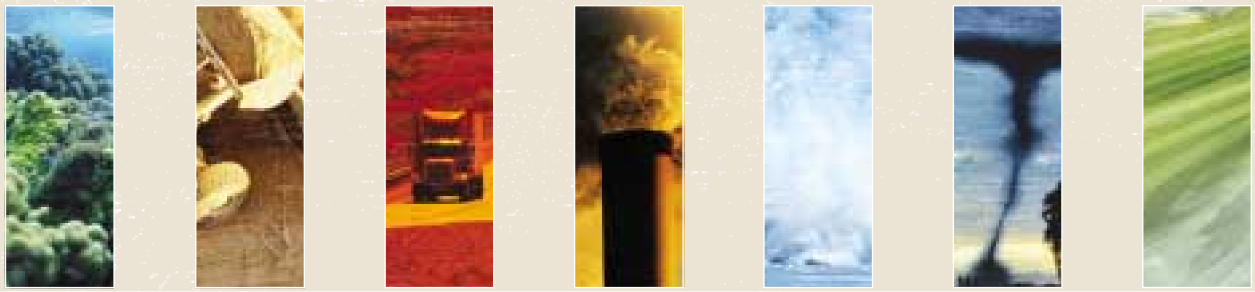
Commission for Environmental Cooperation



The North American Mosaic

A STATE OF THE ENVIRONMENT REPORT

CEC · CCA · CCE

The North American Mosaic

A STATE OF THE ENVIRONMENT REPORT

Forests and Woodland | Agriculture | Fresh Water | Terrestrial Biodiversity and Protected Areas | Marine and Freshwater Ecosystems | Minerals and Energy Use | Transportation | Air Quality | Climate Change | Natural Disasters | Wastes | Population Trends

This publication was prepared by the Secretariat of the Commission for Environmental Cooperation (CEC). It does not necessarily reflect the views of the governments of Canada, Mexico, or the United States of America.

Explanatory notes

All figures are in US dollars, and all measurements are metric unless otherwise noted.

The maps were prepared before the Territory of Nunavut was officially declared and so the new Canadian political boundary is missing. Readers can find information about the Territory at the following web sites:

http://www.gov.nu.ca/
http://www.inac.gc.ca/nunavut/
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Acronym List

BECC	Border Environment Cooperation Commission
CEC	North American Commission for Environmental Cooperation
CFCs	chlorofluorocarbons
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EPA	(US) Environmental Protection Agency
GDP	gross domestic product
GMOs	genetically modified organisms
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
ha	hectare
INE	Instituto Nacional de Ecología
IUCN	World Conservation Union
NADB	North American Development Bank
NAFTA	North American Free Trade Agreement
NGO	nongovernmental organization
NPRI	National Pollutant Release Inventory (Canada)
OECD	Organisation for Economic Cooperation and Development
PCBs	polychlorinated biphenyls
POPs	persistent organic pollutants
Semarnap	Secretaría del Medio Ambiente, Recursos Naturales y Pesca (changed in late 2000 to Semarnat)
Semarnat	Secretaría del Medio Ambiente y Recursos Naturales
SNA	System of National Accounts
TRI	Toxics Release Inventory (United States)
UNEP	UN Environment Programme
WRI	World Resources Institute

Preface

The North American Mosaic has four overarching features. First, it is, to the extent feasible, based on comparable information on the status and trends of major indicators of the state of the environment in Canada, Mexico, and the United States. Second, the report confirms that these three countries together make up an incredibly complex, dynamic, and interconnected ecosystem in which humans play a dominant and decisive role. Third, the report raises important and sometimes disquieting questions concerning the sustainability of some current trends. Finally, the report is a reminder that our economic, social, and physical well-being are utterly dependent on the life-sustaining services provided by nature. This report emphasizes the importance of developing mutually compatible economic, social, and environmental goals and policies across the three-country region.

This report is based primarily on information from a suite of background papers prepared for the CEC's state of the North American environment project. The authors of these background papers are scholars and government experts in the fields of geography, environmental statistics, economics, sociology, political science, natural disasters, and human health. In addition, the statistics used were gathered, harmonized, and published by recognized international bodies, such as the Organisation for Economic Cooperation and Development (OECD), the UN Food and Agriculture Organization, and the World Resources Institute. Since each country collects data in a different way, there are some gaps and inconsistencies. Nevertheless, there was a great deal of data and information that, while not totally comparable, was sufficient to convey important trends. The CEC is confident that the overall message that emerges is valid.

Much of the story is a synopsis of what is happening to environmental media—air, water, land, and biota. Some of the more obvious "direct" impacts driving changes in the North American ecosystem are also discussed, as are important "indirect" and "underlying pressures" stemming from economic, social, and institutional sectors.

Many ecological connections link the countries of North America. Migratory species, transboundary air and water pollution, international trade, and the transboundary movement of people are examples. Watersheds both delineate and cross jurisdictional boundaries. Ecoregions typically transcend political borders (CEC 1997c). The CEC's report on Continental Pollutant Pathways (CEC 1997a) highlighted an important category of transboundary, continental, and even global connections.

Reporting in *The North American Mosaic* is organized by political boundaries because that is the way governments currently compile statistical information. Such compartmentalization makes it more difficult to assess the status of transboundary ecoregions and watersheds. At present, however, most societal responses, including environmental laws and policies, are developed and implemented within political boundaries.

Three broad conceptual frameworks for understanding environment-economy-society relationships are interwoven throughout this document. First, the link between humans and their environment is evaluated based on progress toward a more sustainable model of development. This sustainability concept reflects a goal or purpose, obliges us to think long-term, and challenges us to manage human development in a manner that meets the needs of current generations without compromising the needs of future generations.

Second, the report is influenced by the ecosystem approach, initially developed under the Canada-United States Great Lakes Water Quality Agreement of 1972, and subsequently incorporated in many international agreements. This approach treats humans as an integral part of a larger ecosystem, and provides a basis for managing the system so as to achieve desired ecosystem goals and objectives.

Finally, the report reflects the organization of information and ideas in accordance with the pressure-state-response framework, used extensively in OECD countries. Direct pressures encompass physical, chemical, and biological stresses such as chemical and biological pollution, overexploitation of resources, and habitat alteration. The simplest to assess, direct pressures can typically be evaluated through the natural sciences. Indirect pressures are the economic activities that lead to direct physical stresses. Examples include the transportation, forestry, agriculture, and energy sectors. Integrated environmental and economic analyses are needed to understand the effects of indirect pressures. Underlying pressures that influence the pace and nature of development include the sociopolitical and cultural setting, values and ethical standards, important global trends and trading patterns, and the rules governing trading regimes. Underlying pressures are perhaps best approached from the perspective of political science or sociology.

The concept of sustainable development has, despite (or perhaps because of) the many and varied definitions of the concept, prompted important reflection on the future. Governments, industry, and public advocacy groups have been motivated to identify and pursue sustainable development objectives. Managing ourselves and our activities to enhance our social, economic, and environmental well-being is an ongoing learning process.

It is anticipated that this report on environmental trends will set the stage for future reports on emerging issues related to the state of sustainability in North America. These future reports will provide an opportunity for a more in-depth exploration of selected important trends and issues. While certain unsustainable environmental trends show no signs of slowing, there are also many examples of how our individual and collective efforts have contributed to positive change.

Much can be done to improve our ability to detect, understand, and act on emerging trends at the regional level. First we need to ask what indicators are best suited to measuring whether our economic, social, and environmental goals are being met? Perhaps our present means of monitoring progress are not appropriate. Does the gross domestic product, for example, measure sustainability or human welfare? Is it important that we accelerate the adoption of other indices that better reflect measures of economic, environmental, and social sustainability to balance and/or complement existing indices?

How do we honestly and objectively assess whether free trade, free markets, and the increased integration and globalization of human enterprises are likely to lead to enhanced or degraded environmental quality? What is our rationale for predicting whether they will accelerate or reduce the rate at which the biological diversity of the earth is being lost? Is it likely that future growth in human populations and in human material aspirations will place unsustainable pressures on local, national, and planetary life-support systems?

There are opportunities to cooperate in developing core “sustainability” indicators for measuring and monitoring trends. And the quality and comparability of the data generated by these indicators can be improved to produce information that is more useful and that can be better managed, analyzed and distributed.

Today’s world is, to a large degree, what it is because of the human decisions and actions of the past, just as the future will reflect human decisions and actions taken today and tomorrow.

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Figure 8

Spring Mean Total Phosphorus Trends for Open Lake Waters, 1971–92
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Common Air Contaminants in Canada, 1980–98
From: T. Furmanczyk, Environment Canada. Ottawa: Government of Canada. Reproduced by permission.

Map 3

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From: D. Bryant, D. Nielsen, and L. Tangley. 1997. *The Last Frontier Forests: Ecosystems & Economies on the Edge: What is the Status of the World's Remaining Large, Natural Forest Ecosystems?* Washington, DC: World Resources Institute, Forest Frontiers Initiative. Reprinted with permission of World Resources Institute, Washington, DC, 10 G Street, N.E., Washington, DC 20003, USA. Copyright © 1997 World Resources Institute.

Map 5

Model Forests in North America

From: NRC. 1996b. *Model Forest Network, Year in Review: 1994–95.* Ottawa: Natural Resources Canada, Canadian Forest Service, Science Branch. Updated with information from CMFN. 1999. A Common Goal, Different Approaches. <http://www.modelforest.net/e/home_/indexe.html>. Canadian Model Forest Network. Reprinted with permission of Natural Resources Canada, 580 Booth Street, Ottawa, Ontario, Canada K1A 0E4. Copyright © Her Majesty the Queen in Right of Canada 1998–1999.

Map 7

Average Annual Precipitation in North America

From: ESRI ArcData Online at <http://www.esri.com/data/online/index.html>.

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Map 8

Water Flows from Major Rivers in North America

Original title: Principal River Systems and Those Channels Carrying Mean Flows of More than 1,000 m^3/s. From: H.C. Riggs, and M.G. Wolman. 1990. Introduction. *In The Geology of North America: Surface Water Hydrology,* edited by M.G. Wolman and H.C. Riggs, 1–9. Boulder, CO: The Geological Society of America, Inc. Reproduced with permission of the publisher, The Geological Society of America, Boulder, CO 80301-9140, USA. Copyright © 1990 by The Geological Society of America, Inc.

Map 10

North American Migration Routes of the Monarch Butterfly

Original title: Spring Migrations of the Eastern and Western Populations of the Monarch Butterfly in North America. From: L.P. Brower. 1994. A New Paradigm in Conservation of Biodiversity: Endangered Biological Phenomena. In *Principles of Conservation Biology*, edited by G.K. Meffe and C.R. Carroll, 104. Sunderland, MA: Sinauer Associates, Inc. Copied with permission of the author.

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From: E.B. Wiken and D. Gauthier. 1996. Conservation and Ecology in North America. Paper read at Caring for Home Place: Protected Areas and Landscape Ecology Conference, September 29-October 2, at Regina, Saskatchewan. Map reprinted courtesy of the Canadian Plains Research Center, University of Regina, Regina, Saskatchewan, Canada S4S 0A2 and the Canadian Council on Ecological Areas, 2067 Fairbanks Avenue, Ottawa, Ontario, Canada K1H 5Y9.

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Coastal Ecosystems Threatened by Development in North America

From: D.E. Bryant, Rodenburg, T. Cox, and D. Nielsen. 1995. *Coastlines at Risk: An Index of Potential Development-Related Threats to Coastal Ecosystems.* Washington, DC: World Resources Institute Indicator Brief. Reprinted with permission of World Resources Institute, Washington DC, 10 G Street, N.E., Washington, DC 20003, USA. Copyright © 1995 World Resources Institute.

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Wet Sulfate Deposition in Canada and the United States, 1980–84 and 1991–95

Map conflated from original maps "1980–84 five-year mean wet sulphate deposition for eastern North America" and "1991–95 five-year mean wet sulphate deposition for eastern North America." In "Acid Rain," SOE Bulletin No. 99-3. Ottawa: Environment Canada. 1999. <http://www.ec.gc.ca/ind/English/AcidRain/ Bulletin/arind3_e.cfm>.

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Hurricanes and Tornadoes in North America, 1970–96: Frequency and Resultant Loss of Life

Original title: Hurricanes and Tornadoes: A Wide Path. From: NG Maps 1998. *National Geographic* 194 (1): 2–39. Reproduced with permission of National Geographic Society, 1145, 17th Street N.W., Washington, DC 20036-4688, USA. Copyright © 1998 National Geographic Society, Washington, DC.

Map 16

Population Density in North America

Original title: Gridded Population of the World, prepared by NCGIA. From: W. Tobler, U. Deichmann, J. Gottsegen, and K. Maloy. 1995. *The Global Demography Project, Technical Report TR-95-6.* Santa Barbara: National Center for Geographic Information and Analysis, Department of Geography, University of California. Available online at: <http://www.ciesin. org/datasets/gpw/globldem.doc. html>.

Executive Summary

While this century has been marked by remarkable progress for many, though not all North Americans, economic activities have also damaged our environment, threatening human health and well-being. People are becoming ill because our wastes compromise the quality of the air we breathe and the water we drink.

In recent decades, there have been a number of responses to environmental problems from citizens, nongovernmental organizations, governments, and some industries. But the rate of improvement has not always kept pace with development. For example, some of the successes due to industrial cleanups and cleaner automobile technologies have been offset by increases in the number of industry players, and by the steady increase in the number of motor vehicles, their size, and the distances they are driven. And although there has been a surge in the creation of environmental departments and regulations since the 1970s, there have been government spending cutbacks in the 1990s. Responsibility for many aspects of environmental protection has been transferred to lower levels of government that often lack the resources needed for monitoring and enforcement, or delegated to self-policing programs run by the industries themselves.

On balance, we have an ever-growing ecological footprint. North Americans, mainly US and Canadian citizens, typically use more energy and natural resources, and generate more wastes than citizens of other countries. The health of an environment that sustains 394 million people and an economy worth nine trillion US dollars a year is at risk.

Among major North American environmental trends:

- Our high dependence on burning nonrenewable fossil fuels for energy—coal, oil, and natural gas—releases large quantities of pollutants that contaminate the air we breathe and change the atmosphere in ways that affect our climate. Aside from a long-standing use of hydroelectric energy, there has only been a modest move to renewable forms of energy, such as wind, solar, and geothermal.
- Urban air quality deleteriously affects human health in many urban centers in North America. Positive examples of improvements abound, yet the general trends, particularly in the transportation sector, are disturbing—more people, in bigger cars, driving longer distances, burning greater amounts of fossil fuels, contributing to climate change, smog, acid rain and toxic pollution.
- Despite bans or strong controls on some harmful substances, such as DDT and polychlorinated biphenyls, there is still too much pollution being released into the environment. There is growing concern over the potential of certain chemicals to harm human health, perhaps even to disrupt the hormones that regulate our bodies.
- North America's natural forests continue to decline. Replacing old-growth forests with monoculture tree farms leads to ecosystems that are more susceptible to insect and fungi damage. There are some promising signs of movement from clearcutting to more sustainable harvesting, but the continent is still losing old-growth forests. The tropical forests of Mexico are under the greatest pressures.
- Agriculture has become heavily dependent on machinery, chemicals, and irrigation, and agribusiness is now introducing genetically modified products. There are signs that soil erosion caused by intensive farming is being controlled in many parts of North America due to better soil conservation measures, but on balance more soil is still being lost in agricultural areas than is being regenerated naturally.
- The precipitous decline in the stocks of a number of fish species has led to serious reductions or even collapses in a number of fisheries. Around North America and in much of the world, there is still a struggle to bring fish harvesting in line with nature's productive capacity. There has been a dramatic increase in aquaculture in North America, but fish farming has its own environmental impacts.

- Though levels of biodiversity are relatively high in North America, the region faces threats to many of its species, including loss of natural habitat, introduction of foreign invasive species, overharvesting, and continuing pollution. In the United States, for example, more than 65 percent of freshwater mussel species are extinct or threatened.

- Marine ecosystems suffer from municipal, industrial, and agricultural wastes and runoff, as well as deposition from air pollution. Eighty percent of marine pollution is from land-based activities. Coastal waters in many areas continue to receive untreated or insufficiently treated municipal sewage.

Continuing environmental degradation jeopardizes the proper functioning of critical ecological processes, such as climate regulation and soil formation. Many scientists believe that recent climate changes have already increased the risks of natural disasters, such as hurricanes, tornadoes, floods, and other severe storms, including snow and ice storms. Environmentally unsustainable activities, such as deforesting slopes and building on floodplains, have also worsened the effects of some types of natural disasters.

There are cases in which human-caused changes to ecosystems have increased risks to our health. Smog, contaminated drinking water, and coastal algae blooms are examples.

Among positive responses to environmental problems:

- Much of the gross air and water pollution that was evident in past decades has been eliminated. In regions such as the Great Lakes, a number of species are now re-establishing themselves.

- Emissions of pollutants that create acid rain and smog have been reduced, though not eliminated.

- Water conservation measures, combined with economic and regulatory incentives, have reduced fresh water use in some areas, though there are still many regions where use is greater than replenishment.

- More parks are being created to preserve natural landscapes and marine areas, and to provide habitat for wildlife, although enforcement is a challenge in many areas.

- Canada, Mexico, and the United States now work cooperatively on many environmental protection projects.

- Small but growing markets exist for "eco-efficient" or environmentally sound goods and services.

- New measures of economic activity are being developed that attempt to incorporate environmental changes when calculating the true wealth of nations.

At the turn of the millennium, North Americans are faced with the paradox that many activities on which the North American economy is based impoverish the environment on which our well-being ultimately depends. Much has been done over recent decades to put the human relationship with the natural environment on a more sustainable footing. Yet we are still far from achieving that goal, and it is clear that the scale of effort is insufficient to meet the challenge.

