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# Forest Health & Biodiversity News

## Impact of Exotic Poplars on Natural Forests

In light of the global forestry situation and growing energy requirements, a number of countries are showing an increasing interest in the cultivation of fast-growing trees, such as poplars with exotic components. For several decades, poplar varieties have been developed through breeding programs with the goal of obtaining better performing trees that are better adapted to the various growing environments. However, the use and large-scale deployment of these new varieties (including plants with novel traits) could pose a significant risk, particularly with respect to gene flow (via the pollen, etc.). The reproductive barriers between different poplar species are generally weak, with the possible result that hybrids could form through the dispersal of pollen from the exotic species to compatible native species. In the medium- or long-term, these hybrids could affect the genetic diversity of native species as a result of *introgression*—the flow of exotic genes into the gene pool of native species.

In North America and particularly Canada, a number of exotic poplar species and their hybrids were introduced for ornamental purposes or for reforestation in the late 1800s (e.g., Richardson et al. 2007). Clonal tests and, more recently, plantations of mature exotic poplars (Fig 1.) have also been established almost everywhere in Canada. This unique material can be used to acquire scientific knowledge on the introgression of exotic genes. To date, few studies on this topic have dealt with poplar varieties with exotic components and other compatible poplar species growing in a natural setting.


*Figure 1. Quebec Department of Natural Resources and Wildlife plantations of poplars with exotic components located near natural populations of native poplars. One is located at Matane, Quebec (A) and the other near Sorel, Quebec (B).*

We carried out a project using a combination of empirical and modelling approaches in order to assess the frequency of introgression of exotic genes in native poplars and the consequences of introgression. We applied a step-by-step approach (Wilkinson et al. 2003) with a view to answering the following questions:

- Does spontaneous hybridization occur between exotic and native species in natural settings?
- If spontaneous hybrids do form, to what extent are they viable and able to reproduce in the natural environment?
- What genetic and ecological parameters are likely to influence the infiltration of exotic genes into natural populations of compatible native species?

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**Detection of spontaneous hybrids**

We estimated the rates of hybridization between pairs of compatible exotic/native species by using a set of single nucleotide polymorphism (SNP) markers developed in our laboratories for the detection of hybrids (Meirmans et al. 2007). These DNA markers for specific species make it possible to directly measure gene flow, which is something that cannot be achieved with controlled crosses and studies of the physical dispersal of pollen grains.

In our project, we used markers that had been developed earlier in order to detect the presence of exotic genes in native poplars (*Populus balsamifera* and *P. deltoides*) growing on the periphery of plantations composed of exotic species. Two sites in Quebec with plantations of mature hybrids with exotic components (*Populus trichocarpa*, *P. nigra*, and *P. maximowiiczii*) and adjacent natural populations of compatible species (*P. balsamifera* and *P. deltoides*) were used to assess spontaneous hybridization rates (Fig. 1). We genotyped nearly 5,000 seeds collected over a three-year period from female *P. balsamifera* and *P. deltoides* growing on the periphery of the exotic plantations at these sites.

The percentage of hybrid seeds containing exotic genes varies widely depending on the populations and recipient species (less than 3% in *P. deltoides* and 20% in *P. balsamifera*) but can vary from year to year (Meirmans et al. submitted). However, a portion of the hybrids detected (up to 30%) also contained the genes of native species. These genes, which may have had exotic components, did not come from natural populations but from planted varieties and were spread through pollen. For example, the genes of *P. deltoides* are found in natural populations of *P. balsamifera* by means of the pollen produced by a hybrid such as *P. deltoides* x *P. trichocarpa* or *P. trichocarpa* x P. *balsamifera*.

**Establishment and reproduction of hybrids in natural populations**

The risk that introgression presents does not depend solely on the rate of spontaneous hybridization between plantations of exotic trees and natural populations. It also depends on the ability of the hybrids to become established in natural forests and to subsequently reproduce. We undertook another study to look for advanced-generation (introgressing) hybrids with exotic genetic constituents. In order to achieve much greater precision in measuring the degree of introgression of exotic genes, it is necessary to have a large number of genetic markers specific to the species concerned. This is the reason SNP markers were developed for more than 100 genes to date (Thompson et al. in preparation).

