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Network News
Forest Health & Biodiversity
Canadian Forest Service

Climate change and biodiversity: species dispersal, migration, and adaptation

Rapid climate change resulting from human activities has become a pressing international environmental concern (e.g., Kyoto conference, 1997). Recent weather patterns, from unusual droughts followed by wildfires in southeastern Asia to increased tornado activity across the southeastern USA, have had frightening consequences for many people. More recently, the unusually rapid recession of polar ice caps has received media attention. Wherever possible, we must take steps to reduce the gas emissions that may be contributing to these changes. Increasing forest biomass production as a potential sink or depository for atmospheric carbon from fossil fuel burning is no panacea, and at best will have only a temporarily mitigating effect.

Dramatic climate changes have occurred in the absence of humans and will probably continue regardless of our activities. An important, yet under-appreciated issue in our approach to managing the effects of climate change relates to the ways that plants and animals have responded and adapted to past climatic events and how human interference on the landscape may be affecting their ability to respond to future changes.

Plant and animal populations have adapted to changing climates over the millennia primarily through migration away from unfavorable environments to which they were poorly adapted. Secondly, individuals respond to altered environments through the evolutionary process of natural selection to maintain population fitness. How human activities affect the ability of species to disperse, migrate, and adapt to climate change may ultimately be more important than some of the human activities that promote climate change. Unfortunately, these ecological aspects of "adaptation to climate change" receive very little attention in discussions, research, or actions aimed at addressing climate change issues.

Seed traps for measuring seed dispersal.

Humans can disrupt species responses to unfavorable environments in the short term by preventing species dispersal and migration. For instance, trees can be trapped on the upper slopes of mountains if insect pollinators or the birds that they depend on for seed dispersal no longer visit because of climate-induced environmental changes. These situations may be exacerbated if the natural vegetation connections that allow for dispersal and gene flow between adjacent populations are interrupted in the surrounding valleys because of deforestation that prevents movement across the landscape. For example, several rare species of pine (*Pinus*) and spruce (*Picea*) in Mexico are currently threatened by their isolation on mountaintops.

A decline of seed-dispersing bird populations may already be having an impact on the survival of native trees in Canada. For instance, the recent decline of the Newfoundland red crossbill, *Loxia curvirostra percna*, may be a limiting factor in the ability of rare trees such as red pine (*Pinus resinosa*) and white pine (*P. strobus*) to disperse seed to distant

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habitat patches. The red crossbills of North America represent a group of about seven closely related sub-species that have developed special adaptations for foraging on different tree species or groups of tree species. Some of these trees have specific habitat requirements that result in widely scattered sites. Their survival requires movement from one habitat patch to another to colonize newly available sites as older populations are eliminated through natural catastrophes, ecological succession, human interference, etc. Highly mobile seed dispersal agents such as the crossbill provide a critical competitive advantage for trees in highly fragmented landscapes.

Large-seeded trees such as oaks (*Quercus*), walnuts (*Juglans*), and hickories (*Carya*) are also largely dependent on animals for seed dispersal. Without the highly mobile seed dispersal provided by animals, gene exchange among small, isolated woodlot populations would be restricted. In the absence of gene flow among small populations, the genetic diversity required for adaptation to changing environmental conditions would gradually be eroded. This erosion occurs in plants as a result of inbreeding (excessive self-fertilization and mating among close relatives) and genetic drift (loss of genetic diversity due to small population or sample size) in small, isolated populations experiencing restricted gene flow. Without dispersal and gene flow, these trees may remain trapped and isolated in localities such as small farm woodlots, where movement of animal seed dispersers may be restricted by unfavorable environments (*e.g.*, increased risk of squirrel predation in open fields). In contrast, trees such as aspens (*Populus*), willows (*Salix*), and birches (*Betula*) are so widely dispersed by wind that habitat fragmentation and small population size may be of little genetic consequence.