The North American Mosaic

Map 1. Satellite Image of North America

In North America, as in much of the world, humans are reshaping the environment and using up many parts of it faster than nature can renew itself. In one area after another, we are not only using up all the ecological interest, we are digging deep into the ecological capital.

A snapshot of North America taken from space shows a huge landmass draped in white, green, and brown and anchored in blue seas (map 1). Attached by the tail to Central America in the tropical south, its head is covered with a snowy-white shroud in the north. A brown knobby spine runs along its western flank. It is drained by extensive systems of freshwater arteries, punctuated by hundreds of thousands of lakes. Warm, turquoise oceans bathe its southern limbs while icy seas bind its island masses in the far north. A dark-green swath circles the northern flanks to the tree line, while the forests to the south are a lighter shade of green. The middle is a fertile brown, an expansive breadbasket. Its heart is a deep blue flower of freshwater lakes.

The continent's landmass stretches from the Atlantic Ocean to the Pacific and from the Arctic to the Yucatan Peninsula. It covers about 21.9 million square kilometers, nearly 15 percent of the world's land area. Canada accounts for 47 percent of this landmass and the United States 44 percent, while Mexico covers the remaining nine percent.

North America's mosaic of interconnected natural ecosystems (map 2) provides the foundation for some of the most industrialized and wealthiest parts of the world. Rich soils, waters, forests, and seas feed our economies and give us a sense of place and identity. We humans have been part of these ecosystems for many thousands of years. For most of that time, our impact on the planet was relatively light. We harvested only a tiny fraction of nature's bounty, its ecological interest. But over the past two centuries our numbers and our impacts have risen dramatically.

In North America, as in much of the world, humans are reshaping the environment and using up many parts of it faster than nature can renew itself. In one area after another, we are not only using up all the ecological interest, we are digging deep into the ecological capital. And while such resources as old-growth forests and water from aquifers are being depleted, human activities are also jeopardizing the functional efficiency of critical ecological processes, such as climate regulation and soil formation.

A look at a road map shows the natural environment overlaid by a second mosaic of human settlements and transportation corridors. Over the past few years, liberalized trade has deepened cross-border connections by facilitating the movement of capital, labor, information, and products. Economic and cultural ties have increased. The closer relationship between Canada, Mexico, and the United States has also provided avenues for dealing with some unintended linkages, such as pollutants that are carried across borders by wind and water currents. Many species of birds, mammals, fish, and insects were already migrating over these national borders long before they were created by humans.

Numerous transboundary environmental alliances are being built as countries realize they cannot understand or solve many environmental problems alone. Governments and businesses in North America have spent billions of dollars reacting to and trying to deal with old environmental ills. They are now seeking ways to avoid creating new problems. Along with many other nations, they are looking for forms of economic development that are environmentally and socially sound, and sustainable over the long term.

The message that humans, like other organisms, are an integral part of their environment is becoming clearer as we realize that our actions have direct and indirect effects on our own well-being. Humans are the principal drivers of the increased scale, scope, and pace of local and global change. We have an unprecedented ability to alter our planetary ecosystem. Many of the changes result from our endless quest to harvest more resources and energy to support the growing demands of an ever-increasing population. Yet people are becoming ill because the air we breathe and the water we drink is compromised by wastes derived from our own activities.

Now more than ever, we live in an interconnected, integrated world. Information and financial investments move electronically at the speed of light. And the intercontinental movement and transfer of people, raw materials, manufactured goods, invasive species, and diseases occur in hours or days. The most remote ecosystems and the cells of every human being contain persistent toxic substances made, traded, and released to the environment by other humans. Animal and plant species, many much older than we, are going extinct at unprecedented rates, often because of decisions and actions taken by humans half a world away.

The question of how many people the earth can sustain is a complex one. It depends on more than the actual number of humans and their level of technology and consumption. It also depends on the social, economic, and political means of controlling the production and distribution of the resources we need to survive. Our attitudes, values, preferences, and moral judgements about the use of resources are also important (Livernash and Rodenburg 1998). Our impact on the earth, our "ecological footprint," can be expressed per person (fig. 1) or as a national value (fig. 2). The term ecological footprint refers to the land and water area—regionally and throughout the world—

Map 2
Ecological Regions of North America

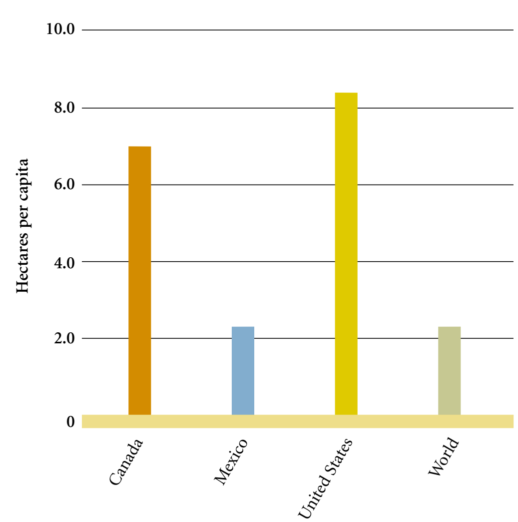
Source: CEC 1997c.

Note: Distinctive ecological regions transcend political boundaries. This map, produced by the CEC, is the first level of three that portray North America's ecoregions, as defined by an international team of experts.

required to produce natural resources and services and absorb all the waste generated per person, using prevailing technology. The Canadian and US ecological footprints extend considerably outside North America (Wackernagel et al. 1997). The total ecological footprint of the United States is much larger than that of the other two countries because of its larger population and its larger per capita footprint. US and Canadian citizens typically use more natural resources and generate more waste than people in other countries. Thus these nations now either deplete their local natural capital stocks or import their missing ecological capacity, or both (Wackernagel et al. 1997; Wackernagel and Rees 1996).

If we are to have any hope of changing of our ecological footprint, we need to understand it. This report assembles information on the state of the environment in North America so that policymakers and private citizens can consider what steps to take to move more rapidly toward sustainability. But before considering the current status of our mosaic of natural ecosystems, the report describes some recent developments that improve our chances of making some much-needed changes.

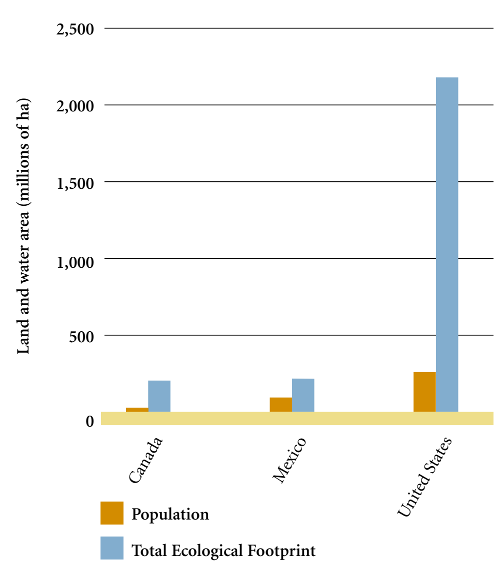
Figure 1
Average Per Capita Ecological Footprint, by Country



Source: Wackernagel et al. 1997.

Note: 1997 population. Hectares per capita expressed in world average productivity, 1993 data.

Figure 2
Ecological Footprint, by Country



Source: Wackernagel et al. 1997.

Note: 1997 population.
Total ecological footprint: Per capita data multiplied by the country's population.

Setting the Stage for Change

Globalization combines the power of truly global markets in the post-Cold War era with rapidly diffused enabling technologies. This powerful convergence creates a host of new opportunities and challenges for environmental policy.

No term has captured public interest in the new millennium with the force and ubiquity of "globalization." The often ill-defined concept embraces a complex and dynamic process characterized by the increasing importance of world trade and trade regimes, the fragmentation of production across sectors and countries, fundamental changes in pricing and market structures, and the incredibly rapid mobility of private capital.

Two underlying trends that influence this globalization process are: a true revolution in communications and life sciences technologies, and our deepening scientific understanding of the ecological interdependencies across borders and, indeed, the globe.

Globalization combines the power of truly global markets in the post-Cold War era with rapidly diffused enabling technologies. This powerful convergence creates a host of new opportunities and challenges for environmental policy. Within this context, a number of trends in North America have the potential to increase or decrease environmental impacts. Recent changes—in information systems, public awareness, technologies, economic accounting, and international policymaking—appear to make it more likely we can change things for the better.

Increased Access to Information

The telecommunications industry in North America is undergoing rapid change, as it is worldwide. In the United States, for example, there are now more than 60 telephone lines per 100 people (O'Meara 1998a). Use of the Internet is expanding, and the United States and Canada are among the world's most "wired" nations: according to various studies cited by Cyberatlas in July 2001, by the end of the year 2000, 48.2 percent of Canadians were online, compared to 43 percent in the US and 2.2 percent in Mexico (Cyberatlas 2001). Mexico is off to a slower start because it began from a lower base, but the county's rate and pace of change are still impressive. An estimated 1.5 million Mexicans have Internet access, and this is set to grow to 6.4 million by 2004; some 67 percent of the "wired" Mexicans are aged 34 or younger. The United States remains the world's most "wired" nation, with 104 million adults having Internet access from home and 168 million having access from either home or work. Almost three-quarters of 12–17 year-olds have access. These and other revolutions in communications technology have given the public greater opportunities to influence decision making related to the environment.

This upsurge in the "information economy" in North America has facilitated the emergence of networks that attempt to inform and influence social, economic, and environmental linkages (Sampat 1998). Cross-sectoral and trinational alliances have formed among environmental nongovernmental organizations (NGOs) and other types of groups promoting sustainable development. This broader dissemination and exchange of information was instrumental in the emergence of numerous multistakeholder, bilateral efforts to improve environmental conditions along the US-Mexican border. Cross-border cooperation is also enhancing recognition of the transboundary nature of the North American ecosystem.

Increased use of e-mail and faxes facilitates the administration and recruiting of new members in environmental NGOs. These organizations offer environmentally oriented sites on the World Wide Web, providing the public with easy-to-acquire information about local and global environmental issues and access to government agencies, other NGOs, and the private sector. Governments also provide information on the Internet to increase awareness of sustainable development. And more and more businesses provide information about their environmental performance on company web sites. Electronic mail permits NGOs, governments, industry, and other institutions to communicate their environmental goals rapidly and to reach broader audiences. Rapid dissemination of information leads to short response times, and helps to mobilize political pressure among concerned groups and individuals.

Consumer Power

Easier access to information also helps consumers find more environmentally benign goods and services. Consumers are beginning to influence environmental practice and policy by expressing environmental preferences in the global marketplace. Partially in response to global competition for markets, once-specialized "niche" markets for shade-grown coffee, sustainably harvested timber, products certified as being produced in an environmentally sound manner by the International Organization for Standardization, and organically grown agricultural produce are experiencing rapid growth in demand (Courville 1999). Moreover, as consumers solicit more information on how the products they consume are harvested or produced, there is a growing need for credible and accurate environmental labeling and certification programs (PCSD 1996a).

Consumer-led market changes also suggest that many people want products that are durable, repairable, reusable, and produced in an environmentally benign manner. This may influence pricing mechanisms and design changes that will make such products more affordable in the future (PCSD 1996b).

Consumer awareness and public opposition to the siting of new landfills may lead to the adoption and legislation of life-cycle management of manufactured products, as it has in Germany. Such programs make manufacturers responsible for the return of packaging and products for reuse or recycling. "Closing the loop" in manufacturing processes can be extended to automobiles and electronic equipment so that they are designed for disassembly and with materials that are recyclable, reusable, and reparable (Fishbein 1995). Such a process not only produces less waste, it also reduces consumption by discouraging reliance on virgin resources and by promoting recycled ones. This helps to conserve the natural resources that are part of North America's natural legacy.

The Rising Influence of Civil Society

The 1970s and 1980s saw a surge in the creation of government environmental departments and regulations. But the recession that started in 1989 brought government spending cutbacks through the 1990s. Many environmental agencies and institutions faced reduced support for environmental regulation, monitoring, research, and development. This was also a period in which some governments transferred more of the responsibility for environmental protection to lower levels, some of which were also cutting budgets. Smaller environment and natural resource departments often lack the resources to monitor trends or to field as many environmental inspectors. New approaches, such as the use of market incentives, performance-based regulations, and voluntary pollution prevention, are now being implemented. But they alone cannot be relied on to provide adequate protection for essential natural resources and services (Ezcurra et al. 1997).

In response, other actors have stepped into the breach. Throughout North America, individuals, voluntary organizations, private enterprises, and charitable foundations are taking on greater roles in the stewardship of natural resources. In addition to the broader public access to information about environmental matters, new opportunities have opened up for public input in all manner of environmental assessments and for partnerships amongst various stakeholders to address sustainable development issues. Unfortunately, environmental NGOs often lack adequate funding, scientists are often unable to secure funds for nontraditional research, and many breaches remain in basic reporting and monitoring.

Environmental Technologies

Another encouraging trend for the future of sustainability in North America is that many corporations have begun to note the advantages of eco-efficiency. Savings in overhead and production costs are good business and many companies are making changes in their operations. In addition, the environmental goods and services sector is growing in North America. This is especially true as regards pollution control technologies, waste management, and site remediation. The United States accounts for 40 percent of the current global market in the pollution control industry, and the US market grew from $126 billion in 1990 to $171.7 billion in 1995 (Renner 1998). The total supply of environmental goods and services in Canada was $15.5 billion in 1997, of which 88 percent were produced domestically. Business sales rose 11 percent from the previous year (Statistics Canada 1999a). Given liberalized trade and movement of capital, a competitive market, consumer demand, and the experience already acquired, the environmental technology industry in North America is likely to continue to grow and its products and services will likely be exported to other regions.

Encouraging the adoption of eco-efficiency and the more holistic changes that industries will need to undertake in order to become more sustainable may require policy changes to reinforce the process, especially if market incentives prove inadequate (PCSD 1996b).

Reformed Economic Systems

While the bottom line in dollars, pesos, or other currencies still dominates our view of economic well-being, a number of experts are looking to broaden the measures of economic health. A nation's overall wealth (or short-term economic activity and long-term economic assets) is measured by the System of National Accounts (SNA), an international standard codified in 1968 by the United Nations so countries could compare economic activity on an international basis (Mueller 1991; Duthie 1993). Most of us see the results of these measures in reports on the gross domestic product. But the System of National Accounts and GDP fail to measure all forms of economic wealth, since they neglect to account for the amount of natural resource assets a nation possesses and can consume before jeopardizing the long-term productive capacity of its natural capital.

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The earth's assets can be viewed as a bank account. By "spending" natural capital without replenishing it, or by damaging processes and living systems that cannot be fixed by technology, we are living off our capital rather than the interest (Snape 1995). Unlike human or fabricated capital such as buildings and machines, the depreciation of natural capital is not written off against the value of its production (Repetto 1992). The challenge of sustainable development is to find ways of living off nature's interest without depleting the capital. Fishing and forestry provide examples: if we keep harvests within the limits of natural regeneration rates, the resource can last indefinitely.

Natural resources constitute the fundamental basis of any economy. Direct assets, such as renewable and nonrenewable resources, supply raw materials for consumer products and the energy to transform and transport them. Indirect assets provide basic life-support functions, such as water, chemical and nutrient cycling. Traditional national accounting systems do not consider the cost of depleting these natural assets. Rather, resource extraction increases national accounts through the sale of the raw material (Hull 1993). Moreover, traditional accounting methods inadvertently reinforce environmental deterioration, since cleaning up pollution appears as positive spending. Money spent to clean up oil spills, for example, increases GDP and thus appears as a public benefit in our current economic reckoning (El Serafy and Lutz 1989; Meadows 1991; MacNeill et al. 1991).

To better measure the true costs of sustainability, the GDP and other indicators of progress must be revised. The discipline known as environmental economics proposes an integrated measurement that includes investment capital and the income it generates, as well as natural capital and the benefits it supports, with a view to maintaining both the sustainability of the environment and economic activity (Gallon 1993; King et al. 1995).

The UN Environment Programme (UNEP), the UN Statistical Office and the World Bank have developed a new system of integrated environmental and economic accounting. An accompanying manual includes economic valuation techniques. This approach has been tested in several countries, including Mexico. During 1990–91, Mexico's National Institute of Statistics, Geography and Informatics (*Instituto Nacional de Estadística, Geografía e Informática*—INEGI), carried out a case study. This pioneering effort led to the first "ecological Gross Domestic Product (GDP)." The conceptual and methodological framework used is laid out in the Environmental Satellite Accounts proposed under the UN's System of National Accounts.

In 1999, this work was updated to include information through 1996. In their economic/environmental account for 1985–92, the National Institute of Statistics, Geography and Informatics showed that, while traditional GDP had a 2.2 percent annual growth rate, "ecological GDP" showed a 1.3 percent annual growth rate (OECD 1998).

Some nations, including all three in North America, have also developed their own environmental and natural resource accounting frameworks. These integrated systems have several major components, including the integration of socioeconomic statistics with biophysical data (Meyer 1993; UNEP 1997a). Statistics Canada, for example, recently extended its SNA to include new measures reflecting the relationship between the environment and the economy (Statistics Canada 1997). By looking at household energy use between 1981 and 1992, it found there was a steady decline in energy use per unit of expenditure during the economic recession of 1981/82 and the rising energy costs at the beginning of the 1980s. On the other hand, a dramatic fall in domestic energy prices around 1986 triggered a rapid increase in energy use per unit of household expenditure. The department concluded that "when energy prices are high, businesses and households can, and do, respond by increasing their energy efficiency" (Statistics Canada 1997).

In the United States, the Bureau of Economic Analysis is also establishing an accounting framework that integrates the economy and the environment. It extends the existing SNA's definition of capital to include natural and environmental resources (DOC 1994). Other integrated initiatives are also under way. A study undertaken by the Environmental Protection Agency analyzed the economic impact of the Clean Air Act over the past 20 years. It found that implementing the Act cost $524 billion, but that savings to the economy were over $6 trillion (Gallon 1997).

