Invasive Species

Key Findings

- Biological invasion and the diversity and abundance of species spreading beyond their natural ranges are at the highest rates ever recorded with serious consequences for the environment, economy and human health.
- A significant increase in the introduction of non-native species into and within North America has been an unintended consequence and cost of the growing scale of global trade, travel, and transport since the early 1900s.
- Individual invasive species have already had profound and quantifiable negative impacts on the environment, economy, industry, infrastructure, human health and ecological function in North America. Climate change is making northern ecosystems more receptive to invasive species because of milder winters creating the potential for a significant increase in the introduction of these species.
- The issue of invasive species is recognized and the spread of certain individual species is monitored on a regular basis but comprehensive trend indicators are not available for major biomes (i.e., terrestrial, freshwater, marine/estuarine) or North America as a whole.

An *invasive species* is a plant, animal or microscopic pathogen that, once transported out of its native range, has established itself, spread and caused harm to the environment, economy or human health in its new habitat.

What Is the Environmental Issue?

Invasive species are a significant environmental challenge. At no time in history has the rate of biological invasion, and the diversity and volume of invaders, been so high and the consequences so great.

Today, goods, services and people are on the move worldwide. These international movements and transactions have brought social and economic benefits to many people in North America, but they also have brought new challenges. The growing rate and scale of global trade, travel and transport since the early 1900s have been accompanied by an exponential increase in the introduction of non-native species into and within North America. At times, non-native species are introduced intentionally for use in a broad range of industries such as agriculture, aquaculture, horticulture and the pet trade. But they also may arrive as inadvertent "hitchhikers" via imported plants and livestock, travelers and their baggage, manufactured goods, packaging materials and conveyances such as airplanes and ships in their ballast water or on their hulls (see table, which presents some common pathways of biological invasion).

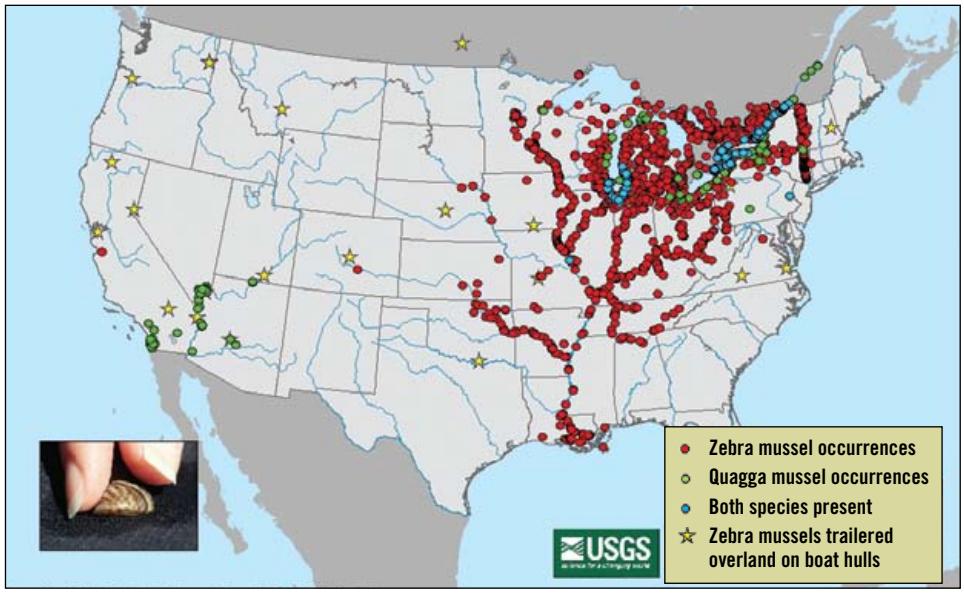
North America's intracontinental transportation systems are vast. They include 7.5 million kilometers of roads, thousands of kilometers of navigable waterways and railroads, extensive coastal shipping routes and nearly half of the world's airports. Once on the continent, invasive species can spread along roads and waterways and hitchhike on vehicles, in baggage and among cargo shipments, while marine/estuarine invaders can travel via intracoastal shipping or be transported by currents. Because invasive species do not respect political boundaries, species that invade one country have the potential to spread within a