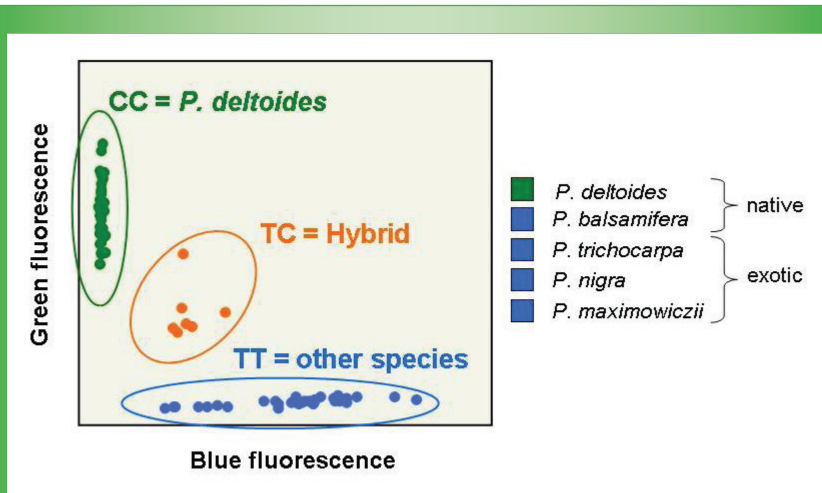


*Figure 2: Genomic contribution of exotic vs. native species in seeds collected from a mother tree of Populus deltoides. Seven hybrids (orange dots) were detected.*

For this study, we focused on the exotic poplars *P. laurifolia* and *P. nigra* and on their hybrids. These species were introduced by settlers in the late 19th century, notably in the Prairies and in Quebec (Richardson et al. 2007). These trees, some of which are now a century old, can be used to assess the flow of exotic genes to natural populations of native species, because several generations have been completed since the species were introduced. More than 30 natural populations of *P. balsamifera* and *P. deltoides* were sampled in Quebec and will be in Saskatchewan.

In Quebec, more than 650 trees from 15 populations of *P. balsamifera* and *P. deltoides* were genotyped using about 40 genetic markers to detect exotic genes belonging to *P. nigra*. The initial results showed that hybrids and natural introgressants (about 2.4%) were present in 8 of the 15 populations (Thompson et al. submitted). These are first generation or more advanced generation hybrids between the native species *P. deltoides* and *P. balsamifera* as well as between the latter two species and *P. nigra*. These hybrids and introgressants are found primarily in disturbed environments.

Based on a compilation of the results (including those from the Prairies), some of the sites that were selected will be further characterized to determine the genetic and ecological factors that influence the rate of introgression. Work is therefore continuing.

**Impact of introgression and other genetic parameters on the risk of spread of exotic genes**

In parallel, we have developed a metapopulation model—a model that is used to study a collection of interacting populations of a species with a fragmented geographic distribution. This helped us orient our current research and it will help us gain insight into the impact of the spread of exotic genes to compatible natural populations (Meirmans et al. 2008). The model showed that small populations of recipient native species are to some extent more at risk and that it is essential to study how genes that confer a selective advantage are distributed within natural populations.

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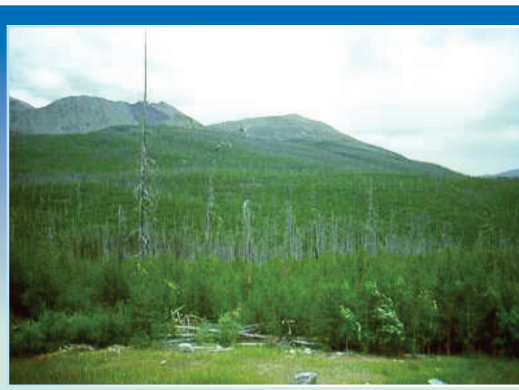
# Scientists at Natural Resources Canada discuss definitions around boreal forest debate

In October 2008, a group of forest scientists from Natural Resources Canada's Canadian Forest Service (CFS) met and discussed the terminology used in mainstream media to discuss conservation and development in Canada's boreal forest. Terms such as ancient forests, old-growth forests, intact forests or intactness, and protected areas were analyzed from a scientific perspective, and their application with respect to forestry practices in Canada was discussed. This article presents some initial outcomes from this discussion and highlights our current understanding of the science underlying these terms and the issues associated with them. As a national science-policy organization, the CFS will continue to further develop perspectives on forest terminology.