There is an important controversy about how to attach monetary value to benefits such as the sheer beauty of nature or to damage such as extinction. How much are ecosystem services worth? How does one put a value on clean air or fresh water? There is no simple answer. In 1997, a team of ecologists and economists sponsored by the National Center for Ecological Analysis and Synthesis in Santa Barbara, California, tried to put a price on ecosystem services, usually by calculating how much it would cost to replace natural services with ones constructed by humans. They came up with a value of at least $33 trillion annually, or 1.83 times the global gross national product of $18 trillion, and said that it is likely to be much higher (Costanza et al. 1997; see also Pearce 1998).

Ironically, a variety of government programs and fiscal policies continue to work against the attainment of more sustainable practices. During the Industrial Revolution, North America was often viewed as a land of milk and honey, endowed with a superabundance of land and raw resources from which to carve a future for millions of new settlers. With the opening up of virgin lands for settlement and resource extraction, governments often leased lands to mining and logging companies at low rates; provided roads, irrigation canals, and other services; and gave direct subsidies for economic development (Roodman 1997). While many subsidies and tax breaks for resource exploitation helped stimulate development or create and protect jobs, they may now be undermining environmental sustainability by encouraging high consumption (de Moor and Calamai 1997).

The fossil fuel industry, hydroelectric power, and water provision programs still benefit from major subsidies. Low energy costs that do not reflect the real environmental costs of developing, distributing, and using these resources exert underlying pressures on the North American ecosystem. Likewise, publicly subsidized infrastructure developments, including roads, dams, and industrial parks, have resulted in environmental damage that is not officially tabulated. Revised tax codes and policies, however, can create incentives to promote sustainability by transferring costs to the polluter.

Globalization, trade liberalization, more open markets, and budgetary cutbacks have already reduced some of the subsidies and taxation regimes that promoted resource extraction and other activities that put undue pressure on various ecosystems. At the same time, however, it is important to note that global trade can also lead to global access to resources, and this can place pressures on ecosystems in even the most remote parts of the world that will exceed their capacity to sustain themselves.

International Cooperation

The three nations in North America have been dealing with transboundary environmental issues for decades. The 1909 Boundary Waters Treaty between Canada and the United States provides the principles and mechanisms to help resolve and prevent disputes concerning the quantity and quality of boundary waters. The International Joint Commission was created and given quasi-judicial powers and other responsibilities to assist the governments in implementing the treaty (IJC 1999). Another early treaty is The Convention for Migratory Birds in Canada and the United States, which was signed in 1916.

Since then, Canada and the United States have entered into numerous other environmental agreements, including the Great Lakes Water Quality Agreement, first signed in 1972 and since updated, and the 1991 Air Quality Agreement. The latter aims to reduce the transboundary movement of acid deposition precursors by providing assessment, notification, and mitigation of air pollution problems (CEC 1998a).

…how to attach monetary value to benefits such as the sheer beauty of nature or to damage such as extinction? How much are ecosystem services worth? How does one put a value on clean air or fresh water? There is no simple answer.

The 1944 Treaty Relating to the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande is considered the centerpiece of the US-Mexican legal framework for managing transboundary waters. It established the International Boundary and Water Commission as a binational commission with many responsibilities, including the allocation of transboundary water resources, management of reclamation works, and development of joint sewage and sanitation facilities.

Growing concerns about environmental quality in the border region have resulted in the creation of several recent binational institutions. The United States-Mexico Border Environmental Cooperation Agreement (the La Paz Agreement) of 1983 established a process to reduce and prevent various forms of pollution in the border area. The Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADB) were created in 1994, under the auspices of NAFTA, to address problems related to water supply, wastewater treatment and municipal solid waste management in the border region, which is defined in the Charter as the area within 100 kilometers (62 miles) north and south of the international boundary between the two countries. The BECC was established to address shortcomings in environmental infrastructure along the border by overseeing initial project development, while the NADB is responsible for implementing long-term oversight of projects (NADB 2000). Another US-Mexico binational arrangement is the "consultative mechanism," created to fulfill commitments under the La Paz Agreement. It commits both countries to publicly disclose information about all existing and proposed hazardous or radioactive waste sites, as well as recycling, treatment and incineration facilities within 100 km of the border. The Integrated Border Environmental Plan (or Border XXI), another recent binational initiative, promotes intergovernmental cooperation and public involvement in sustainable development in the border area (CEC 1998b).

An example of the commitment to address problems that affect shared ecosystems in North America is the North American Waterfowl Management Plan, a partnership between the three federal governments, other local governmental agencies, NGOs, the private sector, and landowners. An agreement between Canada and the United States was signed in 1986 to help reverse a decline in waterfowl populations, mainly by maintaining and expanding critical wetland habitats in North America (CEC 1998a). In 1994, the plan was expanded to include Mexico (NAWMP 2000).

Improved scientific understanding of North America's ecological interdependencies has contributed to an accelerated regional convergence of environmental policies (CEC 1998c). Following the 1992 Earth Summit, and since the North American Free Trade Agreement came into force in 1994, the number of cooperative efforts is growing, many of them involving the Commission for Environmental Cooperation. (For a list of North American environmental treaties, see CEC 1998a.)

Important international agreements and action plans that affect North America include the Montreal Protocol on Substances that Deplete the Ozone Layer, the Convention on Biological Diversity, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Basel Convention (on the transboundary movement of hazardous waste), and the Ramsar Convention on Wetlands. Several of these treaties have yet to be ratified in each of the three countries, however, raising concerns that North American governments may have trouble honoring some of their international commitments. Canada and the United States have not yet been able to stabilize greenhouse gas emissions at 1990 levels, as called for in the 1992 UN Framework Convention on Climate Change. A 1997 agreement with targets for reducing greenhouse gas emissions—the Kyoto Protocol—is still to be ratified by any industrial country and has run into serious resistance in the United States.

Growing economic contacts between Canada, Mexico, and the United States may help people in all three nations recognize the interconnected nature of the North American ecosystem. Designing a sustainable future for North America means working at individual, local, regional and international levels. It means complying with bilateral and multilateral agreements. It also means increasing the dialogue between the three countries, achieving some consensus on a common vision of the future, and then deciding on the goals and objectives that will enable the realization of that vision.

Forests and Woodland

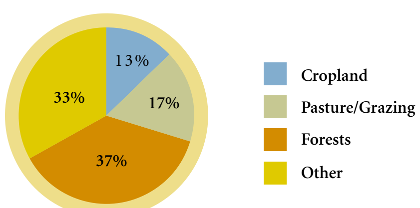
...compared with an estimate of forest cover 8,000 years ago, North America's frontier forests have contracted by approximately 37 percent [in the past two centuries].

Only a couple of centuries ago, the face of North America was dominated by forests, with a broad prairie down the center. Human activities have changed the original vegetation cover and have had a profound impact on the landscape. Taking North America as a unit, about 37 percent of the landmass is now covered by some sort of forest or woodland, 13 percent by crops, 17 percent by pasture and grazing land, and 33 percent by other landforms, such as wetlands, deserts, or mountains, or land uses such as urban and transportation developments (fig. 3). The land cover varies widely among the three countries. In Canada, for example, forests cover 45 percent of the land area.

The region is home to a great variety of forest types, including boreal, temperate, and tropical biomes (FAO 1997a). Boreal forest, dominated by coniferous trees, accounts for the majority of the forests in North America. This forest biome stretches across the northernmost portions of Canada's forested regions in climatic zones in which summers are short and winters are long and cold.

Over the past 200 years, there have been dramatic changes to forests in the settled parts of North America. During pioneer times, forests were cut or burned to clear farmland,

Figure 3
Land Cover in North America, by Type



Sources:

Canada	Total land area and forest area: NRC 1998; Cropland and Pasture: OECD 1995a.
Mexico	Total land area: INEGI-Semarnap 1998; forest area: SARH 1994; cropland: INEGI 1995a; Pasture: FAO 1997c.
United States	Total land area and forest area: Powell et al. 1993; Cropland and Grazing: CEQ 1996.

Some Useful Definitions

Biome: A broad, regional type of ecosystem characterized by distinctive climate and soil conditions and a distinctive kind of biological community adapted to those conditions.

Boreal forest: A vegetation type dominated by coniferous trees (but containing some deciduous broad-leaved species such as aspen and birches) stretching across North America, Europe, and northern Asia (regions characterized by short summers and long, cold winters). It is found south of the tundra in the northern hemisphere, and often contains peaty or swampy areas. Boreal forests grow in the boreal biogeographic region. Also called northern coniferous forest and taiga (Art 1993, 70).

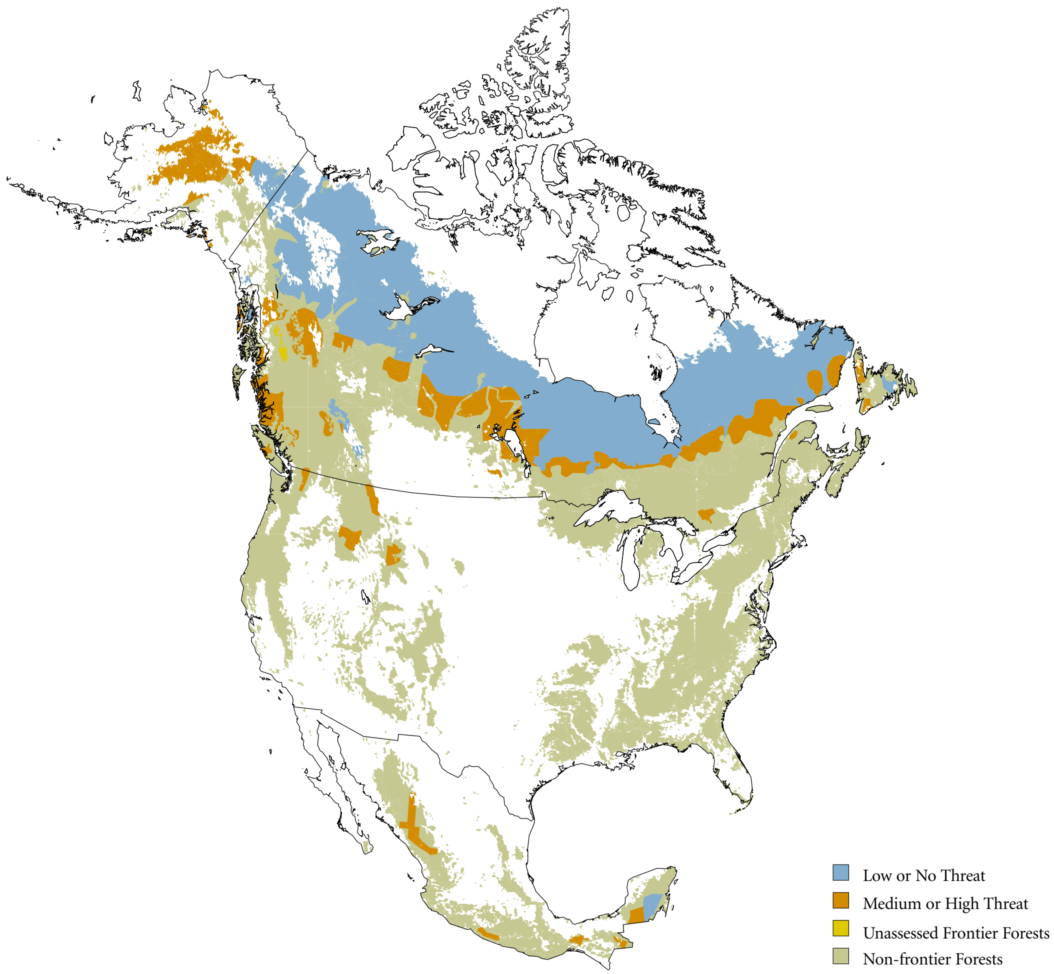
Frontier forests: Primarily forested, of sufficient size to support viable populations of the full range of indigenous species associated with that particular forest ecosystem given periodic natural disturbance episodes (fire, hurricanes, pests and disease, etc.), and exhibiting a structure and composition shaped largely by natural events, as well as by limited human disturbance from traditional activities. De facto, they are relatively unmanaged (natural disturbance regimes such as fire are permitted to occur), are home to most if not all of the species associated with that ecosystem type, are characterized by mosaics of forest patches representing a range of seral stages, and are in areas where such landscape heterogeneity would be expected to occur under natural conditions (Bryant et al. 1997, 39).

Threatened frontier forests: Frontier forests in which ongoing or planned human activities (such as logging, agricultural clearing, and mining) will eventually degrade the ecosystem (through, for example, declines in or local extinctions of plants and animals or large-scale changes in the forest's age structure).

Low threat or potentially vulnerable frontier forests: Forests that are not now considered under enough pressure to degrade ecosystems. But because they are unprotected and contain valuable natural resources, or because human encroachment is likely, most of these forests are vulnerable to future degradation and destruction (Bryant et al. 1997, 11).

Map 3

Frontier and Non-frontier Forests of North America



Source: Bryant et al. 1997. Mapping by World Resources Institute, World Wildlife Fund and World Conservation Monitoring Centre.

Note: See box on previous page for definitions.

build settlements and provide wood for many other uses. During the past century, many farms on marginal lands were abandoned and have returned to forest. According to the World Resources Institute (WRI), compared with an estimate of forest cover 8,000 years ago, North America's frontier forests have contracted by approximately 37 percent (Bryant et al. 1997). WRI deems frontier forests to be those that remain large and sufficiently intact ecologically to support all their original biodiversity. About 27 percent of North America's frontier forests are threatened (map 3).

Today, forested areas—including commercial and protected forests and other types of woodland—cover some 37 percent of the region's total land area (OECD 1997). This amounts to about 16 percent of the world's forests (FAO 1998). In terms of the region's overall forests and woodland, Canada accounts for 54 percent (with 418 million hectares), while the United States and Mexico have 39 percent (298 million hectares) and seven percent (57 million hectares), respectively. For the average amount of forest in each state or province, see map 4.

Large forest areas are still being cut, including old-growth forests. But the overall quantity of North American temperate forests (including evergreen and broadleaf forests found in moderate climatic conditions) has stabilized in recent years as natural regeneration and replanting makes up for harvesting losses (Hall et al. 1996; FAO 1997a). Nevertheless, replanted forests are rarely as diverse, healthy, or aesthetically pleasing as their predecessors.

Single-species tree plantations are more susceptible to insect infestations and disease than mixed forests. They can also suffer from a lack of nutrients in soils impoverished by previous agricultural activity or the prior growth of deciduous species. Fires are suppressed to protect commercially valuable temperate evergreen forests, resulting in a change in composition from fire-tolerant species to those more prone to insect damage. Furthermore, the invasion of exotic forest insects, diseases, and weeds has led to significant loss of species and habitat diversity, and air pollution is weakening or damaging many areas of the region's forests (Hall et al. 1996; USDA 1996).

Tropical forests account for a small share of the remaining forests of the continent. These are found in southeastern Mexico, which ranks fourth in the world in forest species diversity. Although deforestation rates have declined somewhat in recent years, these forests are still undergoing high rates of loss. It is estimated that Mexico has already lost 95 percent of its tropical humid forests. Several estimates of loss during the 1980s, from different forest areas using different methods and concepts, suggest losses that vary, depending on the author, between 370,000 and 1.5 million hectares per year (Semarnap 1995). The United Nations estimates that, more recently, Mexico's annual deforestation rate is 510,000 hectares, ranking it fifth in the world in terms of total annual forest loss (Roper and Roberts 1999).

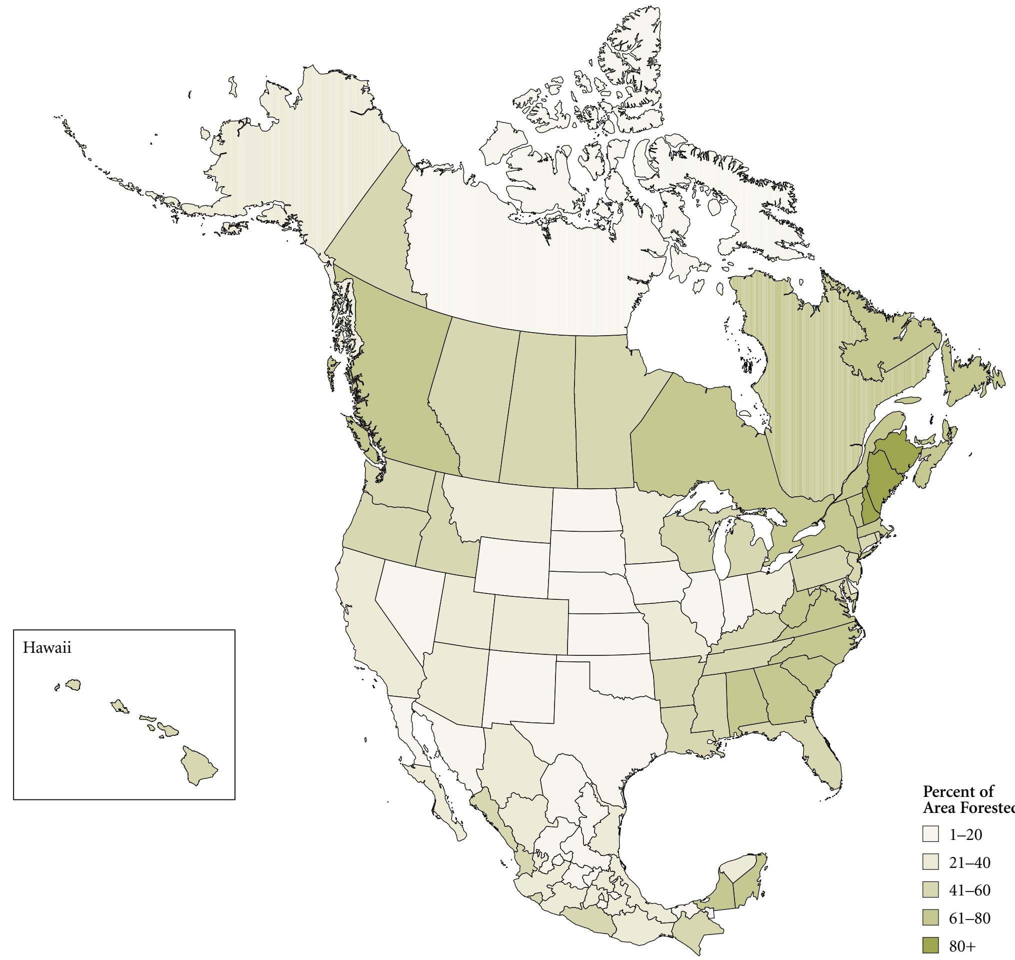
Deforestation in Mexico has been influenced by a variety of underlying pressures, including population growth, agricultural restructuring, land tenure inequities, and government colonization schemes. Large areas of forests have been replaced with cropland, cattle pasture, and urban development. During the 1980s, almost 60 percent of deforestation in Mexico's tropical forests was to make way for cattle farms (Semarnap 1995). In addition, one-eighth of Mexico's population lives in forested areas, where survival needs lead people to cut forests for subsistence farming and for fuel (Masera 1996; WRI et al. 1996; FAO 1997a).