Pathway categories

Transport mechanisms	Living commodities (biological species unintentionally introduced)	Living commodities (biological species intentionally introduced)
Via conveyances, packaging, equipment, and non-living commodites	Via living commodities that are not intended for release into the environment	Via living commodities that are intended for release into the environment
For example: Ship hulls Ballast water Solid wood packaging (pallets, dunnage) Military equipment Clay tiles	For example: Fruits and vegetables for consumption Pets Laboratory animals Animals for zoos and public aquaria displays	For example: Horticultural plants Crops Stocked fish Game animals

Source: Adapted from National Invasive Species Council

Distribution of zebra and quagga mussel sightings in United States and Canada (March 2008)



Source: US Geological Survey.

region. For example, both zebra mussels and quagga mussels were unintentionally introduced to North America through shipping. These invasive mussels were first discovered in the Canadian waters of Lake St. Clair near Detroit in 1988. They have since spread throughout watersheds across the continent with negative impacts on aquatic environments and local economies (see map, which depicts sightings of these invasive mussels in the United States and Canada). Recreational boats are major vectors in freshwaters to redistribute these mussels and other freshwater invasive species once they have invaded North America. Ballast water and hull fouling are important transport mechanisms for the introduction and spread of marine and estuarine species, especially in the Great Lakes and coastal estuaries.

Once invasive species are introduced, ongoing changes in land use, climate and freshwater and marine ecosystems can facilitate biological invasion by making habitats more challenging for native species and more hospitable to invasive species. Because disturbed habitats often favor rapid colonizers, they are particularly vulnerable to the invasion of non-native species. From the perspective of the invasive species, it does not matter whether the environmental changes are natural or human-induced (see box).

When Prevention Fails . . .

Here are a few examples of invasive "hitchhikers" that have already had profound negative impacts on the environment, economy, industry, infrastructure and human and animal health in North America:

Asian carp *(Hypophthalmichthys nobilis*, *H. molitrix* and others): environment

Asian longhorned beetle *(Anolophora glabripennis)*: environment, industry

Asian tiger mosquito *(Aedes albopictus)*: human and animal health

Brown tree snake (*Boiga irregularis*): environment, infrastructure, human health

Chytrid fungus *(Batrachocytrium dendrobatidis)*: environment

Dutch elm disease *(Ophiostoma ulmi)*: environment, industry

Emerald ash borer *(Agrilus planipennis)*: environment, industry

European green crab *(Carcinus maenas)*: environment, industry

Giant African snail *(Achatina fulica)*: environment, industry, human health

Gypsy moth *(Lymantria dispar)*: environment, industry

Norway rat *(Rattus norvegicus)*: environment, infrastructure, human and animal health

Red imported fire ant *(Solenopsis invicta)*: environment, human health

As of 2006, Mexico's *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad* (Conabio) had identified at least 800 invasive species in Mexico, including 665 plants, 77 fish, 2 amphibians, 8 reptiles, 30 birds and 6 mammals. In Canada, invasive alien species include at least 27 percent of all vascular plants, 181 insects, 24 birds, 26 mammals, 2 reptiles, 4 amphibians, several fungi and mollusks, and 55 freshwater fish. Although extensive data on individual species are available, similar totals are not currently available for the United States.

Why Is This Issue Important to North America?

With its many linkages to the global economy, North America is extremely vulnerable to the introduction of invasive species from abroad. Likewise, species native to Canada, Mexico and the United States can be spread via the international movements of people and trade goods to other countries (within North America and beyond) where they can become invasive. As trade, transport and travel expands, so do many of the risks associated with biological invasion. The environmental and economic consequences of invasive species can be significant. Climate change is increasing the risk of introduction of harmful non-native species.

Environmental Implications

Permanent elimination of native species unique to North America is one of the issues at stake. In the United States, invasive species rank second to habitat modification as a cause of species endangerment, and they are the primary driver of extinctions in island ecosystems, as well as many freshwater systems worldwide. Extinction of native species can result from a single or multiple impacts from invasive species, including competition for food, space, or reproductive sites; increased predation; and/or parasites and diseases for which native species have no defense. Invasive species can also degrade eco-

system functions and the production of ecosystem services, from food production to aesthetic value. Even the most well-protected natural areas are not immune to biological invasion. Predicting ecological impacts is made all the more difficult in that the effects of invasive species may be evident immediately or observable only after many years.

