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INVASIVE NON-INDIGENOUS SPECIES

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INTRODUCTION

Natural geographic barriers have separated species from interacting since soon after life began on Earth. Oceans, mountain ranges, rivers and deserts have prevented species from mixing and have allowed the development of distinct ecosystems with their own unique set of organisms. Since the dawn of exploration, however, humans have transported organisms, whether inadvertently or for a purpose, across these natural barriers. With increasing volumes of international trade and movement of people, the rate of introduction of species into ecosystems that would normally be beyond their range of distribution has increased enormously. All types of organisms are transported including disease-causing viruses, bacteria, fungi, algae, mosses, ferns, flowering plants, invertebrates, fish, birds and mammals. Without human intervention, few if any of these diverse organisms would be found in the new location. The chances of cattle or Zebra Mussels or the West Nile Virus being transported naturally from their native ecosystems, half a world away, to Canada, is so small as to be virtually discounted.

Non-indigenous species provide many economic benefits. Historically, they have formed the backbone of the agricultural sector. In the United States, they provide more than 98% of the food system at an estimated value of $800 billion (U.S.).(1) Increasingly, however, the costs of introduced species are being recognized, both in economic terms and in loss of species diversity on a global scale. Further focus on this issue has been created by discussion in the popular press of some recent introductions such as Zebra Mussels and the West Nile Virus. While the global movement of human diseases such as smallpox, influenza and HIV/AIDS is also important, the issue of humans as international vectors for disease will not be discussed. This paper will focus on the problem of invasive non-indigenous species, and some of the action being taken to minimize further economic and ecological damage on national and global scales.

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(1) David Pimentel *et al*., "Environmental and Economic Costs of Nonindigenous Species in the United States," *BioScience*, Vol. 50, January 2000.

THE NATURE OF INVASIVE SPECIES

Isolation of organisms caused by geographical barriers has led to the development of distinct species adapted to various environmental conditions. Some organisms, called specialists, have evolved to require very specific environmental conditions. Should the environment change, or should they be transported to an environment at all different from that to which they are adapted, they will not survive. Others can survive and thrive under a wide range of conditions and have been described as generalists.

When an organism is moved from its natural habitat to another beyond the range it occupies naturally, and could not occupy without human intervention, it is called non-indigenous.(2) What occurs subsequent to its introduction will depend on the nature of the organism and the environment. A plant, for instance, which hitches a ride from the tropics on a transport bound for Alaska is less likely to survive in its new home than one which moves from Europe to temperate Canada. Likewise, a generalist organism is more likely to survive than is a specialist. The large majority of non-indigenous plants do not become invasive; they remain restricted to urban, or other highly disturbed areas, as small-scale garden escapes. Others, such as the Dandelion, can be found in less disturbed, more natural habitats, but do not seem to pose a problem to the native flora and fauna. Many of the non-indigenous plants that survive and thrive are weed species adapted to sites that undergo regular disturbance, such as urban areas and agricultural fields. Such organisms grow rapidly; and they frequently produce abundant seeds, often with dissemination aids, that remain viable for long periods of time.(3) However, it is the small group of plants that thrive in agricultural and natural habitats at the expense of crops and natural plants, which are deemed to be invasive and economically and ecologically harmful.(4) Such invasive species usually have few predators to keep their numbers in check. Invasive non-indigenous animal species have similar characteristics, such as a wide environmental tolerance, rapid reproduction and few natural predators.

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(2) Other terms for non-indigenous used in the literature include: exotic, alien, non-native and foreign.

(3) Erich Haber, Invasive Exotic Plants of Canada, Fact Sheet No.1, http://infoweb.magi.com./~ehaber/fact1.html, National Botanical Services, Ottawa.