Forests with commercial potential cover more than 4.5 million square kilometers, or 57 percent of the continent's total forest area. In the United States, 66 percent of the forested land is considered suitable for commercial uses, followed by 56 percent in Canada and 37 percent in Mexico (table 1) (NRC 1998; Segura 1996; Powell et al. 1993). About two million people are directly employed in the forestry industry in North America, including 365,000 in Canada, 1.4 million in the United States, and 233,200 in Mexico (NRC 1998; Afandpa 1994; Semarnap 1995).

In 1997, forestry contributed 2.4 percent of the gross domestic product (GDP) in Canada (NRC 1999), which is the world's largest exporter of timber, pulp, and newsprint. Exports that year were valued at $39 billion (NRC 1998).

Map 4

Forested Area in North America, by State and Province/Territory



Sources: Powell et al. 1993; INEGI 1995a; CCFM 1996; NRC 1996a.

About 0.4 percent of Canada's forests are harvested each year (NRC 1998). In the United States, the industry ranked among the nation's top 10 manufacturing industries in 1994, with products valued at more than $200 billion per year (Afandpa 1994).

In Mexico, the forestry sector represented only 0.8 percent of the country's GDP in 1994 (Semarnap 1995). About 80 percent of the timber cut there is for fuelwood (Masera 1996). Production in Mexico's forestry sector declined between 1989 and 1993 due to a number of factors, including underutilization because of inefficient timber and non-timber product industries and the loss of production potential through the haphazard harvesting by rural populations. Furthermore, wider resource use and conservation were hampered by the ineffectiveness of past policies that regulated forest use. These were often undermined by poor institutional organization, underfunding, and the powerful pressure to convert forests into agricultural or pasture lands (World Bank 1995). Although 8,417 rural communities in Mexico have access to forest resources, forest activities represent the major economic activity in only 421 of them (Semarnap 1995).

Table 1
Forests with Commercial Potential in North America

	Forested Land Area (1000 ha)	Percent of Total
Canada	234,530	56
Mexico	21,000	37
United States	198,123	66
North America	453,653	59

Sources:
Canada NRC 1998.
Mexico Segura 1996; SARH 1994.
United States Powell et al. 1993.

Much of the timber-productive forested area in the United States is privately held (73 percent), whereas the majority in Canada is publicly owned (94 percent) (CCFM 1996, Powell et al. 1993). In Mexico, most timber-productive forest is the property of indigenous communities or ejidos (about 80 percent), who have traditionally managed these as communally held property (Segura 1996). Since changes to the Constitution in 1992, communities may now claim full property rights and form legal associations with private enterprises to manage forests. In addition, private companies can buy up to 20,000 hectares of forest lands in Mexico for management (Segura 1996).

Clearcutting has traditionally been the industry's preferred method of harvesting trees in Canada and the United States. But controversy over the practice, which entails clearing and then replanting or allowing regeneration on an entire area, has led to recent changes in forest management. The harmful side-effects of clearcutting can include loss of habitat, soil erosion, and loss of scenic value.

In the 1990s, environmental groups campaigned intensively in both countries to stop clearcutting in old-growth forests, stimulating debates over forestry practices on private and government lands. In response, Canada's National Forest Strategy was developed, which includes consideration of three major components of sustainable forest management: natural systems, sociopolitical systems, and economic systems. It involves government officials, academics, industry, NGOs, the aboriginal community, and other interest groups (NRC 1998). It also included the goal of completing, by 2000, a network of protected areas representative of Canada's forest ecosystems. A growing number of forestry companies now manage some lands specifically to encourage old-growth biodiversity (EC 1996; OECD 1995b, NRC 1998).

An International Model Forest Network was established in 1992 to promote sustainable forestry (map 5) (Box 1). The objectives, first formulated by Canada's Model Forest Program, are to apply new and innovative approaches, procedures, techniques, and concepts in forestry management, and to test and demonstrate advanced technologies and practices in sustainable forestry (Hall 1995). Representatives from diverse groups participate in the Model Forest partnership, and international collaboration and networking

Box 1
Emerging Trend: Sustainable Forestry

Forest practices that are more sustainable promise to improve forest soil conditions, benefit soil organisms, provide improved habitat for a greater number and diversity of species, and provide multiple benefits to society. Progress is also being made in protecting more, larger, and more contiguous and representative natural spaces that support diverse forest ecosystems, processes, and species.

Co-management projects, involving local communities dependent on forestry resources for their livelihoods, are also proliferating, particularly in Mexico. Increased public participation in the development and implementation of environmental management strategies is viewed as a positive trend. Stronger local economies and increased protection for threatened forests and biodiversity may result.

Reliance on certification and marketing programs is also on the upswing. The Forest Stewardship Council, for example, certifies products as originating from sustainably managed forests (Rotherham 1996). Another certification program is administered by the International Standardization Organization (ISO), a federation of some 130 national standards bodies. Trade association programs also exist. The effect of these certification and labeling programs on consumer purchasing habits is still inconclusive. There is concern, however, that multiple programs may cause confusion, and potential trade barriers.

is an integral part of the concept. There are currently 17 model forests in North America: 11 in Canada, three in Mexico, and three in the United States.

The US government committed itself to the sustainable management of forests in the Forest Plan for a Sustainable Economy and a Sustainable Environment (CEQ 1996). The American Forest and Paper Association, whose members hold about 90 percent of the industrial forest land in the United States, adopted a Sustainable Forestry Initiative in 1994 (PCSD 1996c). Mexico's Forest Law incorporated sustainable forestry goals in 1992. The objectives include improving management, sensitizing users to the need to sustain the natural assets and services of forest resources, and promoting just and equitable relationships among stakeholders (Semarnap 1995).

In addition, forests account for an important share of the some 200 million hectares of formally protected areas in North America (FAO 1997a). In recent decades, a growing share of the remaining original forested lands has been declared protected areas.

All these responses reflect a desire to reduce pressures on the sustainability of forested lands, and have the potential to markedly improve the status of North America's forests.

Map 5

Model Forests in North America

Sources: NRC 1996b; CMFN 1999.

Agriculture

North America holds about 11 percent of the world's agricultural croplands, and produces 17 percent of the world's cereals, roots, and tubers….

North America holds about 11 percent of the world's agricultural croplands, and produces 17 percent of the world's cereals, roots, and tubers (FAO 1997c). As noted earlier, croplands occupy about 13 percent of the region's total surface area, while pastures cover 17 percent (OECD 1995a). In Mexico, 12.7 percent of the land is suitable for growing crops and 14.2 percent is dedicated to pasture (INEGI–Semarnap 1998). About one-fifth of the United States is used for cropland (USDA 1992), while only seven percent of Canada's large land base is classed as agricultural (although that includes about three-quarters of the nation's potentially arable land) (EC 1996). As a result, 88 percent of North America's agricultural land is found south of the Canadian border; map 6 indicates the average amount of agricultural land in each state or province in the region.

One of the major growing areas is the Great Plains ecoregion. Here, crop cultivation in some states and provinces occupies more than 30 percent of the land area. States with smaller amounts of cropland relative to other types of land use can still make significant contributions to agricultural production. California, for example, holds less than three percent of US farmland, but its highly productive central and coastal valleys produce more than 11 percent of the nation's agricultural revenue (Gleick et al. 1995). Much of this production was made possible by huge irrigation projects.

Agricultural lands are subject to degradation due primarily to erosion, desertification, and salinization as a result of growing and harvesting techniques that reduce the amount of organic matter in the soil, increase the water content, and help expose the soil to wind and water.

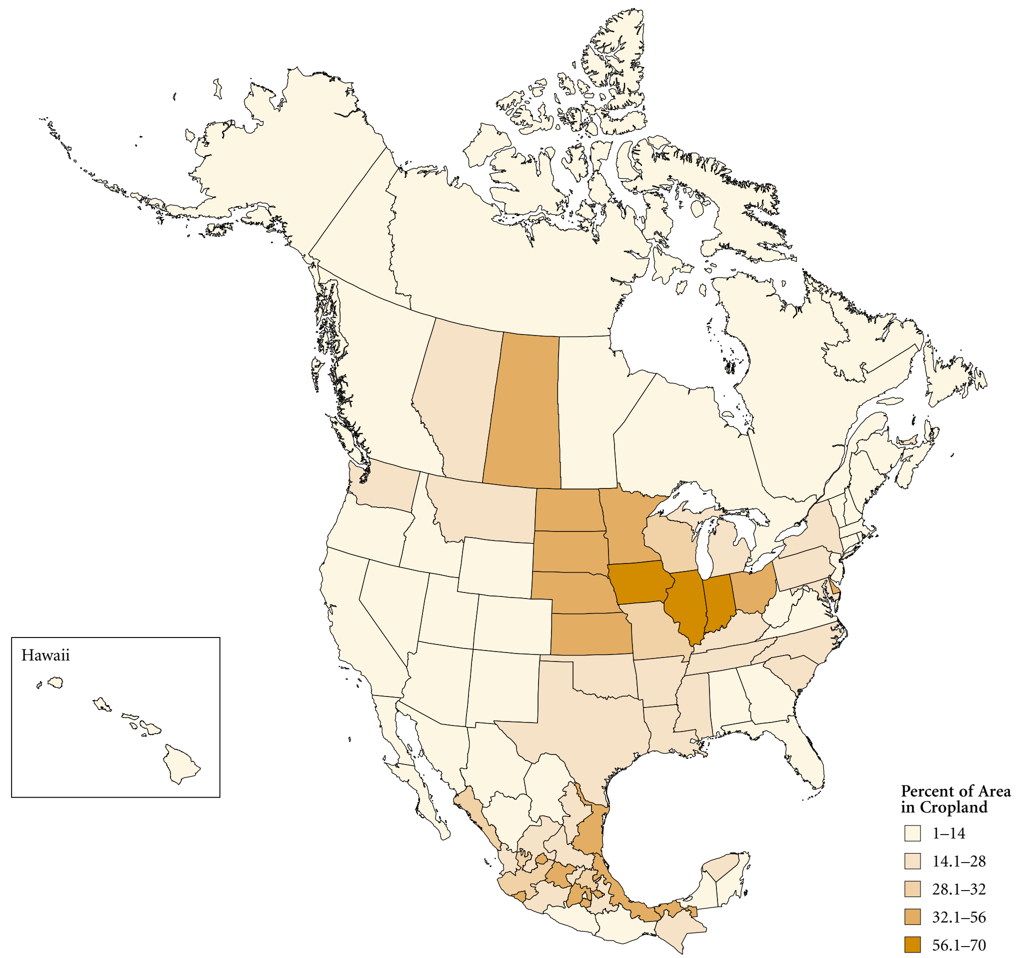
Soil loss through erosion by wind and water is decreasing on the whole in North America, due to better conservation practices and programs. Between 1982 and 1997, total erosion on all cropland in the United States decreased by 41 percent. Erosion totaled 3.08 billion tonnes in 1982, but by 1997 it had been reduced to 1.81 billion tonnes. (USDA 1997). [Soil erosion does not take place exclusively on farmed land, of course; at least 40 percent of all erosion in the United States is the result of activities such as construction, logging, and off-road vehicle use, or of natural events such as fire, flooding, or drought (USDA 1992).] Wind erosion rates are decreasing due largely to better residue management and the construction of control buffers such as windbreaks (Bloodworth and Berc 1997). The US Conservation Reserve Program contributes to the decline in soil erosion by providing incentives for farmers to remove highly erosion-prone cropland from production and to adopt soil conservation practices (Allen 1995). Between 1986 and 1997, over 14.6 million hectares (36 million acres) were enrolled in the program (USDA 1998).

In Canada's prairies, in the mid-1990s, annual soil loss by both wind and water was estimated to be about 177 million tonnes (Wilson and Tyrchniewicz 1995). Soil erosion control practices, such as forage crop rotation, the planting of winter cover crops, windbreaks, and contour cultivation have helped to slow soil loss and promise to continue to do so in the future (Wilson and Tyrchniewicz 1995; Dumanski et al. 1994). In Canada, in the early 1990s, research revealed that 42 percent of all farms polled practiced crop rotation using forage. As a result of implementing reduced tillage, together with declining use of summer fallow, the risk of wind erosion in the prairies dropped by 30 percent between 1981 and 1996 (AAFC 2000).

Each year, Mexico loses between 150,000 and 200,000 hectares of agricultural land due to erosion and conversion to other uses. It has been estimated that about 37 percent of Mexico's land is affected by water erosion and 15 percent by wind erosion (INEGI–Semarnap 2000). In 1995, over 32 million hectares were considered severely eroded. About 535 million tonnes of sediment are lost to erosion per year (Semarnap 1995). Clearing forests for agricultural uses (especially in tropical ecosystems), overgrazing, reduced fallow, and intensive cultivation of marginal lands have contributed to the problem (INEGI–Semarnap 1998).

Map 6

Cropland Area in North America, by State and Province/Territory



Sources: Statistics Canada 1994; SARH 1994; USDA 1994; INEGI 1995a.

Mexico's strategy for conserving and restoring soil resources is outlined in its 1997 *Programa Nacional de Restauración y Conservación de Suelos*. The main objectives include promoting financial strategies to counteract structural problems related to soil deterioration, and adjusting judicial frameworks accordingly; developing and applying technical solutions; and sensitizing the public to the sustainable use of soil resources (Semarnap 1997).

Although soil erosion is declining in many parts of North America, on balance more soil is still being lost in agricultural areas than is being regenerated naturally. Part of the problem is lack of humus because of a heavy reliance on chemical fertilizers, rather than on traditional fertilizers and soil amendments, such as manure and compost, that help maintain soil structure.

Where human activities are a major cause of land degradation in arid, semiarid, and dry subhumid areas, the process is called desertification. North America has about 232 million hectares of dryland area, 12 percent of the world's total (UNEP–GRID 1996). These areas are vulnerable to desertification in conditions of drought, especially when they are also subject to human pressures, such as agricultural and settlement expansion to marginal lands, irrigation causing salinization, and overgrazing.

About 10 percent of North America experiences drought in any given year (Parfit 1998). Drought conditions are frequent in northern Mexico, a condition that makes this area vulnerable to desertification when land-use activities are not appropriate. The largest North American desert is the Chihuahuan Desert, which is bigger than the state of California. It is located largely in northern Mexico, but fingers of it extend into the southern United States. Once grassland, the introduction of large herds of cattle converted the area to a shrub desert (DDL 1999). Mexico is taking steps to arrest desertification under the UN Convention to Combat Desertification, which it ratified in 1995 (UNCCD 1998). If droughts become more severe as predicted due to climate change, the northern and central parts of the country—about 48 percent of Mexico—will be highly vulnerable to desertification (INE 1999a).

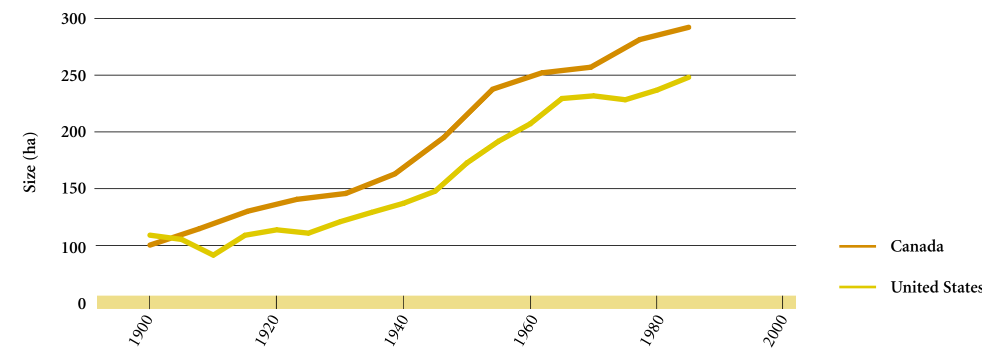
Salinization, the accumulation of natural salts in the upper layer of soil where plant roots exist, is worsened by irrigation that lacks adequate drainage. At least 19.4 million hectares of cropland and pasture in the United States are currently affected by increasing salinity (USDA 1992). In Canada, only two percent of prairie agricultural land has more than 15 percent of its area affected by salinity, while more than 60 percent has less than one percent affected, an indicator of low risk (EC 1996). Of Mexico's agricultural land, 1.5 million hectares are subject to salinity (INEGI–Semarnap 1998).

Although agriculture remains vital for food production, its economic role is slipping. Canada is the world's second-largest exporter of wheat, typically selling an annual average of 75 percent of its harvest abroad (EIU 1998a). However, agriculture accounts for less than two percent of Canada's GDP, and only employs about three percent of the labor force. Mexico's agricultural sector contributed three percent of national GDP in 1998, but its growth has been slower than that of the rest of the economy. Even though the US farming sector accounted for only about three percent of its GDP in 1998, its output is huge. In 1997, the United States supplied 41 percent of the world's corn and 50 percent of its soybeans (EIU 1998c).