Economic

Invasive species can take a heavy financial toll on governments, industries and private citizens. Economic losses can be a direct cost such as lost or reduced crop production, or an indirect loss of tourist dollars from reduced quality reefs or sport fisheries. Globally, the economic losses from invasive species have been estimated at US$1.4 trillion a year. The cost to the United States is more than $100 billion a year. In Canada, the damage to agricultural crops and forestry from harmful invasive plant pests has been estimated at C$7.5 billion annually, and in the Canadian province of Manitoba alone, the economic losses from Dutch elm disease have been estimated at $30 million. Another type of direct economic impact is the cost to meet existing or proposed national and international regulations, such as the proposed requirement for ballast water treatment for all new ships under the International Maritime Organization ballast water treaty. The impact and management costs of a single species can carry a substantial price tag (see box for examples). If indirect costs such as loss of ecosystem services were also counted, these estimates would be substantially higher.

Human Health

The consequences of invasive species for human health can be direct from exposure to new diseases and parasites or indirect from higher and more frequent exposures to pesticides necessary to eradicate and control invasive species. Pathogens and parasites may themselves be invasive species or may be introduced by invasive vectors such as non-native mosquitoes. Cholera and some of the microorganisms that can cause harmful algal blooms are relocated and released in the ballast water carried by large ships. Other high-profile diseases

The Costs of Control and Eradication

The **Formosan termite** *(Coptotermes formosanus)*, introduced into the southeastern United States from East Asia, is an expensive visitor: an estimated US$1 billion a year is spent on property damage, repairs and control measures.

The **European gypsy moth** *(Lymantria dispar)*, introduced into North Carolina in 1993 and eradicated four years later, carried a $19 million price tag.

The Great Lakes Fishery Commission—jointly administered by the Canadian and US federal governments—spends about $22 million a year to control the **sea lamprey** *(Petromyzon marinus)*.

Researchers estimate the **zebra mussel** *(Dreissena polymorpha)* cost the power industry alone US$3.1 billion in the 1990s, with an impact on industries, businesses and communities of over $5 billion. In Canada, Ontario Hydro has reported that the zebra mussel has cost each generating station $376,000 a year.

The cost of eradicating one or more introduced mammals from 23 islands off the coast of northwest Mexico was about $750,000.

Case Study – The Cactus Moth

Larvae of the invasive cactus moth.

The cactus moth (*Cactoblastis cactorum*) reproduces and feeds on cacti in the genus *Opuntia*, commonly known as prickly pears. Originally from South America, the cactus moth has been introduced around the world as a biocontrol agent for invasive cacti. In 1989 the moth was discovered in the Florida Keys, likely having arrived either by natural wind dispersal or on imported horticultural prickly pear cacti from the Caribbean. Since that time, the moth's range has expanded northward along the Atlantic and Gulf coasts of Florida, despite active control efforts. This expansion has put North America's native *Opuntia* at great risk.

Mexico is a hotspot of prickly pear diversity, with 38 endemic species covering 3 million hectares. The United States also has 31 species of prickly pear, nine of which are endemic, including Florida's extremely rare *Opuntia corallicola*. Numerous species of birds, bats, mammals and insects depend on prickly pears for food and habitat, and the cacti provide erosion control for fragile desert soils.

Aside from its enormous consequences for North American biodiversity, the cactus moth threatens the agriculture, landscaping and ranching industries. In 2000 the value of ornamental prickly pear cacti used for xeriscaping, or dryland gardening, in Arizona amounted to US$14 million a year. Prickly pear pads (nopales) and fruits (tuna) are the seventh-largest agricultural crop in Mexico, where they are frequently gathered from the wild to supplement dietary intake. A national symbol, the prickly pear is featured on the Mexican flag and currency.

In a display of international cooperation, the Mexican government has funded US Department of Agriculture efforts to halt the westward spread of the cactus moth. However, in 2006 the moth was discovered on the Mexican island of Isla Mujeres (9 kilometers from Cancún on the mainland), and the Mexican government is now attempting to eradicate it through an extensive trapping program.

Photo: Peggy Greb, http://www.ars.usda.gov/is/graphics/photos/sep06/d588-2.htm.

caused by invasive pathogens are malaria, dengue fever and the human immunodeficiency viruses that cause AIDS. Less well-known diseases can also be problematic. For example, the giant African snail, a potential food source as well as a pet, provides an intermediate host for rat lungworm, which can infect the human brain, causing headache, fever, paralysis, coma and even death.