The high levels of genetic diversity necessary to mount an effective adaptive response are particularly important for long-lived, stationary organisms such as trees which cannot "run away" from environmental problems. All species require many generations to evolve better-adapted forms through evolutionary processes such as mutation, gene flow, and natural selection. In trees that require many years to reproduce, several generations may involve hundreds or even thousands of years. If high levels of genetic diversity are not maintained within natural populations, the anticipated rapid rates of climate change may not allow the required time for populations to adapt effectively.

Human activities can disrupt the longer-term responses of trees to unfavorable environments by undermining the existing high levels of the genetic diversity that characterize most of our native trees. Conservation of genetic resources has become a critical, global-scale issue highlighted in the Convention on Biodiversity (Rio de Janeiro, 1992). The rate of adaptive (genetic) responses in species depends directly on the presence of a large reservoir of genetic diversity at the time of a serious environmental challenge. In the face of environmental challenges to survival, species cannot simply mutate into "new" genetic varieties to overcome such challenges. The lengthy time scales involved in adaptation through evolution must be more fully appreciated to understand the importance of maintaining high levels of genetic diversity in natural populations.

The Canadian Forest Service (CFS) has been researching the potential impact of climate change on species survival. One approach has been to investigate the ecological relationships that support migration through normal dispersal mechanisms and through adaptation via natural selection. For instance, potential relationships between seed-dispersing birds, such as the threatened Newfoundland red crossbill, and dispersal of red pine has been documented through the use of a natural morphological mutation in red pine. This documentation has allowed us to map long-distance dispersal across a highly fragmented landscape in western Newfoundland over the past sixty years. Investigations into the physiological responses of native trees to elevated levels of carbon dioxide are also being conducted. This research will characterize the adaptive responses in black spruce (*Picea mariana*) and red spruce (*Picea rubens*) to anticipated changes that may affect water relations and drought responses in these trees. More recently, the CFS has studied artificial ecological restoration through establishment and promotion of rare native species such as pitch pine (*Pinus rigida)*, which reaches the northern margins of its geographical range in Canada in anticipation of warming climates. The CFS has established seed collections for declining tree species such as red spruce, pitch pine, white pine, and red pine across the northern margins of their range in Canada. These seed sources will be used for ecological restoration efforts in anticipation of climate change.

While reductions in greenhouse gas emissions and the proper management of carbon sources and sinks are important components of managing climate change, conservation of biological diversity may be one of the most effective, practical responses to the threats posed by climate change to ecosystem health. Conservation of this biological diversity at all levels (e.g., from genes within species, to the mosaic of habitat types across a landscape) will permit natural species to "roll with the punches" as their environments change.

by Alex Mosseler,
Atlantic Forestry Centre

Butternut, a threatened species showing a low genetic diversity

If, while taking a walk in the forest, you came across a tree with compound leaves, the only one of its kind or with only a few similar trees in the vicinity, it could very well be a butternut (*Juglans cinerea L.*). Don't be embarrassed if you didn't recognize it at first glance, because not being widespread, it is not well known. It will most likely be found in fertile, moist, well-drained soil, often along streams or gentle slopes.

The butternut is a species mainly found in the Deciduous Forest Region. The southeastern part of the Great Lakes St. Lawrence Forest region and the western section of the Acadian Forest Region mark the northern boundaries of its distribution area. It is not a long-lived species, rarely surviving beyond 80 years, and is identifiable by its wide-spreading and rounded, irregularly-shaped crown and its light grey bark separated by crevices into flat-topped intersecting ridges. In late summer, we find large nuts, oblong-shaped and sharply ridged, enclosed in a very sticky, hairy husk, hanging from the branches. The kernel is edible, with a taste similar to walnuts. The butternut has little commercial value compared with other species, but is an important source of food for wild animals and a major component in maintaining a high level of biodiversity in the forest ecosystems of northeastern North America.