Two trends in agriculture during this century have been to substitute machines for humans and to become more reliant on synthetic chemical fertilizers. While the amount of land devoted to agriculture has remained stable since 1960, a steady rise has occurred in agricultural production, aided by irrigation and the use of fertilizers and pesticides. Underlying pressures, such as government subsidies and tariff protections, and indirect subsidies from low energy prices, have made agrochemicals, irrigation, and fuel artificially cheap. They have also encouraged industrial conglomerates in

Figure 4

Average Farm Size in Canada and the United States, 1900–91

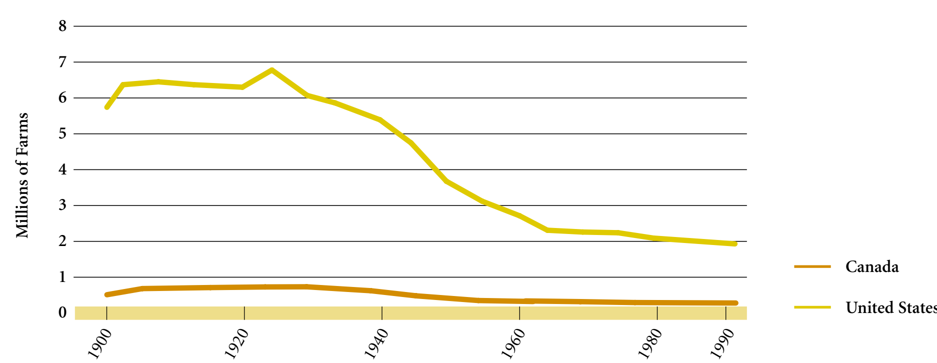


Sources: McAuley 1996; CEQ 1996.

Note: Data unavailable for Mexico.

Figure 5

Number of Farms in Canada and the United States, 1900–91

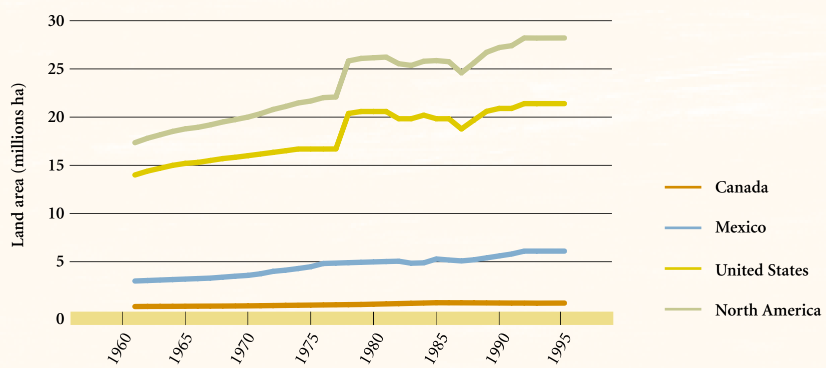


Sources: McAuley 1996; CEQ 1996.

Note: Data unavailable for Mexico.

Figure 6

Irrigated Area in North America, by Country, 1961–96



Source: FAO 1997c.

Table 2

Fertilizer and Pesticide Use in North America, by Country, Early 1990s

	Fertilizer (mean annual values) million tonnes/year	Pesticides (kg/ha)
Canada	2.124	0.81
Mexico	1.681	0.84
United States[1]	18.290	2.40
North America	22.095	1.92

Sources:
Fertilizer: UNEP 1993. (Data for years 1988–90).
Pesticides: OECD 1995a (Canadian data for 1990, US for 1991) INE, no date (data for Jan–July 1993).

Note: Fertilizers in the form of nitrogen, phosphate and potash.
[1] Includes Puerto Rico.

Canada and the United States, which are characterized by single-species monocultures and large-scale beef, pork, and poultry production facilities. Overall government support for agriculture in Canada, however, has been reduced considerably in recent years, through reforms such as elimination of grain transportation subsidies in the prairies.

There has been a continued trend toward agricultural specialization and intensification. Simultaneously, the number of farms has decreased and their size has increased in both the United States and Canada (figs. 4 and 5). In Mexico, export-oriented agriculture, which is more energy-intensive than low-impact traditional farming methods, has expanded in the past decade.

Agricultural intensification in North America was aided by increases in the amount of land under irrigation, which grew from 17.4 million hectares in 1961 to 28.2 million hectares in 1996 (fig. 6). Fertilizer application more than doubled between 1960 and 1980. Despite the large amounts of pesticides applied in North America (table 2), the intensity of use is low relative to some other parts of the world (OECD 1995a).

Intensive farming with substantial chemical use has resulted in considerable water pollution. Large-scale feedlot operations are also important localized sources of pollutants in the form of manure. A number of agricultural pesticides kill wildlife directly while others build up within the food web, placing toxic burdens on top predators, including humans.

There is a growing body of evidence linking pesticide exposure to adverse health effects, including cancer, birth defects, reproductive harm, neurological and developmental toxicity, immunotoxicity, and disruption of the endocrine system (NRDC 1997).

Children are more susceptible than adults to the harmful health effects of pesticides for a number of reasons, including their physiological immaturity, their play activities and their distinctive diet (Bearer 1995; NRDC 1997; EPA 1997b).

Their small, developing bodies are more sensitive to toxic stress and they have a longer expected lifetime in which to develop illness after exposure. The most important factor determining children's increased risk from pesticides is their greater exposure. They are exposed to pesticides more than adults because of their shorter stature and their greater hand-to-mouth activity, which provide more opportunities for inhaling or ingesting pesticide residues in dust, soil, and heavy vapors (EPA 1997b; Johnson 1996; NRDC 1997). Children also drink more fluids, breathe more air, and eat more food per unit of body weight than do adults (NRDC 1998). In addition, they eat a more limited selection of foods (NRDC 1998). Children consume much more apple, grape and orange juice per unit of body weight than the average adult, and most fruit and their juices contain pesticide residues (NRDC 1997).

Pesticides are becoming increasingly better managed, however, as a result of the efforts of farmers, environmental organizations, governments, and industry. The 1997 Declaration of the Environment Leaders of the Eight on Children's Environmental Health provides a framework for national, bilateral and international efforts to improve the protection of children's health from environmental threats such as pesticides (Anon. 1998).

The most persistent types of agricultural chemicals are no longer in use in Canada or the United States, and their use is being sharply reduced in Mexico. Facilitated by the CEC, the Sound Management of Chemicals project is an ongoing intergovernmental initiative to reduce the risks of persistent toxic substances to human health and the environment. Following the implementation of regional action plans, chlordane is no longer manufactured or registered for use in Canada, Mexico, or the United States, and the amount of DDT used in Mexico has declined by approximately 50 percent since 1997. Lindane, hexachlorobenzene, and dioxins have recently been identified as additional candidates for regional action.

The first global agreement to ban or control 12 persistent organic pollutants was endorsed by representatives from 122 countries in Johannesburg, South Africa, in December 2000. Over time, this agreement may lead to the reduced use of hazardous pesticides on produce grown, and traded, around the world.

The use of pesticides and other agricultural inputs may also be reduced through the introduction of transgenic crops that have been engineered to tolerate certain pests (Box 2, below) and from a transition to organic agriculture (Box 3).

The agriculture sector has begun addressing agricultural sustainability concerns through research, enhanced awareness, and the adoption of such tools as best management practices and environmental farm planning. By 1999,

Box 2
Emerging Trend: Genetic Engineering and Biotechnology

The use of genetically modified organisms (GMOs) in agriculture is an emerging trend that will influence the future of agriculture, food production, human health, and levels of biodiversity. In the debate about genetically engineered crops, supporters claim that growing crops that have been modified to resist pests will improve harvests and reduce the need to use synthetic chemical pesticides. Critics of GMOs, however, point to the potential for considerable ecological and human health risks associated with the unintentional transfer of "transgenes" from modified organisms to wild plant relatives. Transgenes refer to genetic materials transferred from one species to another that can act like exotic pest species—the effects of which are unpredictable on natural ecosystems and indigenous crops (Steinbrecher 1996). Critics suggest that genes escaping from the genetically modified crops could accelerate the evolution of highly resistant "superbugs" and "superweeds," or that the toxins engineered into food plants could poison beneficial predatory insects (Concar 1999; Concar and Coghlan 1999).

Final negotiations on a Biosafety Protocol to lessen the threat of transgenic organisms from spreading foreign genes to the wild took place in early 1999 and again in January 2000. The protocol is an outgrowth of the 1992 Convention on Biological Diversity, the core objectives of which are the conservation and sustainable use of the components of biological diversity and the equitable sharing of the benefits that arise from its use. The Biosafety Protocol, agreed to by the Parties of the Convention, would set out "appropriate procedures, including, in particular, advance informed agreement, in the field of the safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity" (UNCBD 1992).

There are a wide variety of national approaches to biotechnology, which is turning into a large industry. The United States, Canada, Australia, Argentina, Chile, and Uruguay—leaders in the exports of GMOs—each regulate their products of biotechnology under domestic regulatory regimes, while supporting negotiation on international commitments that reflect the variety in national approaches. Critics contend that these regulations should be more stringent and precautionary in approach. Although Mexico is a leading producer of transgenic foods, these are largely perishable fruits rather than grains, so Mexico wants transgenic commodities such as grains to be included in the protocol. As the origin of many of the world's cultivated plants and one of the richest in biodiversity, Mexico is particularly concerned about the risks associated with the importation of genetically engineered crops (Weiskopf 1999; INEGI–Semarnap 1998).

some 16,000 farmers in Ontario were participating in the province's environmental farm plan program.

The goal of Canada's Agriculture in Harmony with Nature strategy is to involve sectoral, government, academic, and other partners in the advancement of sustainable agriculture. The objective is to prevent soil degradation and water and air pollution while improving socioeconomic well-being and providing a continuous supply of safe agricultural products (AAFC 1997). The Canadian government has already developed 14 agri-environmental indicators, which are used to monitor the agricultural sector's environmental performance and its adoption of environmentally sound practices (AAFC 2000).

The US government is also encouraging sustainable agricultural practices by strengthening conservation requirements, protecting prime farmland from being converted to nonagricultural uses, and encouraging alternative pest management (UNEP 1997b). Many farmers are also adopting conservation tillage and other soil management strategies and organic farming methods (Box 3, below). In addition to preventing erosion, these practices can save on fuel and labor and can lower machinery investments (CEQ 1996).

As North Americans weigh the pros and cons of "alternative" and "modern" methods of agriculture, environmentally sustainable farm practices are likely to become more common (Papendick et al. 1986).

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Box 3

Emerging Trend: Organic Agriculture

The use of organic agriculture, which has the potential for reducing some of the negative impacts of conventional agriculture on the environment, is growing in North America. There are now over 1.1 million hectares under organic management, with 80 percent of that area in the United States. The land under organic management in the United States doubled between 1995 and 2000 to 900,000 hectares (Willer and Yussefi 2000).

There are many methods of organic farming, but the general aim is to enhance the health of consumers, the soil, and the planet. Organic farmers eschew synthetic fertilizers in favor of enriching soil with compost and manure and with "green manure" crops such as ryegrass and clovers. These methods help to prevent erosion and restore soil structure, while benefiting soil microorganisms, earthworms, and helpful insects. Organic farmers also use alternative methods of pest and weed control. One of the aims is to reduce the amount of chemicals that wind up in our food. Another goal is to reduce the chemical runoff that pollutes North America's groundwater, rivers, and estuaries. Today, there are an estimated 10,000 certified organic farmers in the United States (Bourne 1999). Mexico reports 28,000 small organic farms and Canada has 2000 (Willer and Yussefi 2000).

As in the case of forest products, certification of organic foods may help to market them and ensure their quality. The US Department of Agriculture is preparing a final draft of national standards to bring the labeling of organic produce under federal law (Bourne 1999).

Fresh Water

North America's abundant surface and groundwater resources represent 14 percent of global renewable fresh water. The continent is home to the Great Lakes, which, with 18 percent of the world's surface water, can claim to be the greatest freshwater system in the world. Most of the continent's renewable fresh water, however, is stored in the ground.

Water Availability

North America's abundant surface and groundwater resources represent 14 percent of global renewable fresh water. The continent is home to the Great Lakes, which, with 18 percent of the world's surface water, can claim to be the greatest freshwater system in the world. Most of the continent's renewable fresh water, however, is stored in the ground. Both surface and groundwater stocks are maintained by precipitation, which varies from minimal in such places as deserts or the Arctic to more than six meters a year along parts of the Pacific coast, where temperate rainforests are found (map 7).

Canada has about half of North America's renewable freshwater resources. On a per capita basis, this is 10 times more than in the United States and 20 times that of Mexico (table 3) (WRI et al. 1998). However, 60 percent of Canada's water flows north (map 8), while 90 percent of the population lives in the southern part of the country, within 300 kilometers of the US border (EC 1998a).

To compensate for local and regional scarcities or to generate hydroelectric power, improve navigation, or control floods, North Americans have built extensive water control projects, including dams and canals. The resulting water management infrastructure has altered hydrologic flows and increased the water surface area in North America, often by flooding valleys. Low-lying valleys are typically populated and are the most productive regions for both agriculture and wildlife conservation. The impoundment of water for hydroelectric projects can have profound effects on water quality and freshwater resources, such as fish populations, and hence on human communities. Fewer than half of the rivers in North America remain "wild," where water flows in a natural course unaltered by humans. Canada has developed more water diversions than any other country in the world, primarily to generate hydroelectricity (Linton 1997).

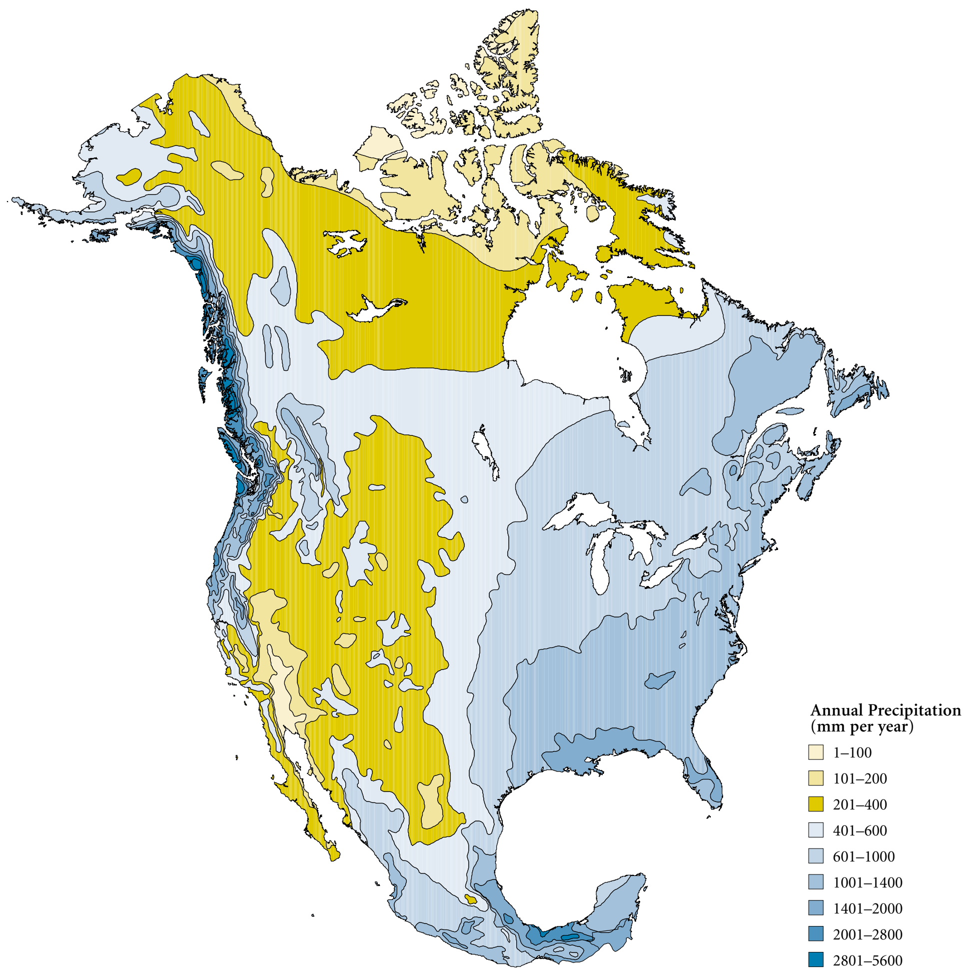
Residents of the United States and Canada are the world's largest consumers of water on a per capita basis (using about twice as much per person as Mexicans) (table 4) and demand is growing, especially in some very dry areas. It has been projected, for example, that dramatic population growth in the dry interior of the western United States will continue—Las Vegas is the fastest growing city in the nation—and may increase by more than 30 percent by 2020. But the heaviest demands on freshwater resources come from agriculture and thermoelectric power generation, which together account for about 80 percent of water withdrawals (OECD 1996).

As most of the water used in thermoelectric power generation is returned to the immediate water environment after use, it is the agricultural sector of Mexico and the United States that accounts for the largest proportion of total consumptive water use in North America (fig. 7) (USGS 1993). It has been estimated that only about 30 percent of water withdrawn from rivers or lakes for irrigation returns to its source (Linton 1997). A large share of irrigation water is pumped from underground sources that were created by the accumulation of small amounts of rain over many centuries. Over 75 percent of North America's irrigated cropland is in the United States, while only 2.5 percent of the region's irrigated land is found in Canada (map 9) (FAO 1998; OECD 1995a).

In the United States, 90 percent of water withdrawals for irrigation occur in the West (OECD 1996). Groundwater depletion threatens aquifers that are important for irrigated agriculture. The Ogallala Aquifer that underlies the Great Plains, for example, is one of the largest aquifer systems in the world, with water resources equivalent to Lake Huron. The rate of water table decline in this aquifer peaked at one meter per year before slowing in recent years, but depletion is still faster than recharge (HPWD 1997).

