador have been combined into one breeding zone, with the remainder of insular Newfoundland comprising a second breeding zone.

Gaps in Gene Conservation

Gap Analysis and Forest Conservation Priorities

The PAA has developed priorities for *in situ* conservation. These priorities were developed in consultation with scientists and resource managers from three sources: federal and provincial government departments, the Memorial University of Newfoundland, and environmental non-government organizations concerned with the protection of natural areas. The CFS has played an important role in promoting the conservation of unique and rare forest tree populations by providing scientific documentation on these conservation issues.

Forest management policies that explicitly recognize the need to preserve the biological diversity of Newfoundland are needed. For instance, a greater emphasis needs to be placed on the need to maintain viable populations of rare species when implementing silvicultural and harvesting operations. Red pine, white pine, and black ash will require better *in situ* protection if they are to be maintained as naturally occurring species in Newfoundland. These species must be conserved for their contribution to the ecological diversity and perhaps to the ecological stability of Newfoundland.

Research Needs

The main research questions relating to genetic resource management in Newfoundland are: (i) measurement of genetic diversity and genetic characterization of populations for conservation; (ii) documentation of the genetic effects of small population size and a definition of minimum viable population sizes for rare and declining species; (iii) characterization of the ecological roles of individual tree species within the ecosystem; (iv) identification of factors affecting reproductive success; (v) identification of specific threats to survival, particularly those from introduced pests like white pine blister rust, sclerroderis canker, the balsam woolly adelgid, etc. and from forest management practices such as fire suppression; and, (vi) identification of seed transfer zones.

There is an immediate need that the extent, location, and significance of natural populations of the rare tree species such as white pine and black ash be documented. Roberts (1985) has done this for red pine. This kind of documentation must form the basis of "status reports", such as those produced by the Committee on the Status of Endangered Wildlife in Canada (see Cook and Muir 1984), from which recovery plans could be developed for rare and vulnerable species. The main elements of this plan would be *in situ* conservation within protected areas and forest management practices that ensure the maintenance of all native trees regardless of economic importance.

Summary

A forest gene conservation strategy needs to be developed by the forestry community of Newfoundland and Labrador. This strategy should consider both the economically important species and the rare and threatened tree species that may presently be of little or no commercial importance. The latter must be protected in the interest of conserving the ecological diversity of the Island and for their economic potential. The pulp and paper industry could play a major role in the protection of rare species by adjusting harvesting practices in the vicinity of rare populations. The provincial government could assist in the maintenance of red pine and white pine by planting areas presently covered by unproductive woodlands. Red pine and white pine are highly productive on these areas and would be capable of supporting a future pine sawlog industry.

One of the main benefits of protected areas to forest management and forest science is the establishment of areas for long-term ecological research. Such areas will play an increasingly important role in genetic resource management, especially if intensive genetic management is practised. Within clonal breeding programs, a narrowing of the genetic base of artificial populations may be expected. Thus, maintenance of a reservoir of genetic diversity within a system of protected areas provides important insurance against foreseeable and unforeseeable problems with artificially bred and managed populations. Given the uncertainties associated with climate change, the existence of natural reservoirs of genetic variability may become critically important in obtaining or reconstituting the genetic diversity necessary for continued survival and adaptation of a species. The forest management community has a strong, direct interest both in supporting the establishment of a network of protected areas that maintain natural populations in a relatively pristine form and in adjusting harvesting practices so that population viability is maintained.

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Appendix 1

A Framework for a National Strategy on Forest Genetic Resource Conservation and Management

The following are outlines of a framework for developing a national strategy for the conservation and management of forest genetic resources in Canada. Input for the development of such a national strategy came from representatives of industry and provincial and federal governments from across Canada who met at a workshop held in Toronto (November 15-18, 1993) to review and discuss genetic resource management and conservation issues.

The development of a national strategy was seen as important for the following reasons: (i) to provide a focus for enabling progress towards sound management of genetic resources across Canada, (ii) to fulfill commitments made by Canada under the Convention on Biodiversity, and (iii) to promote a coordinated approach to genetic resource management and gene conservation issues. The framework presented below represents a general consensus among the participants at the workshop. This consensus was developed during discussion groups that focused on specific questions related to the development of a national strategy.

Goal or Mission Statement

To promote and perpetuate the genetic diversity, adaptive potential, and evolutionary capacity of forest tree species.

General Approach or Guiding Principles

1. Recognize that species distributions cross provincial (national) boundaries and promote interprovincial cooperation in the conservation and management of genetic resources.
2. Strategies for management of genetic resources should be based on species as opposed to provincial boundaries or forest regions.
3. Recognize that tactics and priorities will be determined locally.
4. Maintain the adaptive potential of tree species in Canada by preventing the erosion of genetic diversity and restoring genetic diversity where needed.
5. Promote the integration of genetic conservation and genetic resource management into forest management.
6. Recognize that an understanding of the genetic system and life history provides a foundation for sound management of the genetic resources of a species.
7. Recognize that it is easier to maintain genetic diversity than it is to restore it.
8. Effective genetic management requires balancing evolutionary forces to prevent anthropogenic extinctions, while recognizing that local extinction is also part of a natural process.
9. Effective management of genetic diversity must integrate the use of various techniques/tactics for *in situ* and *ex situ* protection of genetic resources.
10. Ensure the availability of genetic resources across Canada.
11. In identifying conservation priorities, we should consider: (i) rarity, (ii) specific threats to the species/population, (iii) opportunities to do something, (iv)economic or community importance, (v) economic or ecological potential, and (vi) current genetic status.

Objectives

1. Develop a national action plan for genetic resource management and conservation, particularly for the protection of valuable or threatened forest genetic resources.
2. Establish a genetic resource conservation/management Working Group within the Canadian Tree Improvement Association.
3. Establish a coordinator or a coordinating committee to monitor a national strategy for genetic resource management/conservation and report on progress.

4. Assist in the development of federal guidelines to identify (measure) genetic diversity, its vulnerability, and relationship to biodiversity (i.e.: COSEWIC, RENEW, etc.).
5. Establish common principles, guidelines, terminology, and systems for documentation.
6. Develop a national database on genetic resources preserved in *ex situ* gene banks, provenance and progeny tests, seed orchards, etc. that would be coordinated by PNFI with information provided by provincial land management agencies.
7. Develop a status report and gene conservation strategy for each tree species.
8. Develop a communications plan for genetic resource management so that results can be disseminated and incorporated into forestry practices.

Research Priorities

1. Population viability analyses and life history investigations.
2. Identification of minimum viable population sizes and the effects of small population size on genetic diversity and reproductive success.
3. Identification of specific threats to genetic diversity.
4. Development of protocols for germplasm storage, especially for non-commercial and threatened or vulnerable species.
5. Development of new/better estimates of genetic variation, structure, and diversity.
6. Document the impacts of forest management practices on genetic diversity and structure.
7. Identification of mating systems and genetic architecture, particularly for minor forest tree species.
8. Characterization of metapopulation dynamics.

Role of the Canadian Forest Service

1. Conduct research on genetic resource management and conservation issues.
2. Address international commitments (i.e.: Biological Convention).
3. Maintain a national centre for tree seed and germplasm storage for conservation and research purposes.
4. Identify gaps in the conservation and management of genetic resources and provide direct funding to address these issues.
5. Foster collaboration among provinces.
6. Maintain national databases on genetic resources.
7. Act as a catalyst in facilitating surveys on the status of Canada's forest genetic resources.
8. Facilitate the coordination of a national strategy for genetic resources management and conservation.