Unfortunately, the integrity of butternut populations has been threatened in recent years not only by urban development, but also by a disease called "butternut canker," caused by a highly virulent fungus, *Sirococcus clavigignenti juglandacearum*. Due to the rapid dispersal of this pathogen, traces of the disease can now be seen in almost all of the butternut's range. For the last fifteen years or so, the butternut population in the United States has been depleted to such an extent that the species is currently designated an "endangered forest species" by the Forest Service of the US Department of Agriculture. An inventory done recently in Wisconsin indicated that 91% of the butternuts in that state showed symptoms of the disease. Inventories done in North Carolina and Virginia revealed that between 1966 and 1986 the butternut population plummeted by 77%. The situation is not as catastrophic in Canada. However, the disease did not appear until the early 1990s, and the situation could degenerate quickly. In 1996, butternut mortality as a result of the disease was estimated at 80% in southern Ontario. Our knowledge about butternut is fragmentary. It is essential that we undertake studies to deal with the anticipated situation.

Canker with black exudate on bark (present in early summer).

It was with this in mind that a study was done on the genetics of butternut populations by a team from the Canadian Forest Service-Laurentian Forestry Centre, in collaboration with Dr. Jean Bousquet of the Forest Biology Research Centre at the Université Laval, under the auspices of the national forest biodiversity research network. The specific aim of this project was to estimate, using isozyme markers, the butternut's level of genetic diversity and to study the genetic structure of populations at the northern end of its range, where the effects of the disease are still marginal.

Study results indicate that butternut seems to be the least genetically diverse species of the genus *Juglans*. The indicator values of the level of genetic diversity amount

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to only a quarter of the average values observed for deciduous species whose seed dispersal depends on gravity. The most plausible reasons for this low degree of genetic diversity are historical and related to the biogeography of the species. Given the limited capacity of the species to travel because of its mode of seed dispersal, it probably went through bottle-necks during ancient glacial states and lost genetic diversity as a result. Moreover, the degree of differentiation of butternut populations is relatively high, in the range of 9%. However, when only Canadian populations are considered, the butternut population differentiation is only about 3%.

Elliptical black canker visible with bark removed.

Given the threat that hangs over Canadian butternut populations, conservation measures are urgently needed. These measures must take into account not only the genetic resources present, but also the dynamics of the ecological environments and host-pathogen interactions. However, there is no *a priori* indication that some populations should be favored because they are more valuable than others at the genetic level. Butternut can already be found in some ecological reserves such as the Micocoulier and Lake Tapani reserves in Quebec which ensures, at least temporarily, *in situ* conservation. The number of protected areas is limited, however, and should be increased, particularly when one considers the almost complete absence of genetic diversity noted in the Lake Tapani population. Moreover, given the ease with which pathogen spores disperse and the low level of genetic diversity observed in butternut, both signs of potential problems in dealing with the pathogen, other measures must be considered. On one hand, the virulence of the butternut canker calls for the rapid development of *ex situ* means of conservation. In Ontario, the Forest Gene Conservation Association and their associates have undertaken a program to select and conserve putative resistant trees. Promising research is also being done by Dr. Tannis Beardmore at the Atlantic Forestry Centre on the cryoconservation of embryogenic tissue. On the other hand, the campaign to inform private woodlot owners about the devastation the pathogen can cause in their woodlots must be stepped up. Technical advice, based on tips developed by the US Department of Agriculture on how to visually detect and control the disease, must also be disseminated by forest health specialists. Landscape-level monitoring involving both demographics and genetics is needed to establish the best possible strategy for the conservation of this noble species' genetic resources.

By Ricardo Morin, Jean Beaulieu and Gaëtan Daoust, Laurentian Forestry Centre

The Forest Health Network: Building on the past, for the benefit of our future

The Forest Health Network (FHN) is committed to monitoring and research for the long-term health of our forests. Faced with the problem of developing a strategy that builds on the best practices of the past, the FHN must ensure that information gaps in forest health sustainability reporting are addressed. This requires an integrated monitoring and research agenda to build a more solid foundation to influence forest policy nothing new to the FHN.