In several areas of northern Mexico, groundwater tables continue to decline dramatically (OECD 1996; USGS 1993). In the 459 groundwater aquifers that have been identified, pumping exceeds natural recharge in about 80, mainly in the northwest (OECD 1998). Most irrigation water is extracted in dry areas where natural recharge is low and groundwater levels are declining (INEGI 1995a).

Map 7
Average Annual Precipitation in North America



Source: ESRI 1999.w

Some Useful Definitions

Surface water: An open body of water, such as a pond, stream, river, or lake. Mainly supplied by precipitation; the time required to replenish such water bodies varies from days to hundreds of years.

Groundwater or underground water: In the broadest sense, all subsurface water, including the saturated and unsaturated zone, as distinct from surface water. The term is most commonly used to refer to subsurface water in the saturated zone. Unlike surface water, the time required to replenish the water stored in groundwater systems can be on the order of tens of thousands of years or more.

Withdrawal: The act of removing water from the ground or diverting it from a surface water source for use.

Consumptive use: Water that has been evaporated, transpired, or incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumption. This water does not return to the stream or groundwater source immediately after use.

Nonconsumptive use: Water that is returned to the immediate water environment after use. The water is sometimes returned with different physical, chemical, or biological characteristics.

Instream use: Water use occurring within the stream channel. Examples are hydroelectric power generation, navigation, aquaculture, and recreational activities. Also called nonwithdrawal use and in-channel use.

Offstream use: Water withdrawn or diverted from a groundwater or surface source for public water supply, industry, irrigation, livestock watering, thermoelectric power generation, and other uses.

Renewable water supply: Rate of supply of water (volume per unit time) potentially or theoretically available for use in a region on an essentially permanent basis.

Source: Adapted from USGS 1993.

Overdrafting of groundwater also contributes to land subsidence and damage to infrastructure in Mexico City and the Valley of Mexico (Postel 1996).

Groundwater is becoming a particularly important issue along the US-Mexican border, where growing populations and vulnerable groundwater supplies suggest an urgent need for coordinated, equitable, binational strategies (Bixby 1999; Coronado 1999) (Box 4). The lack of comprehensive, cooperative management for transboundary groundwater resources promises to become one of the most pressing challenges of the next century (CEC 1998b).

One encouraging trend is that, after increasing between 1950 and 1980, water withdrawals for offstream use in the United States declined between 1980 and 1995. Although demand for irrigation water is high, withdrawals were reduced by the use of better irrigation techniques, increased competition for water, and a downturn in the farm economy. Increased reliance on demand management tools has also resulted in greater efficiency of use. Despite an increase in population of 16 percent from 1980 to 1995, the United States withdrew two percent less water in 1995 than in 1990, and nearly 10 percent less than in 1980. Total freshwater consumptive use, however, was six percent more in 1995 than during 1990 (Solley et al. 1998).

Canada experienced a seven-percent increase in total water withdrawals between 1986 and 1991, but on a per capita basis withdrawals remained nearly constant (Linton 1997). In Mexico, water withdrawals have increased with economic development and population growth, with most growth due to agricultural needs. It is expected that agricultural water use there will be 100 percent greater in the early years of the 21st century than it was in 1980 (INEGI 1995a). Worldwide, agricultural use of freshwater has tripled in the century from 1901 to 2000 (UN Economic and Social Development 1997, especially figure 6).

Another factor that will almost certainly affect freshwater demand and availability is global climate change, if its effects follow modeled predictions (see section on Climate Change). Rising temperatures and diminished precipitation in regions that are already arid or semi-arid, and declines in crop yields in these and other sensitive regions, can be expected to produce increased pressures on freshwater withdrawals, migration of populations, and increased hardship for those who remain on the land (UN Economic and Social Development 1997, and IPCC 2001).

Water Quality

Many of North America's estuaries, rivers, streams, lakes, and groundwater reserves are polluted by industrial discharges, agricultural runoff and insufficiently treated municipal wastewater. Drinking water disinfection systems are widespread, but aging water distribution systems sometimes have trouble maintaining high standards of water quality.

Water pollution was one of the first major issues to seize the attention of North Americans during the rise of the environmental movement in the 1960s. At the time, some rivers were so polluted that their oily surfaces could catch fire. Public reaction to gross water pollution triggered a great number of anti-pollution laws and cleanup programs, so that many waterways are cleaner now than they have been in decades. But industrial, agricultural, and municipal expansion has brought at least some water pollution to areas that were once pristine. In addition, some of the millions of tonnes of pollutants released into the air in North America, as well as some from abroad, land on waters across the continent. Some of the heaviest concentrations of chemical deposition take place in high altitudes and in the cold, northern regions, particularly the Arctic.

Table 3

Annual and Per Capita Freshwater Resources, by Country, 1998

	Annual Internal Renewable Water Resources (km^3)	Water Resources Per Capita (m^3)	Percentage of North American Resources	Percentage of Global Resources
Canada	2,849.5	94,373	49	6.9
Mexico	463.0	4,755	8	1.1
United States	2,459.1	8,983	43	6.0
North America	5,771.6	36,010	100	14.1
World	41,022.0	6,981	–	–

Sources: WRI et al. 1998 for Canada and the United States. Mexico's data derived from INEGI-Semarnap 2000.

Note: Annual internal renewable water resources refers to the average annual flow of rivers and groundwater derived from precipitation. Per capita annual internal renewable water resources data were calculated using 1998 population estimates.

Map 8

Water Flows from Major Rivers in North America

Source: Riggs and Wolman 1990.

Note: Principal river systems and those channels carrying mean flows of more than 1,000 m^3/s.

Box 4

Emerging Trend: Water Crises?

Urban water users, farmers, ranchers, and tribal peoples will need to find sustainable ways of sharing and conserving the same limited resource while leaving enough water to maintain environmental quality (WWPRAC 1998). As in many issues of shared resources, multi-stakeholder management projects are emerging as the way of the future. One example of cooperation is in the basin of the San Pedro River, on the Arizona-Sonora border. The river is a vital migratory corridor for millions of songbirds, but it is also in demand for consumptive water uses. A CEC project brought together people from the region, who called for measures to "balance the water budget for human and ecological needs" (CEC 1999a).

Comparing trends in water quality across North America is very difficult due to the scarcity of comparable data and the differences in water quality standards in different jurisdictions. A few examples of the state of water quality in some regions of North America provide a sketch of the mixed trends.

On the positive side, phosphorus discharges have declined substantially in the past two decades. Phosphorus loadings to the Great Lakes, for example, decreased thanks to anti-pollution regulations, voluntary industry initiatives, and the investment of tens of billions of dollars on sewage treatment systems since the 1970s. Total phosphorus loadings to Lakes Erie and Ontario declined substantially, while loadings to Lakes Huron, Michigan, and Superior have generally remained below target levels since 1981 (fig. 8). Concentrations of nitrogen compounds remain elevated, however (EC 1996).

Concentrations of DDT and its metabolites (such as DDE) and polychlorinated biphenyls (PCBs) have generally been declining in the North American environment. They decreased markedly in the 1970s, following the introduction of strict regulatory controls on persistent organic pollutants (POPs). Measurements in the Great Lakes show that levels of these two groups of persistent toxic chemicals, as well as a number of other POPs, have fluctuated since then but, during the 1990s, have been at or near their lowest levels in most lakes since monitoring began (DFO 1999). Fluctuations can be due to a number of reasons, including changes in the composition of wildlife communities, the release of PCBs still in use, the escape of PCBs from storage and dump sites, and the airborne transport of PCBs from other countries (DFO 1999; EC 1998b).

The decrease in these chemicals is believed to be the leading factor behind the increase in the number of double-crested cormorants, signs of a bald eagle recovery, and a general reduction of PCBs in Great Lakes Lake Trout (fig. 9). There has also been a decrease in the frequency of warnings that fish are too contaminated to eat safely.

North America still faces many challenges in improving the quality of its water resources and finding ways to protect them from continued pollution. There is evidence that children of mothers who consumed contaminated fish from the Great Lakes region have suffered growth retardation, decreased birth weights, and neurological effects (EPA 1995; Colborn et al 1996). The primary routes of exposure for these infants were through placental transfer in the womb and through breast-feeding. The role of some synthetic chemicals as hormonal mimics and endocrine disrupters is an important emerging health issue. These chemicals can interfere with normal hormonal functioning.

In addition to chemicals such as POPs, microbes can pollute waters to unhealthy levels. The United States has experienced several outbreaks of illnesses due to protozoan parasites such as *Cryptosporidium.* Drinking-water sources polluted with agricultural animal excreta is a problem that requires more attention and action. The intensification of animal production systems, especially hog farms, and the inadequacy of available land for manure recycling is increasing the risk of water pollution from field runoff and spills and leaks from storage facilities (Harkin 1997). About 40 percent of US waters surveyed in 1996 were found to be too polluted for fishing, swimming, and other recreational purposes (EPA 1996a). In 1994, almost 20 percent of the US population lived in areas where community drinking-water systems sometimes violated EPA standards (CEQ 1996).

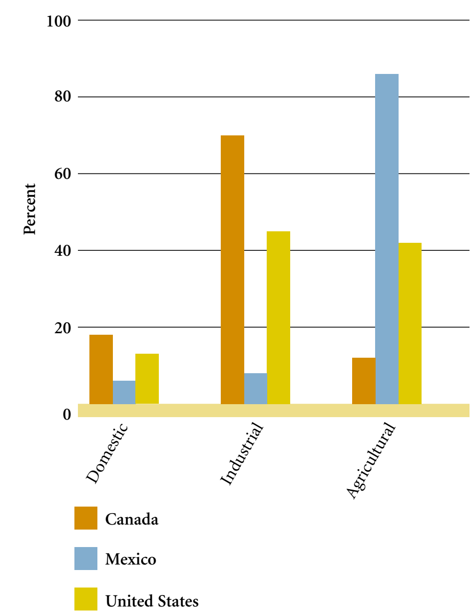
Mercury continues to be a pollutant of concern in North America and is being addressed by the CEC in its North American Regional Action Plan for Mercury. Fish advisories resulting from high-levels of mercury persist in many lakes in North America. Lakes in the northeastern and mid-western United States and central and eastern Canada have elevated levels due in part to the long-range transport and

Table 4
Annual Freshwater Withdrawals, by Country

	Total (km^3)	Per Capita (m^3)	Percentage of Total that is Surface Water	Percentage of Total that is Groundwater
Canada	45.1	1,611	97.7	2.3
Mexico	79.4	872	64.5	35.5
United States	467.34	1,724	76.6	23.4
North America	591.84	1,518	76.9	23.1
World	3,240.00	645	–	–

Sources: WRI et al. 1998 for freshwater withdrawal data for Canada and the United States. Data for Canada are from 1991 and for the United States from 1990. Percentage of total by source is derived from data in OECD 1995a for Canada and the United States. Data by source for Canada are from 1993 and for the United States, 1990. INEGI-Semarnap 2000 presents 1997 data for freshwater withdrawal for Mexico, and for percentage of total by source. Per capita figures are derived from 1998 population estimates that show Canada with 28 million people, Mexico with 91 million, and the United States with 271 million.

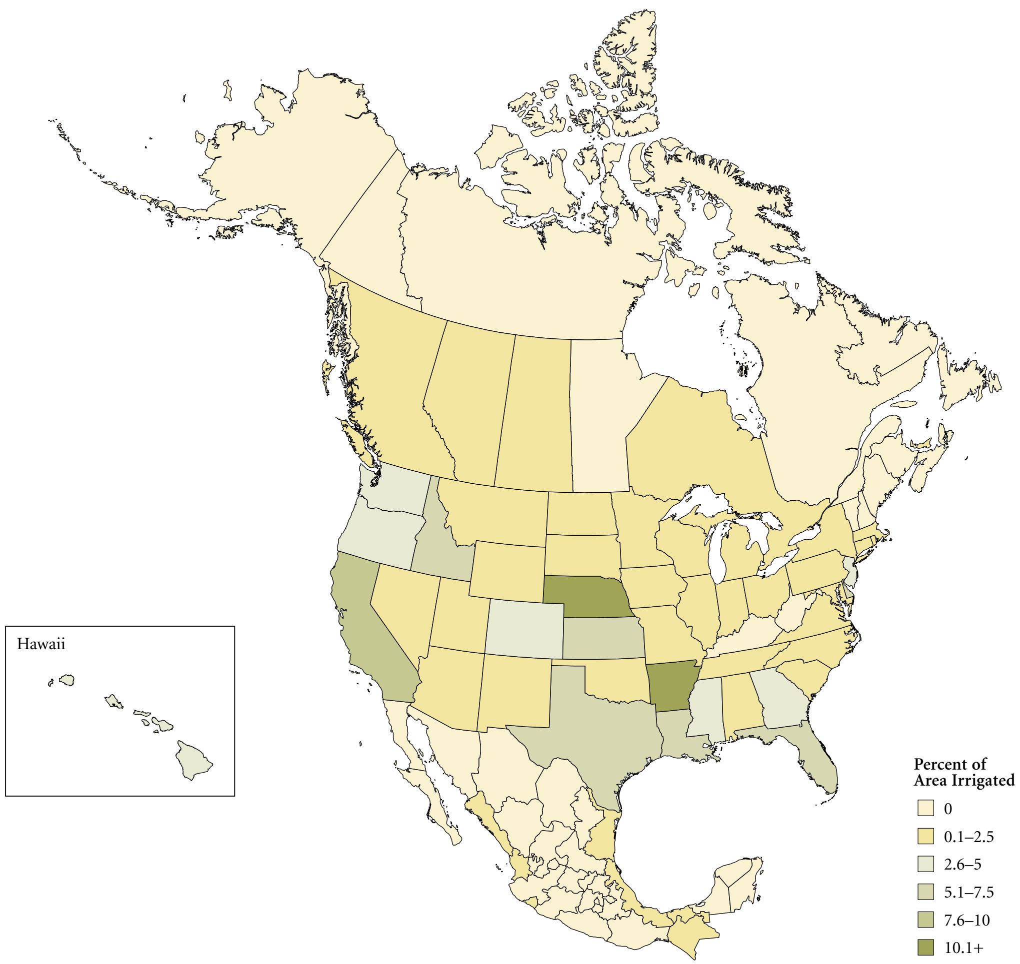
Figure 7
Annual Freshwater Withdrawals in North America, by Sector and Country



Source: WRI et al. 1998, with data for Canada and Mexico from 1991, and the United States 1990.

Map 9

Irrigated Land Area in North America, by State and Province/Territory



Sources: USDA 1994; Statistics Canada 1998; INEGI 1990.

deposition of mercury from coal-burning and waste incineration in North America's industrial heartland. Efforts are underway to control mercury pollution and significant reductions have been achieved for some sectors. Coal-fired power stations remain one of the largest and still unregulated emitters of mercury in North America.

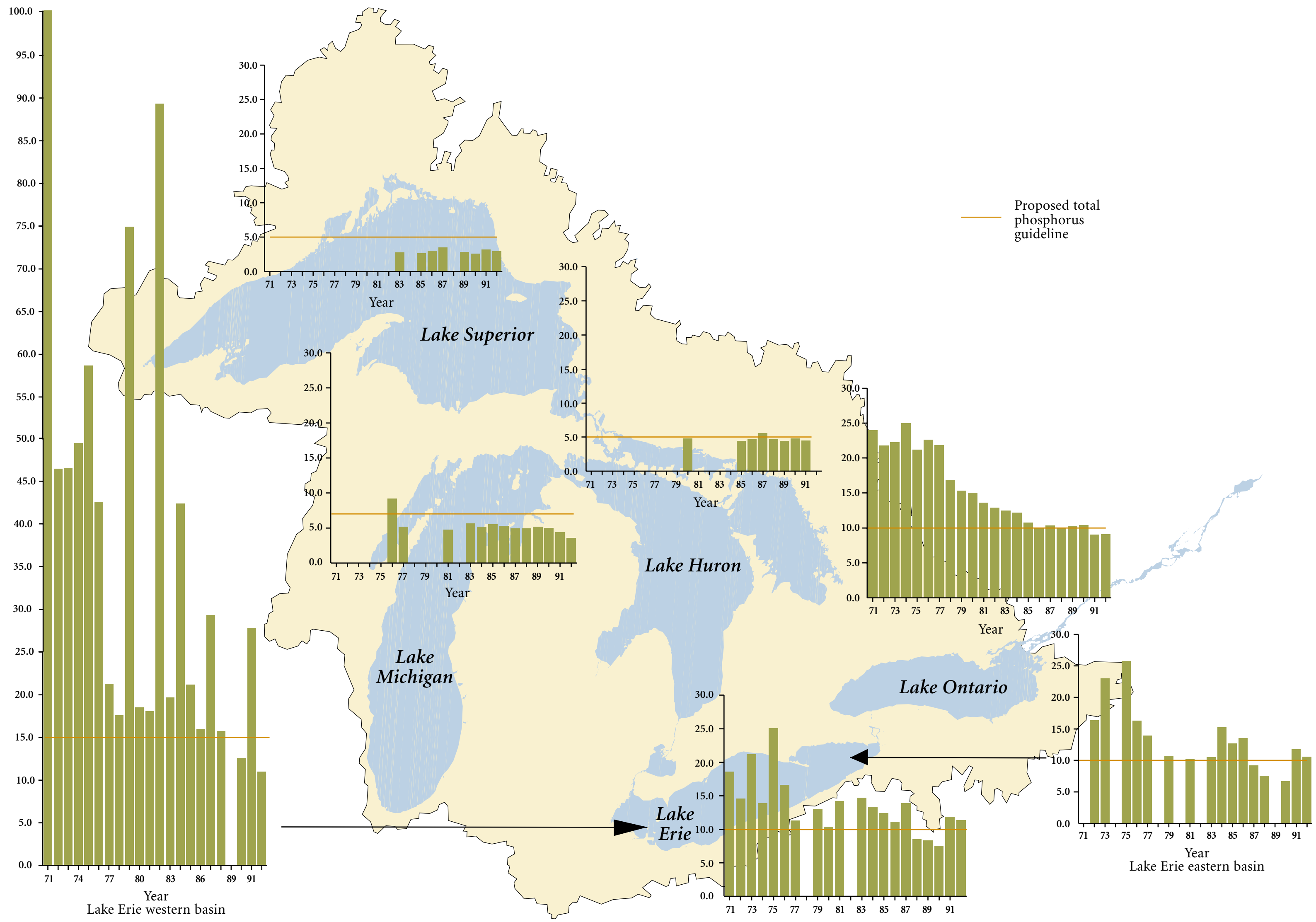
In Mexico, only a small percentage of municipal sewage and industrial wastewater discharges is properly treated. Serious public health consequences result from the contamination of water with raw fecal matter. Gastrointestinal diseases are prevalent in about one-third of Mexican states (OECD 1998). The main stem of the Rio Bravo/Rio Grande is often contaminated by fecal coliform bacteria due to inadequate wastewater treatment, and levels of total dissolved solids and chlorides are elevated (TNRCC 1994).