*Catastrophic stand replacement by fire, followed by natural regeneration of lodgepole pine in the boreal forest of western Canada.*

*Mature lodgepole pine forest overstory being destroyed by Mountain pine beetle infestation and shade-tolerant spruce-fir understory ready to take the place of pine in the absence of wildfire.*

**Boreal Region and Boreal Forest**

The group found that it is important to distinguish between the boreal region and boreal forests. The boreal region is an area that has the climatic characteristics under which typical boreal vegetation species associations have the potential to occur, given local site conditions. It covers an extensive contiguous area in contrast to altitudinal belts in mountainous areas. The location of the boreal region has shifted in latitude between ice ages. It has been moving north over thousands of years since the last ice age and will continue to shift as the climate changes. As recently as 21 000 years ago, at the peak of the Wisconsin glaciation, almost the entire northern half of the continent was covered with ice. Since that time, plant associations have varied continuously, appearing and then disappearing through time.

The boreal forest is the area of the boreal region occupied by forest in a variety of successional stages, ranging from young regeneration to old growth. The Canadian boreal forest is driven by stand-replacing disturbances, renewing itself mainly through fire and insect outbreaks. These disturbances are characteristic of the boreal forest (1), as are the relatively short-lived tree species (<250 years) found in them.

**Old-growth and Ancient Forests**

The term "ancient" has no ecological basis and has limited use in scientific literature. The United Kingdom Forestry Commission used "ancient woodland" to refer to woodland in continuous existence from before 1600 in England and Wales (2). The term "ancient" should probably not be used in the context of Canada's boreal forest because of repeated stand-replacing disturbances. More scientifically recognized terms used in the context of old forests include old growth and unmanaged old forests.

Old-growth forests are those in a late stage of forest succession, with characteristic ages and structures that vary with forest type. In temperate regions, old growth may be defined as forests with many trees older than 250 years. In the boreal region, forests are not composed of long-lived tree species and an "old growth" forest can comprise those with trees between 100–250 years old, depending on the tree species and the local forest type. Although some forests in the boreal region may escape stand-replacing disturbances over long periods of time (>500 years), such forests are not a common feature of the boreal region and none of the trees on these sites are very old. Elsewhere in Canada, such as in western coastal temperate rainforest regions, some tree species have a natural longevity exceeding 500 years (3).

**Fragmentation and Intactness**

There is also limited scientific application for the terms "intact" or "intactness" because they are largely redundant when applied to forests. In the scientific literature, the concept of intactness is dealt with in more precise ecological terms, such as forest "fragmentation," "continuity," and "connectivity," all of which are related to the structure of a forested landscape and the effects of forest fragmentation, forest loss, continuity, and connectivity on the maintenance of viable populations of fauna and flora.

Any concept of landscape continuity considers human activity, spatial and temporal scales appropriate to the issue, maintenance of ecological processes, and the conservation of biodiversity. For any given concern, an appropriate scale is linked to the associated ecological processes and individual population requirements of the species of interest. The scale cannot be linked to arbitrary choices of space

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# Forest Research Today: Taking Advantage of Generations of Knowledge

Natural Resources Canada's national research forests, Acadia and Petawawa, are two living laboratories that have historical scientific data spanning over 90 years. This unique data provides researchers and forestry practitioners with long-term trends to help address current and future ecological and operational forestry issues.

Situated in the heart of the Acadian forest, the Acadia Research Forest was established in 1933. Its sister forest, the Petawawa Research Forest is nestled in the Great Lakes–St. Lawrence Forest Region and was established in 1918. Together, these forests cover over 19 000 hectares and have some of the oldest continually measured sample plots in the country.

The Acadia and Petawawa national research forests provide stakeholders with an opportunity to learn first-hand the results of past and current projects and to plan future collaborative studies. With their combination of history, experimental sites and data, these forests provide a unique opportunity for both long- and short-term research. Researchers conducting studies at the forests enjoy multiple benefits from enhanced site security to opportunities to revisit a variety of historical databases.