(4) Canadian Wildlife Service, Invasive Plants of Natural Habitats in Canada, http://www.cws-scf.ec.gc.ca/habitat/inv/index_e.html

Non-indigenous species arrive and spread by a number of different means, either intentional or unintentional. Intentional introduction of species can occur for many reasons, e.g., agricultural or horticultural purposes. The large proportion of non-indigenous plants in Canada are ephemeral garden escapes of deliberately introduced species.(5) Such garden escapes can, however, have drastic consequences, as has happened with the Old World Climbing Fern in the everglades of Florida. Someone emptying an aquarium into a natural system most likely introduced the imported Eurasian Milfoil, a decorative aquarium plant, which is infesting many waterways of Canada. Others are imported in attempts to control a pest. The Common House Sparrow was introduced in an unsuccessful attempt to control the Canker Worm. Still others are brought in for more esoteric reasons. In one well-known case, someone who wanted to bring all the birds mentioned in the works of Shakespeare to the United States introduced the European Starling.

A more recent type of deliberate introduction has occurred through aquaculture. Farmed Atlantic Salmon have escaped off the coast of British Columbia, and some of them have been found in breeding streams and caught by fishers.(6) Though the escaped salmon do not seem to have established themselves as invasive, the worry is that they may compete for breeding areas and for food with the native species. The same seems to have occurred on the east coast of Canada regarding escaped exotic Rainbow Trout.(7)

Unintentional introductions of non-indigenous species occur as a result of organisms "hitchhiking" on various modes of transport. Ballast water is a common means of transport for many of the aquatic invasive non-indigenous species. Ships without cargo need to take on water in order to remain stable at sea. When this water gets exchanged for cargo at another port, the water – and any organisms in the water – are released into the new system. Zebra Mussels were introduced into the Great Lakes in this manner. The Brown Tree Snake was most likely introduced into Guam in the wheel well of an airplane with devastating results to the native populations of organisms. The most likely means by which the West Nile Virus arrived was in a shipment of infected birds, either pets or agricultural. The Brown Spruce Longhorn

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(5) *Ibid*.

(6) Associated Press, "Alaska Worried About Threat Posed by Atlantic Salmon: Concerns include diseases, competition for food," *Times Colonist*, 28 August 2000.

(7) Paul McKay, "'Ultimate' Invader Threatens Salmon: Aquaculture Complex Suspected Source of Rainbow Trout," *Ottawa Citizen*, 15 June 2000.

Beetle, recently confirmed in Halifax's Point Pleasant Park, is thought to have arrived on wooden packing crates. The more goods that are shipped around the world, the greater will be the chances of inadvertent introductions of non-indigenous species.

A minority opinion holds that non-indigenous invasive species cause no real ecological harm and that their economic harm should not be treated any differently than native pests.(8) This argument states that ecological arguments against non-indigenous species are strictly aesthetic, that ecosystems are always in a state of change, and that proliferation of so-called alien species cannot be differentiated from natural changes in the abundance of native species. Thus to argue that invasive non-indigenous species are bad is strictly a matter of aesthetic values and not one of science. While one person may like a lake surrounded by natural stands of cattail, another would rather view the more colourful Purple Loosestrife. Equally, the economic damage caused cannot be differentiated from damage caused by native pests. In fact, it is argued, many unintentional non-indigenous species, such as Zebra Mussels, are beneficial to the environment because, for example, they increase water clarity.

The credibility of such arguments is diminished by a lack of scientific rigour and the use of a few select facts, such as water clarity, taken out of context of the broad base of scientific studies.(9) While water clarity may seem to be a good thing, it is the result of the Zebra Mussels stripping the nutrients and plankton out of the water, which drastically changes the food chain in the lakes. In addition, many species, such as the commercially important Walleye, prefer more turbid waters. The general consensus is that the global movement of organisms as a result of human activity is causing serious ecological and economic damage.(10)

THE NATURE OF ECOLOGICAL DAMAGE

The most severe ecological damage caused by invasive non-indigenous species occurs on islands. The flora and fauna of islands can evolve in almost complete isolation, which results often in species that are endemic, i.e., they are not found anywhere else but on the island.

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(8) Ronald Bailey, "Preaching Ecological Xenophobia: Ronald Bailey Asks: Are We Really Under Attack by 'Non-Native' Species? Should We Care?" *National Post*, 3 August 2000.

(9) Hugh MacIsaac and Anthony Ricciardi, "Why We Shouldn't Let the Bugs In," *National Post*, 9 August 2000; see also Paul Ehrlich and Anne Ehrlich, *Betrayal of Science and Reason*, Island Press/ Shearwater Books, Washington, D.C., 1996.