Many look to the Acid Rain National Early Warning System (ARNEWS) as a "best of our past." ARNEWS was the cornerstone of federal forest health monitoring activities in Canada for nearly 15 years. Initiated in response to concerns over possible forest health damage, ARNEWS was created to determine if air pollution and acid rain were affecting our forests. Today, as the issues broaden and evolve, the ARNEWS experience is playing a valuable role in determining current and future research activities that focus on climate change.

ARNEWS did not exist in 1983 when the Minister of the Environment, the Honourable Charles Caccia, visited European forests and witnessed firsthand the damage caused by acid rain and air pollution. As a result of his visit and his concern for the Canadian forest environment, Mr. Caccia initiated the ARNEWS program and the Canadian Forest Service (CFS) began developing a monitoring system a year later. The objective was to assess the effects of acid rain on forests in Canada thus the conception of the Acid Rain National Early Warning System.

ARNEWS initially consisted of 103 plots representing Canada's major forest regions to create a national monitoring network, expanding to about 150 plots in 1994. National reporting on results began in 1990. Between 1990 and 1994, five reports were submitted to the North American Forestry Commission, including the trilingually produced (English, French and Spanish) 1992 report. This report reflected the fact that Mexico was participating in monitoring activities with an ARNEWS plot located near Mexico City. The data provided fundamental information, previously unavailable, to identify new opportunities for relevant, detailed research projects.

Between 1986 and 1992, the ARNEWS program influenced Russia, the US, Europe and Mexico to adopt similar protocols to assess the state of their forests. In the early 1990s, damage from acid rain and air pollution were recognized as global environmental issues.

A scientific review of the ARNEWS program was carried out in 1994 by an international review panel. Mr. Charles Caccia, no longer the Minister of the Environment but still a Member of Parliament, returned to personally address the panel. ARNEWS was deemed to be a highly worthy program. The panel noted that the ARNEWS program had the best data set of its kind, possibly in the world, with the potential to contribute to Canada's climate change studies.

In 1996, CFS formed the Forest Health Network. Under the new structure, significant shifts in strategy and program directions resulted. The network and research contribute to national goals, including global change issues affecting forest health.

The national ARNEWS plots remain, and many are being incorporated into new studies such as the following: CFS Forest Indicators of Global Change Project, Climate Change Impacts on Productivity and Health of Aspen Study, and a study of the "1998 Ice Storm of the Century" in eastern Canada and the US, which will use ARNEWS to evaluate the forest's post-storm resilience and recovery. The Canada-US Air Quality Accord uses ARNEWS data as a basis for reporting and effects monitoring. ARNEWS plots provide links to other organizations and federal departments where plot locations fall within the jurisdiction of such collaborators as Canada's National Parks and the Canadian Model Forest Network.

The CFS ARNEWS program has done much to influence how the science of forest health monitoring and research is conducted. Though needs are changing and a new strategy is being implemented, the ARNEWS experience will live on by way of the current research studies, and those yet to be identified in the future.

Shirley Pegler,
Science Communications Officer,
Atlantic Forestry Centre

Special thanks to Dr. Les Magasi, a "founding father" of ARNEWS, for his personal perspective and historical recollection of ARNEWS events.

To obtain a copy of the *ARNEWS Manual for plot establishment and methods*, please download a copy from the ARNEWS section of the CFS Forest Health Network web site: http://atl.cfs.nrcan.gc.ca/fhn/ma/arnews_e.htm

An exotic disease: Scleroderris canker, European race

Readers with a long memory may recall the concern generated in 1978 by the first report in Canada of the European race of Scleroderris canker (a fungal disease) occurring in red pine (*Pinus resinosa*) plantations along the New York State - Quebec border. The disease was first noticed in North America when it caused extensive mortality in 14,000 ha of red pine stands in New York state in 1975. In the following years, this European race was found in New Hampshire, Maine and Vermont in the US. In Canada, it was detected in Quebec (1978), New Brunswick (1979), Newfoundland (1980) and Ontario (1985). The North American race infects and kills only lower branches covered with snow, usually to a maximum height of two metres. The European race is not limited to this two-metre height and can infect the crowns of large trees.