"I am quite excited to do work at Acadia and to work with Natural Resources Canada," says Dr. Fan-Rui Meng, Research Director of Nexfor-Bowater Forest Watershed Research Centre and professor at the University of New Brunswick. "I work there because it is dedicated to forest research. Forest research suffers from not having secure land for long-term studies. Trees take a long time to grow and we need to have sites that will continue to be there. I like the fact that I can plan for a longer time, and should my funding run out, I know that the study or site can be easily used by someone else to keep it going. There is great research history there and I will be taking advantage of its availability."

Dr. Meng is currently working with a variety of partners to erect an environmental tower that will measure ecological parameters such as soil respiration, weather and carbon monitoring. The hope is that many scientists can benefit from its monitoring abilities. Researchers will be able to save money by not having to measure all the ecological parameters separately.

*Debby Barsi, Natural Resources Canada, and John Butner, U.S. Department of Agriculture, are conducting climate change research at the Petawawa Research Forest.*

*Edwin Swift, a forester with Natural Resources Canada, explains to forest practitioners some of the commercial thinning trials that are being conducted at Acadia Research Forest.*

Dr. Mike Wotton, a researcher at the University of Toronto, helped develop a collaborative new graduate program focused on forest fire behaviour research with Natural Resources Canada. "The research forest has staff and a network of former staff available for consultation. This, coupled with the possibility of working in stands that have been monitored and characterized in detail under many situations for decades, is unique and exceptionally valuable," says Dr. Wotton.

"The forest offers an established base from which to operate. I am able to go there or even just pick up the phone and say 'I'd really like to do some work in a stand that has qualities X,Y,Z' and within a short time I have a number of options presented to me. It is really exceptional," says Dr. Wotton. "In addition, the location is staffed daily and there is radio contact over the entire property. As a supervisor of research assistants and graduate students, this is very attractive from a safety and logistics point of view."

Research activities at the national research forests have covered most of the topics in forestry at one time or another, responding to the changing research priorities of the forest industry. Some of these research studies and potential collaborative opportunities include:

- enhanced forest productivity through silviculture treatments;
- biological evaluation of alternative harvesting treatments;
- forest health;
- forest vegetation management alternatives;
- forest diversity and natural succession;
- biodiversity;
- provenance trials using seed from various locations; and
- clonal studies including somatic embryogenesis.

Universities, colleges, and provincial governments are already taking advantage of the opportunity to collaborate with Natural Resources Canada at these forests. For instance, the Ontario Ministry of Natural Resources, along with partners like the University of Montreal, Bowater, and the Forest Engineering Research

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# Shifting regeneration subsidies - A route to saving money and restoring temperate forest

It is not possible to calculate revenues from forest operations as they depend on unknown future market demand for species and dimensions of material harvested. Growing wood profitably for delivery to processing industries has two main expense drivers: the cost of re-establishing 'free-to grow' trees after harvest intervention and the cost of harvesting mature trees.

On New Brunswick Crown land, after conventional large block clear cut harvesting operations are carried out, silvicultural operations are required to assure the establishment of trees (by plantation) and/or to assure that excess natural regeneration does not result in stagnating over-dense stands (by pre-commercial thinning). The expense for this silviculture is borne by provincial taxpayers.

In the presettlement temperate mixed wood forests of eastern Canada (Acadian and Great Lakes-St. Lawrence), large scale catastrophic regeneration dynamics (fire, wind, insects, and disease) were not as important as those drivers of forest renewal are in the boreal forest. Renewal, in large portions of these temperate mixed wood forests, occurred in small scale gaps that were scattered across the landscape. New growth was initiated by advance regeneration or the establishment of germinating seeds from nearby exposure-prone species with varying degrees of shade tolerance.

Large canopy openings, on almost all 'unrestrained' Crown land, became more predominant due to the low cost. The hot, dry postharvest regeneration microclimates following these harvests resulted in the replacement of exposure-prone temperate, long-lived temperate species such as red spruce, eastern hemlock, white cedar, sugar maple, and white ash by such exposure-resistant, short-lived boreal species such as balsam fir, jack pine, black spruce, eastern larch, white birch, and trembling aspen.