(10) See Science, Vol. 285, 17 September 1999.

The introduction of a predator into such specialized ecosystems can wreak havoc. The introduction of the Brown Tree Snake into Guam has caused the direct extinction of 10 of 13 forest bird species and 9 of 12 native species of lizards.(11) Since the arrival of humans on Hawaii, approximately 2000 years ago, 70 of the 140 known species of birds have become extinct, and invasive species are a major culprit.(12)

Continental species also suffer as a result of non-indigenous invasive species. Zebra Mussels have displaced most native mussels from both Lake St. Clair and Lake Erie, populations that have a natural history of over 10,000 years.(13) Approximately 40% of the species listed in the United States *Endangered Species Act* are threatened primarily as a result of competition from invasive non-indigenous species.(14)

Although some ecosystems may actually have more species after an invasion, there is mounting evidence that the opposite occurs more frequently. In one study of ant populations, a reversal in the normal trend of increasing biodiversity with more tropical climates was seen along a study route from Florida to New York, a trend that was correlated with the presence of the invasive Fire Ant. Even if an invasive non-indigenous organism did add to the biodiversity of a habitat, the tendency is that most invasive species are the same, such that, on a larger scale, biodiversity is lost as the world becomes a "planet of weeds."(15)

THE ECONOMIC COSTS

While non-indigenous species have traditionally been seen as beneficial in terms of the agricultural and horticultural sectors of the economy, it is becoming clear that the invasion of non-indigenous species carries significant costs. These costs are very difficult to estimate, but one recent attempt estimated costs to the U.S. economy at more than $130 billion (U.S.) per year.(16) The overwhelming costs were borne by agriculture, the industry that also benefits the most from introduced species. The total costs to the U.S. agricultural sector of loss and damages

(11) Pimentel *et al*., January 2000.

(12) Richard Stone, "Keeping Paradise Safe for the Natives," *Science*, Vol. 285, 17 September 1999.

(13) MacIsaac and Ricciardi, 9 August 2000.

(14) Pimentel *et al*., January 2000.

(15) David Quammen as cited by Joel Achenbach, "The Invaders: Local Plants and Trees are Buried Alive as Foreign Species With No Natural Predators Mount a Full-Scale Assault," *Montreal Gazette*, 5 August 2000.

(16) Pimentel *et al*., January 2000.

combined with control of weeds, crop plant pathogens, rats, crop pests and livestock diseases amounted to more than $80 billion (U.S.). Other studies, although they vary in what they are attempting to estimate, confirm that invasive non-indigenous species cost the global economy many billions of dollars every year. Losses in biodiversity will, presumably, lead to unknown economic losses in the future.

WHAT CAN BE DONE: PREVENTION AND CONTROL

Article 8(h) of the Convention on Biological Diversity, which Canada has ratified, states that Contracting Parties, as far as possible and as appropriate, shall "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." It is generally agreed that preventing the introduction of non-indigenous invasive species is cheaper and more effective than trying to control them after they have arrived.(17) The difficulty is in predicting what the next invader will be. While invasive species seem to have certain characteristics in common, there are no predictive models that can clearly identify what will become an invasive species.

Predicting when an invasion will occur also remains problematic. Some introduced species remain innocuous for years and only then, for mostly unknown reasons, become invasive. The introduction and invasion of Zebra Mussels into the Great Lakes had been predicted since the 1920s; however, the invasion did not occur until the late 1980s. Presumably some environmental factors play a role in determining when a species might become invasive. For Zebra Mussels, it is theorized that improving water quality in the Great Lakes facilitated invasion. Climate change may also play a role in what becomes invasive.(18) Without a means to predict what species may invade under which circumstances, it is very difficult to control their entry.

Attempts can be made, however, to minimize introductions by identifying pathways that are known to be at high risk for causing introductions, such as ballast water and wooden packing crates. Once identified, these routes can be regulated in a manner that minimizes entry of organisms, without having to identify particular organisms as potentially

(17) IUCN (World Conservation Union) Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species, February 2000.