The concentration of industry and population centers without adequate municipal infrastructure appears to be an underlying pressure contributing to a number of transboundary water-quality problems along the US-Mexican border (Kelly et al. 1996). Related to this activity is the illegal dumping of hazardous waste that is compromising water quality in the Rio Bravo/Rio Grande basin (TNRCC 1994). Response to this problem, in the form of cooperative activities involving the shared border environment, began in the mid-1990s (EPA 1998d). One good sign is that the percentage of population with access to treated drinking water has been increasing and over 94 percent of water for human consumption in Mexico has been disinfected (CNA 1997).

Lake Chapala, Mexico's largest lake, suffers from an accumulation of nutrients and persistent chemicals. Accelerated industrial and agricultural development, and rapid population growth have put increasing pressures on water quality in the entire Rio Lerma basin, which includes the lake. Recent research indicates that the basin suffers from an unprecedented level of environmental degradation (Sota-Galera et al. 1998). Public and private efforts to improve the situation

Figure 8

Spring Mean Total Phosphorus Trends for Open Lake Waters, 1971–92

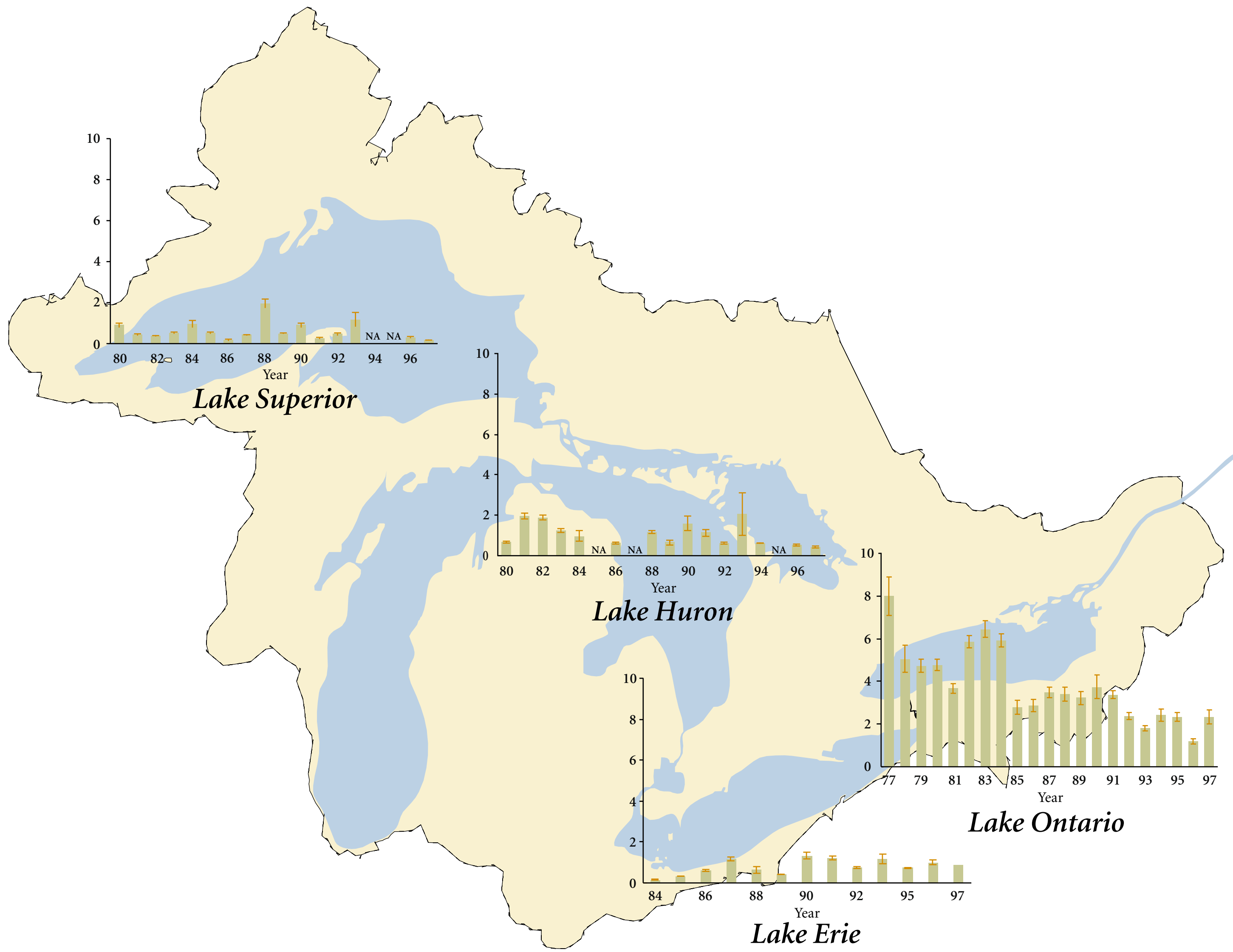


Source: EC 1996.

Note: Phosphorus concentrations are in µg/L.

Figure 9

Total PCB Levels in Great Lakes Lake Trout, 1977–97



Source: DFO 1999.

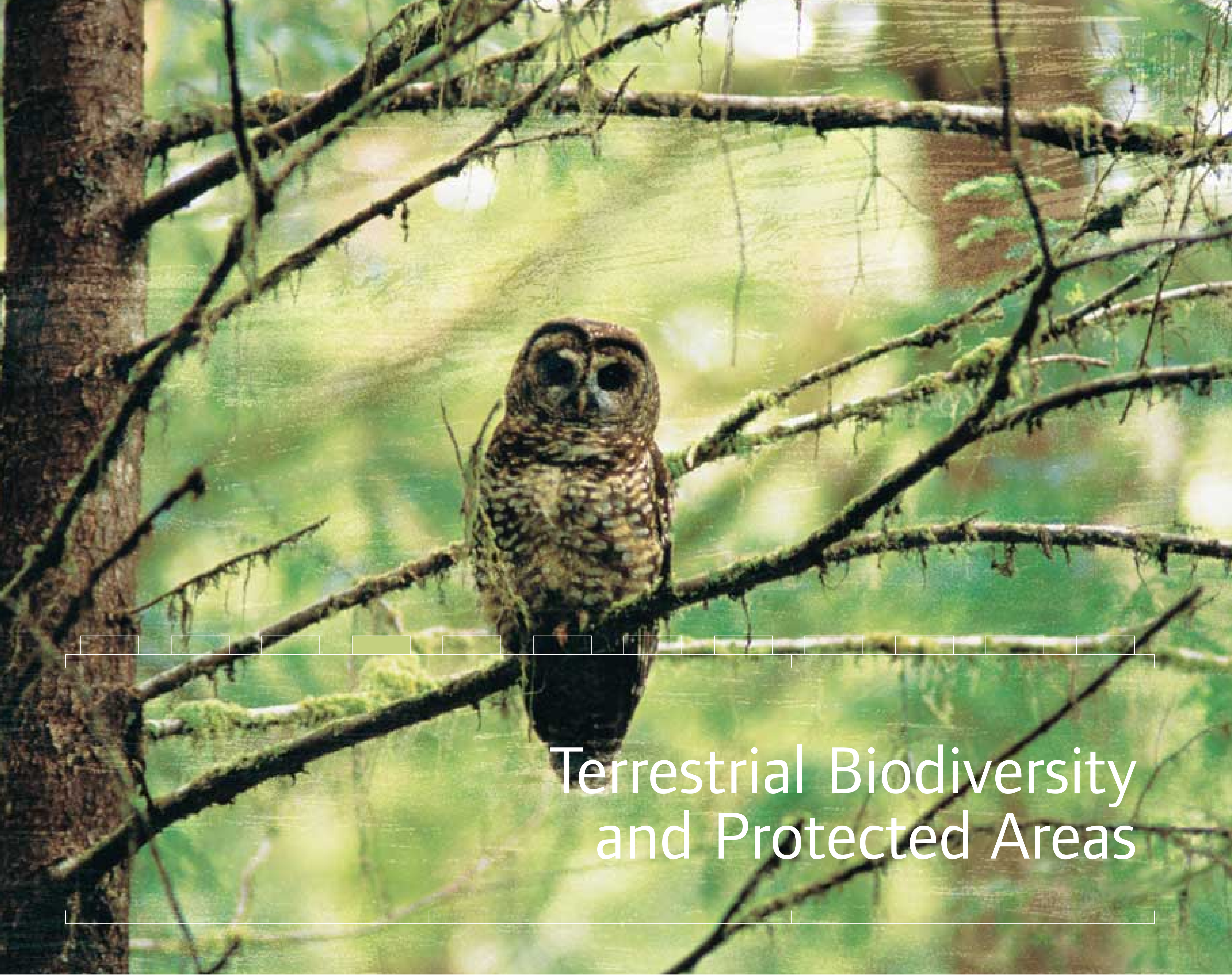
Note: µg/g wet weight +/- standard error, Whole Fish, Age 4+.
(NA - Not Analyzed)

have so far reduced the pollution load in the basin by 65 percent. And, in 16 priority basins, some pollution parameters such as lead show improvement (OECD 1998).

In Canada, the untreated sewage wastes of about 1.6 million people are still released into water bodies, although the percent of people serviced with at least primary wastewater treatment rose from 85 percent in 1991 to 93 percent in 1994 (EC 1998c). There has been a noticeable decrease in the amount of pollution entering Canada's waterways in the past two decades. Contamination by organic and inorganic substances in the St. Lawrence River decreased substantially between 1986 and 1992 (EC-Quebec Region 1996). Reductions in industrial wastewater emissions have been a significant factor. The growth in mega hog farms in Quebec and other regions of Canada, however, is contributing to ongoing river pollution (Le Fleuve 1997). Hog factory wastes that reach waterways and estuaries contribute to excessive nutrients that may be related to recent outbreaks of organisms that can cause toxins harmful to fish and humans (Harkin 1997; CIBE 1999).

Groundwater contamination in Canada is also a widespread and growing concern, as the recent disaster (May 2000) in Walkerton, Ontario, bears unfortunate testimony. The largest groundwater quality problem is high nitrate levels and fecal coliform bacteria in wells, originating from fertilizers, manure, and septic tank leakage (EC 1996). It is mainly a problem for rural dwellers and smaller towns, most of whom rely on well water or smaller riverine sources that may not be adequately purified.

The three nations of North America are in a unique position to accomplish environmental monitoring and management of aquatic resources on a regional scale. Bilateral agreements in the region have created a long history of cooperation. Canada and the United States signed the Boundary Waters Treaty in 1909 and the Great Lakes Water Quality Agreements in 1972 and 1978. Mexico and the United States have long cooperated on issues of water management and conservation along the Rio Grande.



Terrestrial Biodiversity and Protected Areas

North America's diminishing biological diversity has profound consequences. Because the loss is irreversible—species that are lost are lost forever—the potential impact on the human condition, on the fabric of the continent's living systems, and on the process of evolution is immense.

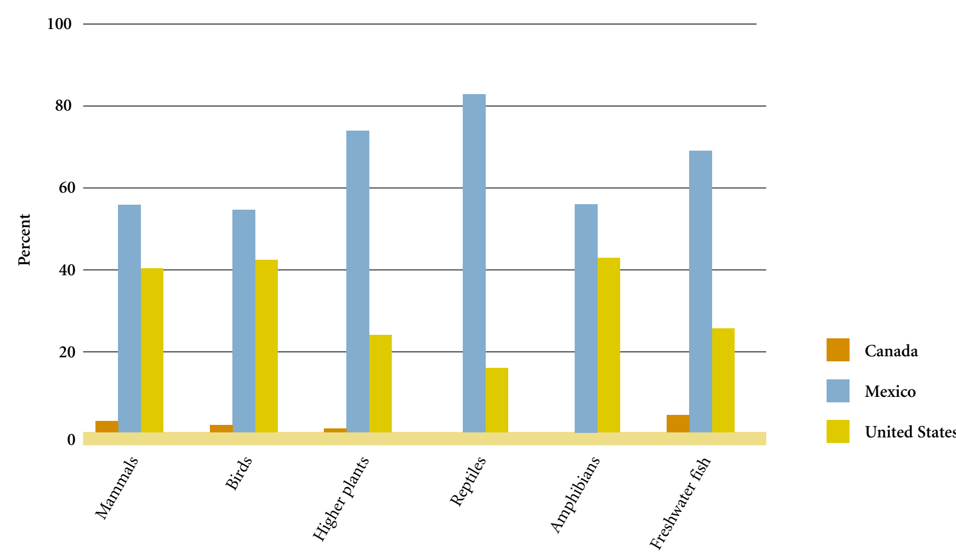
From heavy industry and tourism to subsistence agriculture and fishing, North Americans depend on natural resources for survival and well-being. Yet, the extent of our dependence, the connectedness of our condition, and the precariousness of our situation is little recognized. North America's diminishing biological diversity has profound consequences. Because the loss is irreversible—species that are lost are lost forever—the potential impact on the human condition, on the fabric of the continent's living systems, and on the process of evolution is immense.

"Biological diversity," or "biodiversity," refers simply to all life on earth. It means the variety of species and the genetic variability within each, as well as the ecological complexes in which they occur. Biodiversity increases as one moves southward toward the equator, and 12 of the world's nations in warmer regions are considered "megadiverse" because they contain between 60 and 70 percent of the planet's total biodiversity. Mexico, as one of these megadiverse nations, contains 10 percent of all planetary biodiversity (INEGI–Semarnap 1998). Southern Mexico alone supports a large portion of the world population of a number of migratory bird species (Greenberg 1990). Endemism—species that occur in only one part of the world—is also higher in warmer regions such as Mexico, because endemic species are found mainly in areas that escaped glaciation (fig. 10).

While North America now has several thousand protected areas, strong conservation groups, and governmental commitments to maintaining biodiversity, over the past 200 years, the region has experienced some of the most dramatic landscape transformations and reductions in species abundance of any part of the world. In the process

Figure 10

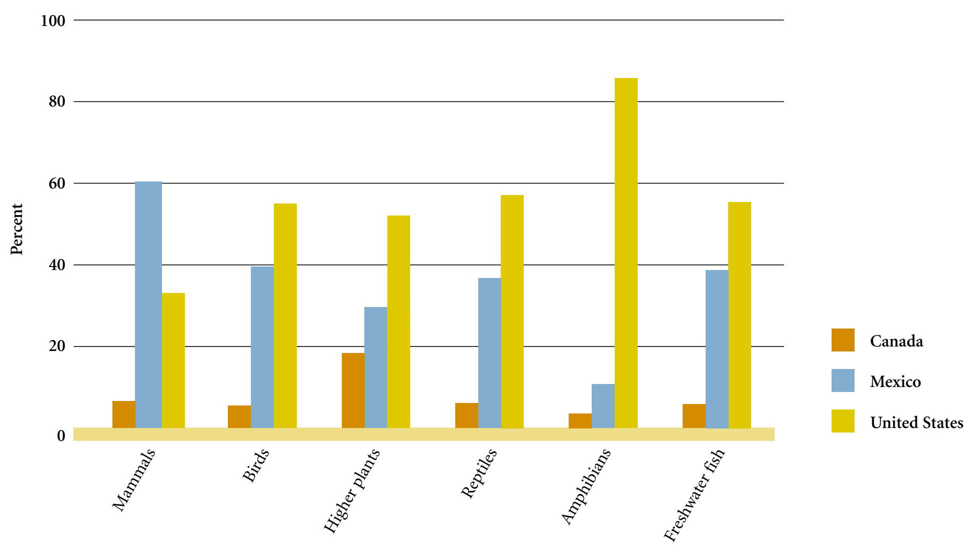
Endemic Species in North America, by Country



Source: WRI et al. 1998.

Figure 11

Threatened Species in North America, by Country



Source: WRI et al. 1998.

Note: Threatened species data are as of 1996, except for higher plants, which are as of June 1993.
Data according to IUCN category of threatened species, which includes critically endangered, endangered and vulnerable.
Threatened freshwater fish includes a few marine species.

of finding solutions to our transportation, settlement, energy and other material needs, remaining natural environments have been placed under enormous stress, and continue to be fragmented, polluted or damaged in other ways. This decline of habitat, plus specific hunting and harvesting practices, has led to a widespread crisis not confined to any one country or region. Over the past few decades, the loss and alteration of habitat has become the primary threat to biodiversity. Half of North America's most diverse ecoregions are now severely degraded (Ricketts et al. 1997). Given the paradox that habitat loss and fragmentation in North America is a consequence of both wealth and poverty, most human activities involving natural landscapes have had negative consequences for biodiversity.