A lack of adequate regeneration of late-successional temperate species and the domination of harvested areas by insect-prone boreal softwoods (especially balsam fir) and shade intolerant hardwood species, not highly valued by markets, led to the adoption of very expensive, taxpayer-funded plantation silviculture. Plantations deployed less insect prone boreal softwood species that produced the fibre quality desired by export markets. The maintenance and expansion of these exports depended on consumers whose affluence was driven by cheap and abundant fossil fuel supplies, while energy depletion is expected to dominate future market conditions.

*Strip cutting to regenerate exposure-prone tree species.*

The economic and population growth that has driven Canadian forest product export markets is not expected to continue. Accordingly, predictions on the type of forest products that will be in demand when trees beginning life now reach the age where they can be harvested are based on speculation.

As large block clear cut harvesting has continued, so too has the expensive taxpayer funded plantation silviculture that was instituted to deal with its biological results. The cost of mechanical site preparation, planting, and chemical control of hardwood competitors usually exceeds $1,000 per hectare. If this establishment/reforestation expense/investment is carried forward at 4% interest for a 60 year rotation, it would total $10,520.

Studies have shown that harvesting methods (patch and strip cutting with side selection) that approximate gap dynamics will produce good, inexpensive natural temperate species regeneration. This is because these exposure-prone species require the cooler, moister regeneration microclimates that characterize small canopy openings. A shift toward increased alternative harvesting that approximates gap dynamics would allow some remedial planting of nursery-grown temperate species in areas where they have been totally replaced by boreal species as a result of a history of large canopy opening harvests, site preparation, plantation, and herbicide application. Thus, a move away from relatively inexpensive large canopy opening harvests toward somewhat more costly gap approximating harvests would incrementally affect a gradual restoration of the temperate forest species assemblage. The boreal species assemblage, that increasingly dominates temperate forest sites, is expected to be considerably stressed if current climate warming continues into the future. Temperate forest species assemblages are expected to be able to adapt to these climate stresses more readily.

Increased costs as high as 6% or $2.50 per cubic metre for alternative harvesting were recently described in a report entitled "Management Alternatives for New Brunswick's Public Forest" (1). These costs are usually borne by the Crown lease holder. In the present funding climate, Crown forest lease holders would be reluctant to change their harvesting behaviour.

If taxpayer funding were slowly shifted from the large block clear cutting/boreal species plantation silviculture that has become the method of choice, toward support for gap approximating harvest methods that mainly rely on natural regeneration, then increased

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and time. Each process or issue (e.g., decomposition) or species of interest (e.g., caribou (Rangifer tarandus)), needs to be considered and viewed at an appropriate scale.

Human intervention does not necessarily mean that forest ecological processes are undermined or no longer intact. The assumption that forestry activities are completely incompatible with forest resilience (the ability of a forest to recover following disturbance) is inaccurate. Harvesting, carried out in a sustainable manner, need not detract from the maintenance of ecological processes and biological diversity. The evidence from both human-caused and natural disturbances suggests that forests can retain their resilience and recover following a disturbance.

**Protected Areas**

As of 2005, Canada had protected approximately 98 million hectares of land, which represents about 9.9% of the country's total land base. About 8% of the land area of the Boreal Shield and Plains ecozones are protected. Of these protected areas, 95% are within International Union Conservation of Nature (IUCN) Categories I to IV[1], which largely prohibit industrial activities such as forestry, mining, and hydroelectric development (5).

When setting targets for protected areas, it is important not to resort to arbitrary numbers. Simple targets are not enough. Targets should be based on factors such as natural disturbance regimes, species distributions and habitat requirements, maintenance of biodiversity and viability of natural populations, climate change adaptation, and maintenance of ecological processes. As well, land tenure, governance, land base and extent, species presence, and land ownership all require consideration in setting such targets.

Given the natural disturbance patterns in the boreal forest, we need to employ all categories of protection, including those areas under sustainable forest management planning, if we wish to have effective conservation. Conservation has to go beyond protected areas to enable linkages, connectivity, and effective population and species management across the broader landscape and over time.