(18) Martin Enserink, "Biological Invaders Sweep In," *Science*, Vol. 285, 17 September 1999.

invasive. In the case of wooden packing crates, the Canadian government is increasing vigilance at ports and is leading discussions on the development of an international solid wood packing material standard. There are many efforts on many scales to try and minimize the transport of organisms through ballast water.

A. The Problem of Ballast Water

Over ten billion tonnes of ballast water annually are transferred around the globe, potentially carrying thousands of species.(19) The Zebra Mussel, introduced into the Great Lakes by ballast water, has infested over 40% of waterways and has caused billions of dollars worth of damage and control costs. The introduction of the Comb Jelly Fish into the Black Sea in 1982 virtually destroyed all fisheries at a cost of $500 million (U.S.) annually.(20)

A number of actions can be taken to control entry of organisms through ballast water. The United Nations International Maritime Organization (IMO) has produced guidelines for the management of ballast water that include such measures as: minimizing uptake of organisms by choosing when and where to take on water; regular cleaning of ballast tanks; discharge to on-shore holding facilities; and exchange of ballast water at sea. The fourth method is thought to be effective because salt-water organisms generally will not survive in fresh water. It is not perfect, however, particularly if a lot of sediment remains in the ballast tanks and if water is taken on from an area that has organisms with a wide salt tolerance, such as can be found in the Black Sea. Other means being studied are more intensive and involve, for example, filtration of water, sterilization by UV light or biocides, and the addition of predators to the tanks. Currently, the United Nations IMO guidelines are voluntary; however, work is progressing to incorporate them into a legally binding convention, perhaps as an annex to the International Convention for the Prevention of Pollution from Ships (MARPOL).

Various governments and international organizations have in place a variety of guidelines or laws to try and control this route of entry. The most common method is to require ships to exchange ballast water at sea. The *Canada Shipping Act*, as amended in June 1998, includes the authority to regulate ballast water; however, ballast water control remains voluntary.

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(19) Global Ballast Water Management Programme, UN Moves on Alien Invaders, Media Release, 10 July 2000.

(20) *Ballast Water News*, Issue 1, April-June 2000.

False declarations regarding ballast water management have been successfully prosecuted under this *Act*. The United States has had mandatory regulations requiring ballast water exchange for ships destined for the Great Lakes since 1993. Both Canada and the United States report high levels of compliance; however, a 1995 report noted that only 50% of vessels entering the seaway submitted Canadian-requested reports on the procedures followed for ballast water management.(21) The current ballast water exchange programs – such as the Vancouver Port Authority mandatory ballast water exchange program – may only require an 85% exchange, which is insufficient to dilute the ballast water to lethal levels for many organisms. One option would be to require a three times exchange at sea, which is more effective. However, no ballast water management program will ever have a 100% success rate, short of requiring biocide use. Such programs can be used only to reduce risk.

Another problem with most ballast water regulations is that they only encompass ships with ballast. Ships that have cargo, or so-called NOBOBs (no ballast on board), are not regulated but contain some unremovable sediment and water. These have been identified as high-risk ships, especially if they enter the Great Lakes, unload their cargo, and then take on ballast water to go to another port within the Great Lakes.

Regulations regarding management of ballast water are one of the few ways by which unintentional introductions of invasive species can be mitigated. Some other countries, particularly ones that have a history of significant invasions, have more stringent rules such as the fumigation of arriving aircraft. Even with tight regulation and relatively easy access to arriving transport, invasive species will still enter. With the ever-increasing traffic in goods, unintentional arrivals will increase in numbers. Intentional species introductions are another problem and can be addressed through import restrictions of pest organisms.