The forestry implications of these discoveries were very serious and as a result, intensive surveys and new research projects were initiated by the Canadian Forest Service (CFS), provincial cooperators and others to delineate the extent of the problem. The disease is now known to occur throughout much of Quebec, but is restricted to a small portion of central Ontario, the Avalon Peninsula in Newfoundland, and to one location in New Brunswick.

After the discovery of the European race in Canada, the first priority was to develop a test to reliably distinguish the European from the native North American race of the fungus. The two appear identical, even under the microscope. In 1975, CFS research scientists at the Great Lakes Forestry Centre in Sault Ste. Marie were the first to recognize and develop a serological method to identify the races of Scleroderris canker. In the late 1980s, research scientists at the CFS-Laurentian Forestry Centre (LFC) in Sainte-Foy developed the electrophoresis technique for race determination which was found to be more reliable, and it has now replaced serology as the standard identification technique.

A red pine with Scleroderris, European race.

If the disease occurs at low intensity in a stand, work conducted in Quebec has shown that the European race of Scleroderris can be controlled through pruning of lower branches. Other research conducted by CFS has shown that not all pine species are equally susceptible to the disease; for example, jack pine is largely resistant. In collaboration with the CFS-Northern Forestry Centre, work is presently being conducted at LFC to determine if western pines can be damaged by the European race of the disease. More information on this exotic pest in Canada is presented in a recent article entitled *"Status of the European race of Scleroderris canker in Canada."* (*Forestry Chronicle*, July/August 1998, Vol. 74, No. 4, pp 561-566.)

by G. Laflamme, A.A. Hopkin and K.J. Harrison, Canadian Forest Service

Forest Health Network Asian long-horned beetle team wins award

Canadian Forest Service (CFS) and Canadian Food Inspection Agency (CFIA) employees have won the "Head of the Public Service Award" for collaborative work addressing the serious threat to Canada's forests by the Asian long-horned beetle (ALB).

In a special ceremony in Hull, Quebec on December 6, 1999, 49 employees were awarded the "Head of the Public Service Award" recognizing excellence in policy. The team has made a difference in many ways new policy development, excellent education and workshop materials, strong media awareness campaign, and coordinated monitoring and identification efforts resulting in ALB interceptions.

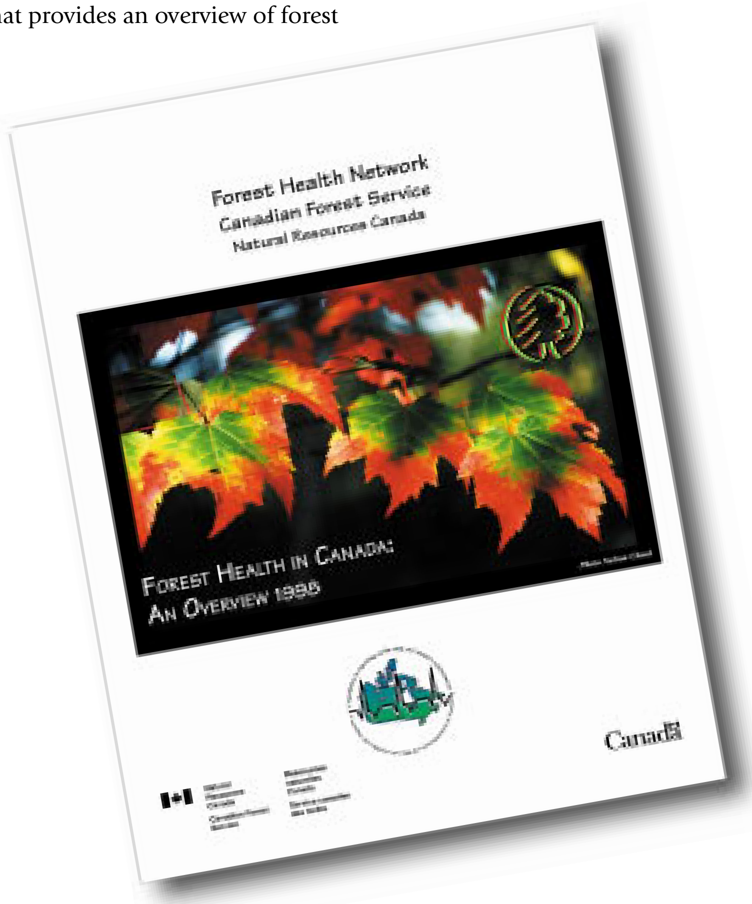
CFS award recipients: Eric Allen, Guy Bird, Robert Duncan, Nick Humphreys, Ben Moody, Mark Newcombe, Hans Ottens, Jane Seed, Georgette Smith, Dave Winston, James Brandt, Pierre DesRochers, Ken Harrison, Leland Humble, Edward Hurley, Kathryn Nystrom, Thomas Sterner, Jim Wood. CFIA recipients: Jean-Guy Champagne, Patricia Cuglietta, Marcel Dawson, Rob Favrin, Jean-Pierre Hanchay, Bruce Howard, Jim Johnson, Andrew Lam, Brian Radey, Archie Stewart, Roger Trudel, Doreen Watler, Mike Wood, Jon Bell, Hong Chen, Gregg Cunningham, Paul Farrel, Bruce Gill, Nancy Kummen, Ken Marchant, Krista Mountjoy, Francine Pepin, Joanne Rousson, Yudi Singh, Greg Stubbings, Mark Van Dusen, Bill Weiler, Lloyd Foster, Francine Belley, Normand Downing, and Ken MacLeod.