**Web-based citations:**

(1) http://canadaforests.nrcan.gc.ca/articletopic/top_suj/12/articles

(2) http://www.forestry.gov.uk/pdf/prog-aw-practice-guide.pdf/$FILE/prog-aw-practice-guide.pdf

(3) http://cfs.nrcan.gc.ca/subsite/oldgrowth/brochure

(4) http://www.iucn.org/resources/publications/index.cfm?uNewsID=1662

(5) http://www.cws-scf.ec.gc.ca/publications/habitat/cpa-apc/index_e.cfm

[1]The IUCN defines protected areas as "*a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*." For international reporting purposes, the IUCN has defined six protected area management categories based on primary management objectives. They range from Category I (managed mainly for science or wilderness protection) to Category VI (managed mainly for the sustainable use of natural resources).

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Institute, have established a 20-year study at Petawawa National Research Forest to examine the effects of natural disturbance and silviculture on tree survival, growth, wood quality, and species and genetic diversity on mixed-wood white pine stands. This fundamental research will help forest practitioners maintain or enhance fibre quantity and quality, maintain soil and water resources, conserve biological diversity, and reduce the risk of losses to fire, insect, or disease.

Through collaborative research at these forests, many important questions plaguing the forest industry will be addressed. The knowledge gained from this research will continue to enhance forest management practices around the world.

**To learn more about the forests or opportunities for collaboration, visit:**

***www.cfs.nrcan.gc.ca/subsite/researchforests***

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costs per hectare would be expected to be about $350 if the average harvest is 140 cubic metres per hectare. If this establishment/reforestation expense/investment is carried forward at 4% interest for a 60 year rotation, it would total $3,682. The difference in the two forest renewal approaches is at least $6,838 per hectare. The shift in forest renewal funding (or decrease in royalties/stumpage) to support alternative harvesting would result in a more resilient, climate adaptive, and diverse forest that offers increased management and market flexibility. Pre-commercial thinning, needed to avoid stagnation caused by overstocking, is often necessary for both naturally regenerated stands and plantations. Commercial thinning that can produce an operating profit allows management to shift growth onto the type of trees that markets appear set to require at final harvest.

Wood from eastern temperate forest lands faces decreased future demand as conventional dimension lumber and pulp and paper, but increased demand from the bioeconomy as the ‘new petroleum’ for its carbon-carbon bonds that will replace those formerly gleaned from fossil fuels. Concern with species and fibre attributes that have dominated markets in the recent past would be expected to be less important under such conditions. In the context of uncertain future forest fibre markets, there can be no assumption that demand for long fibre from boreal softwood species will continue to the rotation age of trees being planted now. While intensive plantations have the potential to produce superior volumes of wood, cost-benefit analysis for this increased production is not possible without knowledge of future market demand.

Changing the character of the forest, from one dominated by large clear cuts and plantations to one that approximates the natural distribution of small gap openings, may decrease pressure from public interest groups that wish to set aside increasing amounts of forest land in preserves, where no harvesting is allowed, in order to provide a representation of natural forest remnants on the landscape.

(1) ‘Management Alternatives for New Brunswick’s Public Forest’ http://www.gnb.ca/cnb/Promos/Forest/pdf/ErdleReport-e.pdf

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A pan-Canadian study is currently being carried out on *P. balsamifera* in collaboration with B. Schroeder (Agroforestry Division of Agriculture and Agri-Food Canada).

**Conclusions**

- The existence of plantations of sexually mature poplar enabled us to study the spread of exotic genes to adjacent natural populations of *P. balsamifera* and *P. deltoides*. Our results show clearly that hybridization between introduced species and native species can occur locally, particularly in small populations of native species.
- The risk of sustained introgression also depends on the ability of the hybrids to become established and reproduce in natural forests. Our preliminary results show that this is possible, although the frequency of the phenomenon appears to be low. To permit more accurate assessment of the risks, this phenomenon needs to be quantified to a greater extent and efforts need to be devoted to obtaining a more precise picture of the main genetic and ecological factors favouring the introgression of exotic genes.
- The empirical data obtained are also being used to develop and refine a predictive model for assessing the medium- and long-term impacts of the spread of exotic genes or new combinations of genes on the genetic diversity of native species.

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**For more information:**

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