B. Prevention Through Legislative Restrictions on Importation

Many countries have import restrictions on animals and plants, particularly to prevent harm to domesticated plants and animals. In Canada, the statutory authority to restrict the movement of plants and animals is derived from a number of *Acts*. The *Plant Protection Act* is designed to “prevent the importation, exportation and spread of pests injurious to plants and to

(21) Proceedings of Maintaining Biological Integrity of the Great Lakes: Preventing Harmful Invasions, International Joint Commission, 25 September 1995.

provide for their control and eradication and for the certification of plants and other things." A plant pest is determined through a risk assessment process as outlined by the North American Plant Protection Organization, NAPPO Standard for Plant Pest Risk Analysis, a standard largely based on potential economic harm. NAPPO is a regional organization of the International Plant Protection Convention (IPPC) of the Food and Agriculture Organization (FAO) of the United Nations. The pests regulated by this *Act* include obvious problem organisms such as various crop diseases and predators but also include some true aquatic plants such as Hydrilla and Eurasian Milfoil, which are defined as pests and whose entry into Canada is prohibited. However, because the Eurasian Milfoil is already in Canada – and Hydrilla is widely touted as being the next invader of the Great Lakes, it having already spread from Florida to Pennsylvania(22) – there seems little power in this *Act* to prevent invasions without correctly identifying possible invaders and classifying them as pests, before they invade. The IPPC has been recently amended to be in accord with World Trade Organization phytosanitary standards, which exist to ensure that nations do not use entry of potential threats as a technical barrier to trade. Because species must be shown to be economically harmful before action can be taken, the IPPC does not seem to be a very powerful tool to be used as a precautionary measure to avoid invasions.(23)

In a similar manner, the *Health of Animals Act* is "An Act respecting diseases and toxic substances that may affect animals or that may be transmitted by animals to persons, and respecting the protection of animals." Importation of some invasive non-indigenous species is prohibited under this *Act*. The *Honeybee Prohibition Importation Regulations* of the *Act*, for example, are designed to prevent the importation of honeybees from the U.S. because of the invasive Varroa mite, that was first found in that country in 1987. In fact, the honeybee is a European import that has largely taken over the position of pollinator from the native pollinators for many insect-pollinated plants, making it one of the most important insects from both an ecological and an economic point of view. Because the honeybee was so highly invasive after its introduction, it is now making those plants and industries which depend on it vulnerable to other

(22) Phil Surguy, "Waiting for the Unwary: Human Inadvertance Will Probably Bring to the Great Lakes a Weed That Knows No Limits," *National Post*, 20 June 2000.

(23) Chris Bright, *Life Out of Bounds, Bioinvasion in a Borderless World*, W.W. Norton & Company, New York, 1998.

invasive diseases and pests of honeybees such as the Varroa mite.(24) So far, for a combination of reasons including import restrictions, the mites have not become a serious problem in Canada. Ironically, the invasive African honeybee, the so-called killer bee, is being touted by some as a remedy to the mite because it is more resistant to the mite than is the European honeybee.(25)

The *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* (WAPPRIITA), although largely designed to prevent the importation and movement of plants and animals listed in the Convention on international trade in endangered species of wild fauna and flora (CITES), also has clauses to prevent the introduction of harmful species into Canada. Schedule II of the *Wild Animal and Plant Trade Regulations* contains a list of such species for which importation is prohibited. The list is currently limited to the Racoon dog, a number of genera of mongoose, and a few birds.

A fourth *Act* that can have the effect of preventing the importation and spread of potentially harmful species is the *Seeds Act*. However, this *Act* is designed to maintain crop seed quality rather than to prevent the spread of invasive non-indigenous species in natural systems. Of the 44 species listed in the Canadian Wildlife Service publication *Invasive Plants of Natural Habitats in Canada*, the *Seeds Act* lists three that are prohibited noxious weeds, one that is a primary weed and another that is a secondary noxious weed. Prohibited weeds are not allowed in seed lots while the level of harm and abundance of other noxious weeds are used to designate a seed lot quality.

The federal *Seeds Act* has been described as having potential only as a weak preventive measure for control of invasive non-indigenous species. Provincial Weed Acts have greater potential to require control of noxious weeds and many empower municipal governments to list species as being noxious weeds.(26) However, the listing of a species as a noxious weed may not be of much benefit to the natural environment because most control measures are designed for urban or agricultural purposes and may not be appropriate in natural settings where they may also harm the native flora.

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(24) *Ibid*.

(25) Debora MacKenzie, "A Kinder, Gentler Killer," *New Scientist*, 1 July 2000.

(26) See the Canadian Wildlife Service publication *Invasive Plants of Natural Habitats in Canada* for a more detailed description of Provincial Weed Acts as they relate to invasive non-indigenous species.