The CFS team has also been awarded the Canadian Forest Service Merit Award for 1999. Congratulations to all involved!

To view a copy of the press release, visit the Treasury Board of Canada web site at: http://publiservice.tbs-sct.gc.ca/news99/1206_e.html Or to view a virtual 'webcast' of the award ceremony, please visit http://www.thebusinessedge.com/reruns/leadership120699

Forest Health Report

Recently released, *Forest Health in Canada: An overview 1998* is the first report produced that provides an overview of forest health program issues, analyses, technical and scientific journal papers, and general pamphlets.



Complied by the Forest Health Network, Canadian Forest Service, the report gives a national, synoptic overview of the health of Canada's major forest ecosystems. The last page of the report includes a readership survey and we'd appreciate your feedback. For your free copy (in limited numbers), please contact:

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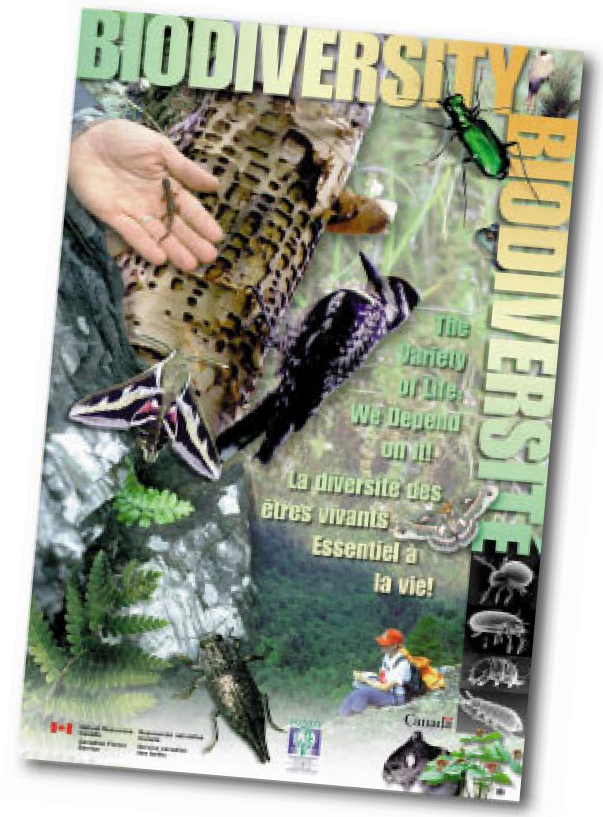

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