What Are the Linkages to Other North American Environmental Issues?

Invasive species are associated with a range of continent-wide environmental issues. Rapidly changing environmental conditions will tend to increase the diversity, spread and impacts of invasive species.

Climate Change

Climate change is likely to increase both the rate of new invasions into North America as well as promote the spread of invasive species already established. Stress on natural environments, such as that caused by climate change, may decrease their ability to resist biological invasion. Climate change is likely to increase the opportunities for invasive species to establish themselves after a storm or fire. Warmer temperatures or changes in rainfall patterns may enable certain species to expand their ranges and occupy new roles in ecological systems. Changes in the direction and strength of airflow could influence the spread and migration of airborne species, such as flying insects, while changes in near-shore currents could affect the distribution of marine/estuarine invaders.

Land Use

Because many invasive species are fast-growing, highly opportunistic ecological generalists, land use change generally favors biological invasion. For example, road building, edge maintenance for roads and power transmission corridors, and logging can open new areas to invasive species and facilitate their spread via equipment and workers. Agricultural activities can introduce invasive species into new areas through seed contamination and crop "escapes." And abandoned agricultural areas may be invaded by invasive species before natural succession can restore the local plant community. In urban and suburban environments, gardeners introduce non-native species for gardening that may spread into natural environments by means of "green space" corridors.

Water

Invasive species can place significant limits on the availability of potable water, as well as surface water for use by wildlife. Certain species such as pines and eucalyptus can draw down water tables and negatively influence regional water cycles. By affecting nutrient cycling, aquatic invasive species can promote eutrophication or the growth of undesirable algae. Invasive aquatic plants can choke waterways and trap sediment, causing the aquatic system to stagnate and eventually fill in. Stagnation can also increase the risk of disease such as West Nile virus by fostering mosquito populations.

Energy

Governments around the world are investing in biofuel energy production. Many of the characteristics that make plants good biofuel candidates—such as rapid growth rates and tolerance of disturbed environments—are the same characteristics that make a plant an effective invader. In fact, several species of invasive plants have been proposed for biofuel production in North America. The risk then becomes the potential escape of non-native species used for biofuel into the natural environment.

Case Study – Tree Pests

Asian longhorned beetle. Photo: US Fish and Wildlife Service

In the United States and Canada, the recent appearance of several invasive species that are threatening forests and forest product industries turned a spotlight on a neglected pathway: solid wood packaging materials, including the crates, pallets and dunnage used to transport various commodities. These materials can harbor the eggs, larvae and adult forms of bark- and wood-boring insects. Recent examples of serious pests that may have been introduced through untreated packaging materials are the emerald ash borer (*Agrilus planipennis*) and the Asian longhorned beetle (*Anoplophora glabripennis*).

The emerald ash borer was first discovered in 2002 on infested ash trees in Detroit, Michigan, and neighboring Windsor, Ontario, but apparently it arrived undetected and became established over a decade earlier. Native to China and eastern Russia, the beetle feeds on ash trees, killing them in the process. Ash trees are an important part of North American forests, providing food for numerous species of wildlife, and are a popular street tree in many midwestern US and Canadian cities. The emerald ash borer has spread into Ohio, Indiana, Illinois and farther into Michigan and Ontario, killing over 15 million ash trees in southeastern Michigan alone. Hitchhiking on nursery shipments, lumber and firewood, it has repeatedly escaped the quarantine areas set up by federal, state and provincial governments. Unfortunately, the prospects for successfully eradicating the emerald ash borer are not good.

The Asian longhorned beetle was first discovered in New York in 1996, followed by detections in 1998 in Illinois, in 2002 in New Jersey and in 2003 in Ontario. The beetle attacks and kills many types of hardwood trees, including maples, and could drastically alter the region's forests, as well as cost the forestry, landscaping, maple syrup and fall color tourism industries billions of dollars. This insect also could decimate 30 percent of urban street trees in the United States at a replacement cost of hundreds of billions of dollars. Since first detecting the insect, the US and Canadian governments have undertaken costly eradication efforts, requiring the removal of thousands of neighborhood, park and street trees. Although proceeding slowly, the eradication efforts have had promising results. Moreover, national, regional and international standards for fumigation and labeling are being developed to prevent invasive species from infesting packing materials.