C. Prospects for Eradication and Control

Although it is generally recognized that prevention is better than trying to eradicate or control invasive non-indigenous species once they are established, there is often no other possibility than to react to an invasion after it has occurred. For a well-established species, eradication is often impossible and there is little alternative but to attempt to control its spread.

As stated in the World Conservation Union (IUCN) Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species, control and eradication of invasive non-indigenous species is far easier with informed and co-operating local communities, appropriate sectors and groups. In Australia, where, according to some accounts, the "average taxi driver" is aware of the serious consequences of invasive species, it is far easier to mobilize public support for drastic measures to eradicate them.(27) At Easter in 1999, divers found a highly invasive small mussel, similar to the Zebra Mussel, in three marinas in the vicinity of Darwin. Within five days the Australian government had, despite boaters' protests, quarantined the marinas and soon thereafter had killed everything in the water with a mixture of chlorine and copper. No mussels have been seen since and the natural biota is beginning to return. A highly invasive species of algae which has been causing great damage in the Mediterranean region has been tentatively identified in a California lagoon causing a consortium of agencies to cordon off the lagoon in preparation for eradication.(28) In Canada, a park in the Halifax Regional Municipality has recently been put under federal quarantine and thousands of Red Spruce are being destroyed in an effort to eradicate the Brown Spruce Longhorn Beetle (BSLB).(29)

The ease of eradication will depend to a large extent on how well the invasive non-indigenous species has established itself. This in turn will depend on how early the infestation is determined. The BSLB has actually been in the park in the Halifax area since 1990, but at the time, samples taken were misidentified as a North American species. Had the samples been correctly identified, an earlier pest risk assessment may have saved a lot of the trees that are currently being destroyed. Clearly, detailed monitoring and acute vigilance is required to identify possible invaders at the earliest stage possible, particularly when the threat is to one of the biggest industries in Canada, such as forestry.

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(27) Jocelyn Kaiser, "Stemming the Tide of Invading Species," *Science*, Vol. 285, 17 September 1999.

(28) Jocelyn Kaiser, "California Algae May be Feared European Species," *Science*, Vol. 289, 14 July 2000.

(29) Canadian Food Inspection Agency Press Release, 30 May 2000.

If the early stages of an infestation are missed and the species becomes established, it is often very difficult to eradicate. There are some examples of eradication of established species, such as the Nutria, a rodent introduced for the fur industry in the United Kingdom. Such eradications are, however, rare and very costly. Controlling established invasives is usually all that can be hoped for.

Control of invasive non-indigenous species can occur through a number of means. Because most invasive non-indigenous species are adapted to disturbed landscapes, one method of limiting their spread is by limiting the level of disturbance of the landscape. This is not an easy task given the amount of, and need for, agricultural land. Physical methods of cutting plants and trapping organisms may have limited success, particularly in the case of plants that produce seeds which have an extended dormancy or with aquatic plants which can propagate from the small pieces created by cutting. That being said, the eradication of the Nutria was performed through a massive trapping campaign.

Various methods of poisoning can be used. Clearly, the more specific the toxin is to the target the better. The Sea Lamprey – which established itself in the Great Lakes and devastated the Lake Trout population after the completion of the canal systems that form the St. Lawrence Seaway – has been largely controlled through the use of a very specific toxin directed against the larval stage of its lifecycle. The effectiveness of a toxin will depend on knowledge of the physiology of the target, when the organism is most susceptible to it, and exactly how it is delivered. Basic research on the life history of the target is thus essential to increase effectiveness and decrease the chance of affecting non-target organisms.

One of the most promising, though often risky, methods for long-term control is through biological control. Non-indigenous species can become invasive, in part because they may have very few predators or diseases. Thus, the introduction of a predatory organism or disease from the invasive species' native habitat could theoretically establish a balance and keep the growth under control. This type of control also requires a great deal of basic research prior to release to ensure that the introduced organism doesn't affect native plants or animals. The openness of the research process is also important. In Australia, a virus was being studied on an island; the virus, which was going to be released against rabbits on the mainland, escaped. It has apparently been a success in controlling rabbit populations, but has raised much concern

regarding the openness and transparency of the study.(30) In an age where people have heightened concerns over release of organisms, either genetically modified or non-native, it is essential to keep the public informed of the procedures being followed.

In the past, many errors have occurred in the introduction of species for biological control. The English (House) Sparrow, introduced into North America to control the Canker Worm, has since become a pest without affecting the Canker Worm. Other introductions of biological controls have turned into a fool's game of having to introduce a series of control organisms to control the latest unsuccessful attempt at biological control.(31) Many of these examples of failures are derived from past mistakes, particularly associated with vertebrate introductions, that would not occur given today's more stringent standards, though errors still do occur. As has been pointed out, however, the risks associated with the introduction of a biological control agent cannot be weighed in a vacuum, but must be rated against the risks of doing nothing or using other control mechanisms such as pesticides.(32) Agriculture and Agri-Food Canada has been primarily responsible for the approximately 70 exotic insect species that have been released since 1952 in an effort to control 21 weeds, largely of importance on rangeland.(33)

CONCLUSION

Prevention, eradication and control of invasive non-indigenous species requires co-operation at the international, national, provincial and community levels. The introduction of invasive species through primarily inadvertent means can best be approached by identifying pathways at high risk of allowing introductions, such as ballast water and shipping materials. Addressing the problem can occur through legislation on a national level, but ultimately will require international co-operation and possibly binding conventions, such as has been suggested for MARPOL with respect to ballast water and a convention on shipping materials to prevent such introductions as the BSLB in Halifax. Given that introductions will continue to occur, it is

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(30) Elizabeth Finkel, "Australian Biocontrol Beats Rabbits, But Not Rules," *Science*, Vol. 285, 17 September 1999.

(31) Bright, 1998.

(32) David Pimentel, "Biological Control of Invading Species," *Science*, Vol. 289, 11 August 2000.

(33) Lethbridge Research Centre, Crop Sciences Section, Biocontrol Project, http://res2.agr.ca/lethbridge/crops/bioproj.htm#declerck

essential that a comprehensive monitoring plan be in place and, should an invasion be found, steps be quickly taken to eradicate the organism.

Clearly, the federal government has a role to play in research. Research is necessary to develop best practices for eradication and control, develop preventive legislation, and monitor non-indigenous species' movements. Monitoring is an important aspect in mitigating this problem, and such projects as the Invasive Plants of Canada (IPCAN) project are invaluable.

Other international efforts, such as the International Plant Protection Convention and the World Trade Organization's phytosanitary standards, currently emphasize the economic implications of trade in goods. Because of the emphasis on facilitating free trade and the potential for the use of phytosanitary standards as a non-tariff trade barrier, however, there would seem to be little in these documents that could be used as a precautionary invasion-fighting tool.(34) Action on article 8(h) of the Convention on Biological Diversity, through implementation of the IUCN guidelines, may be better able to prevent invasions for strictly ecological reasons. With many international agreements that touch on this issue, the potential for conflict between agreements is high.

Currently, legislation in Canada, as in most of the world, is primarily designed to prevent damage to agricultural crops. Legislation to address the impact on natural systems is lacking, although WAAPRIITA could presumably be used more effectively for this purpose. With many laws and government agencies involved at all jurisdictional levels, co-ordination is of paramount importance. Recognizing the importance of the invasive non-indigenous species issue, and the *ad hoc* manner in which this problem is approached, United States President Bill Clinton signed Executive Order 13112 in February of 1999. In part, this Executive Order created an Invasive Species Council with the mandate to produce an Invasive Species Management Plan, one that would help co-ordinate the fight against invasive non-indigenous species. The draft plan seems to have been received well.

Above all, an informed public is necessary to help alleviate the problem. If people continue to transport organisms unknowingly, or to plant organisms such as Purple Loosestrife in their gardens, it will be next to impossible to prevent the spread of harmful invasives. In addition, many of the control projects currently underway depend on informed volunteers. An informed public is also necessary to create the political will to allow for the formation of strong legislation and to take decisive action upon the discovery of a potential invasive non-indigenous species.

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(34) Bright, 1998.