A significant proportion of the plant and animal species of North America is threatened (fig. 11)—especially in Mexico and the United States (fig. 12). And the problem is by no means limited by the political boundaries between the countries. There are at least 235 threatened species of mammals, birds, reptiles and amphibians in North America, of which 14 are shared by all three countries, 35 by Mexico and the United States, 15 by Canada and the United States, and seven by Canada and Mexico (Bailie and Groombridge 1996). In addition, the growing number of invasive species introduced to North America through increased travel and trade also poses serious threats to native biodiversity, including competition, predation, disease, parasitism, and hybridization (Box 5).

Some of the region's species depend on healthy, contiguous forest ecosystems. Habitat fragmentation and loss within these forests now threatens many migratory species. Birds are losing nesting, feeding, and resting areas. And, the trans-North American migration of the monarch butterfly—an indicator species reflective of the general threat to biodiversity—faces many threats. These include coastal development in California, deforestation of oyamel fir forests in Mexico and the use of pesticides on and around milkweed plants. Monarch caterpillars eat only milkweed leaves for nourishment, and the adult butterflies feed on milkweed nectar and deposit their eggs on the underside of milkweed leaves (Malcolm 1993; Schappert 1996; CEC 1999c).

All three nations of North America share the responsibility for protecting the habitat of the monarch butterfly (map 10). Each country contains some combination of habitats in which monarchs breed, migrate, or overwinter. Any weak link in this chain of habitats threatens the viability of the entire migratory phenomenon.

National Initiatives

While all three countries have a long and complex history of developing national and subnational strategies for conservation purposes, the new challenges of biodiversity conservation are being met only gradually. Each country has adopted a unique approach with different legislative and temporal priorities.

In June 2000, Mexico announced its national biodiversity strategy in compliance with the United Nations Convention on Biological Diversity. To cope with the rapid decline of Mexico's biodiversity, the Mexican federal government has designed its national conservation strategy around three components:

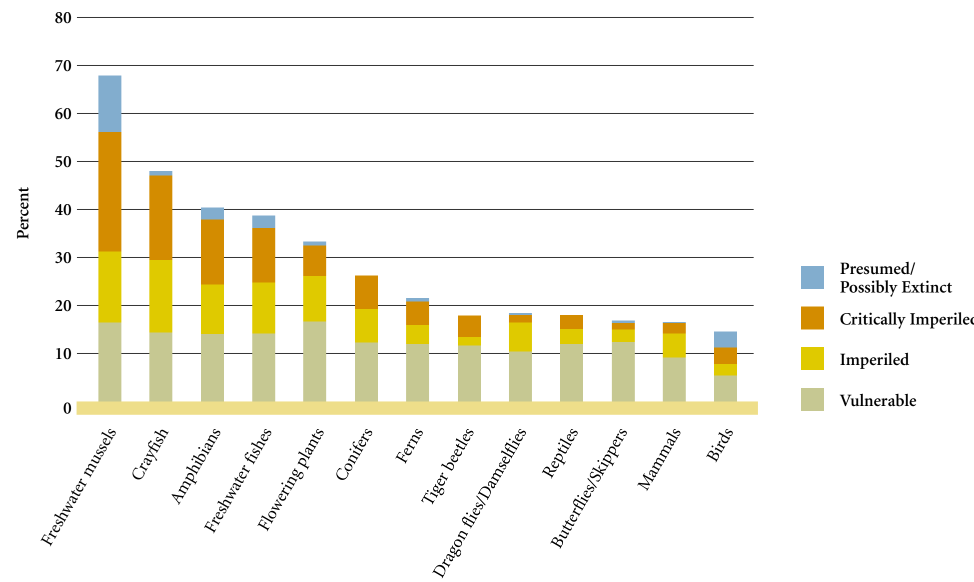
- the management and sustainable use of wildlife (*Unidades para la Conservación, Manejo y Aprovechamiento Sustentable de la Vida Silvestre*—UMAS), a program which addresses both native and non-native species;

- the strengthening of the National System of Protected Areas (*Sistema Nacional de Áreas Protegidas*—Sinap) of which the biosphere reserves are particularly important because they address socioeconomic considerations along with conservation needs and are supported by a legal framework (in contrast to the situation that obtains in Canada and the United States); and

- increasing knowledge about biodiversity through the National Commission for the Understanding and Use of Biodiversity (*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad*—Conabio), the Mexican clearinghouse and biodiversity information agency.

Figure 12

Species at Risk in the United States



Source: Stein and Flack 1997.

The Canadian approach is more decentralized. In the Canadian confederation, the primary responsibility for conserving biodiversity and ensuring the sustainable use of biological resources is shared between federal, provincial, and territorial governments. On the federal level, the government of Canada, with support from provincial and territorial governments, became the first industrialized nation to ratify the UN Convention on Biological Diversity in 1992. Its national biodiversity strategy was developed by the end of 1994.

A major challenge in implementing the Canadian strategy is the existence of different jurisdictions. The federal government, through the Canadian Wildlife Service, has authority on migratory species, while the provinces have jurisdiction over the management and conservation of habitat and non-migratory species. Federal legislation to protect species at risk was proposed in 1996, but had yet to become law by December 2000. In March 2000, the Department of Canadian Heritage published a review on the ecological integrity of the country's national parks. Carried out by an independent panel, the review identified major challenges and recommendations. Urgent action was called for to mitigate the impact of ongoing stresses (Parks Canada 2000).

Although the United States is among the few countries that have not yet signed the UN Convention on Biological Diversity, the importance granted to biodiversity conservation is reflected in the involvement of numerous government agencies at all levels. No single locus exists, however, for biodiversity conservation and planning. Both federal and state agencies invest huge amounts of their time and budgets in habitat and species protection. Total US investments in protecting biodiversity overshadow those of Canada and Mexico combined. Much of the money flows through partnership arrangements with public and private sector organizations, a practice far more common in the United States than in either of the other two countries. Some of the initiatives that have emerged are on the leading edge internationally. These include the technological capacity to monitor changes, programs that support legislation such as the Endangered Species Act, and and the activities of the US National Park Service.

The United States has a history of innovation in the designation of protected areas, starting with the world's first national park. Yellowstone was designated in 1872. The US Park Service was created in 1916 and the Wilderness Act was passed in 1964. Some 42 million hectares, approximately 2.4 percent of the land area of the continental United States, is preserved within the National Wilderness Preservation System (NWPS). In 1998 President Clinton launched an unprecedented initiative to protect marine biodiversity. The order directs US federal agencies to create a network of ocean conservation areas. The idea is to protect coastal seas in the same way that 80 million hectares of forests are already federally protected as wilderness areas or national parks.

Box 5
Emerging Trend: Bioinvasions

Many observers believe that "bioinvasion," or the spread of non-native species, has become one of the greatest threats to biological diversity (Bright 1998). North America's freshwater fishes, mussels, crayfish, and amphibians—already suffering from pollution and major alterations to natural water flows caused by dams, dredging, and other human activities—are also under assault by the introduction of exotic species, such as the zebra mussel. Exotic species enter aquatic ecosystems in many ways. Some are accidentally brought in, perhaps in the ballast water of ocean ships that is discharged once the vessels are ready to receive cargo, for example. In other cases, species are deliberately introduced, sometimes to prey on existing species, or are used for sport fishing. Other exotic species are used in aquaculture, but can escape into the surrounding environment.

The invasions have been called a form of biological pollution, and one that is likely to be longer lasting than chemical pollution. Invasive alien species often prey on native organisms, compete for food and space, and bring in disease. Once introduced, successful invaders will reproduce and spread, further endangering native species and populations, including many that are rare and endemic. In the southern United States, for example, the kudzu weed, introduced from Japan in 1876, now covers almost three million acres and continues to spread (Barr and Vaughan 2000). Successful biological invaders are, like extinction, irreversible.

Increased trade and travel, and the expansion of aquaculture provide dangerous opportunities for non-native species to be introduced into North American ecosystems. Without additional safeguards, it is almost inevitable that increased international trade will also increase the rates at which alien species are introduced into domestic waters and terrestrial ecosystems.

Conservation through Cooperation

In 1995, the Canada/Mexico/US Trilateral Committee for Wildlife and Ecosystem Conservation and Management was established. It facilitates and enhances coordination, cooperation, and the development of partnerships between the wildlife agencies of the three countries and their interested stakeholders. Projects and programs are undertaken for the conservation and management of wildlife, plants, biological diversity, and ecosystems of mutual interest. Among this Committee's agenda items are: endangered species, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), law enforcement, wetlands, migratory birds, monarch butterfly migration, and scientific understanding of wildlife conservation issues.

There are some 1,400 species of birds in North America, of which more than 250 are migratory (map 11). The CEC is working to conserve "terrestrial" birds and their habitats through the North American Bird Conservation Initiative (NABCI). It has produced a directory of Important Bird Areas and is helping to develop conservation strategies with local citizens' groups (CEC 1999d). This project is linked to other CEC initiatives. One focuses on cooperation in the production of shade grown coffee as a sustainable development activity and as a benefit to bird conservation. Another is the development of an information network on birds as part of the North American Biodiversity Information Network (CEC 1999b).

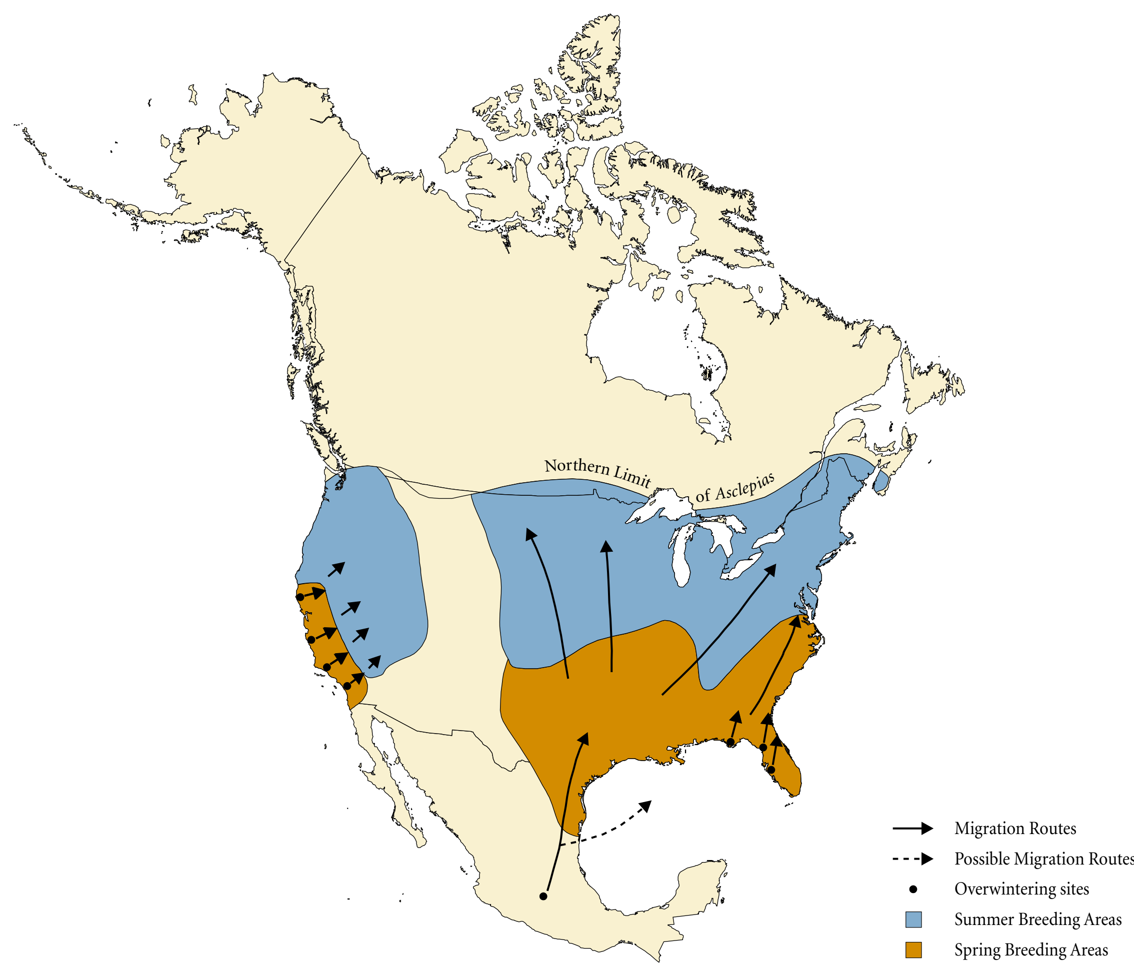
Protected Areas

Over the past three decades, a remarkable transformation has taken place in North America's protected areas. In 1970 there were about 800 such sites, including national parks and various reserves. By 1980 that number had increased to about 1,300, and now it is above 2,800 according to IUCN categories I–VI (fig. 13). The total surface covered by protected areas has increased over this period from under 100 million hectares to some 300 million hectares, about 15 percent of the continent's land area (Gordon 1995; IUCN 1998).

During the 1990s, 19 new biosphere reserves were decreed in Mexico. Over the last three decades, Canada's protected area has tripled. In 1980 alone, the US system doubled in size with the enactment of the Alaska National Interest Lands Act (McCloskey 1995). About half of the protected area in Canada takes the form of national and provincial parks, and federally managed wildlife areas. In contrast, most of Mexico's protected areas (72 percent of the total area) are designated as biosphere reserves, although there are only 26 such reserves compared to 64 national parks (INEGI-Semarnap 2000). In the United States, nationally

Map 10

North American Migration Routes of the Monarch Butterfly

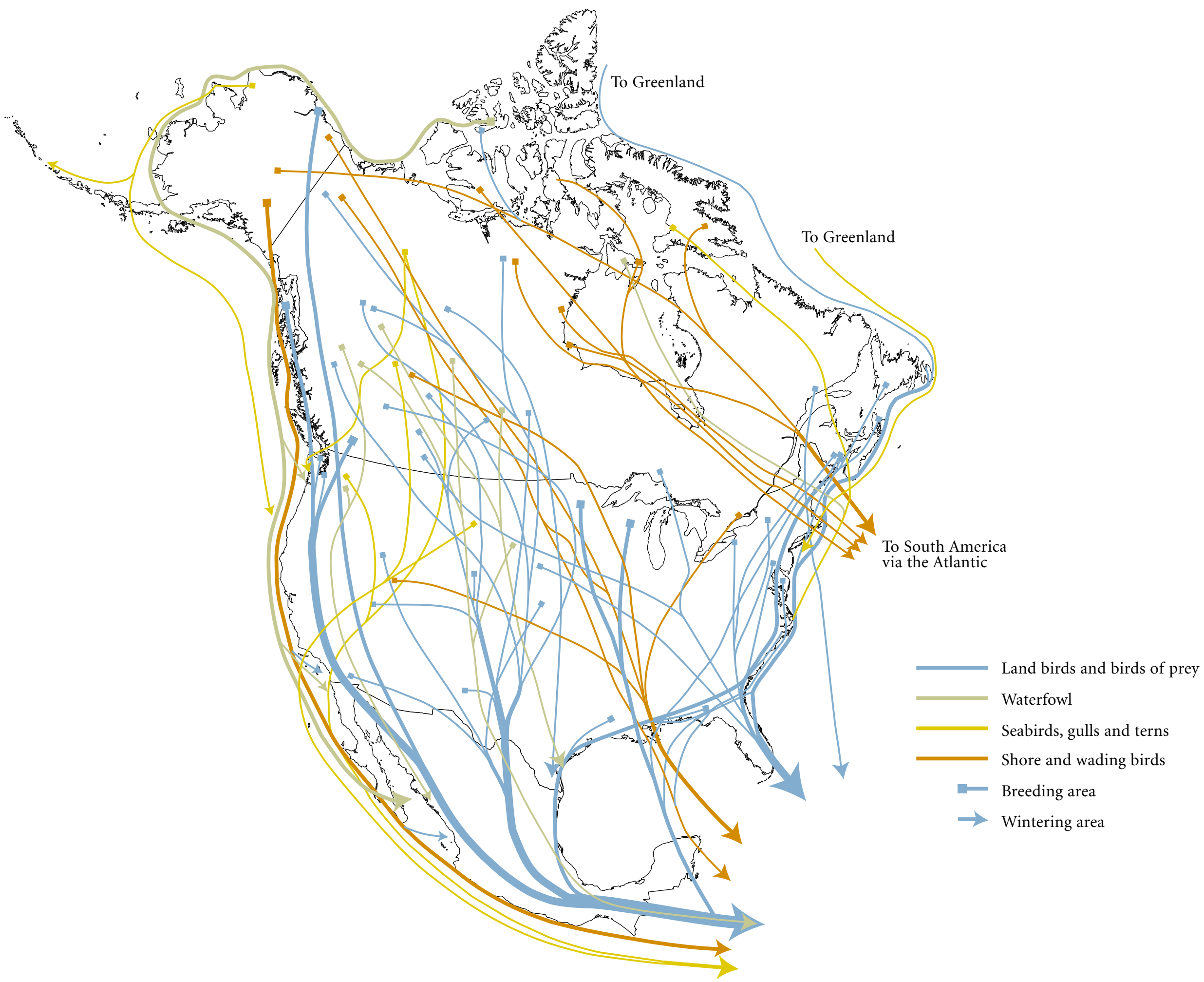


Source: Brower 1994.

Note: Only spring migration routes are shown. In the fall, monarch butterflies return to overwintering sites from summer breeding areas. *Asclepias* is the milkweed genus.

Map 11

Migratory Bird Routes in North America



Source: Brower 1994.

Note: Routes that proceed directly from North America to another continent without crossing a border have been omitted. Ocean migrants are not shown. Terminus points and pathways are general; birds may be found hundreds of kilometres from location shown.

protected areas are divided among national wilderness preserves, national wildlife refuges, national parks, and biosphere reserves.

There is enormous variety in the levels of protection afforded to these areas, however, both among and within the three countries, depending on their designation. Some areas that are deemed "protected" actually encourage development activities that put biodiversity at great risk. The World Conservation Union has devised a system that can be applied internationally to compare levels of protection. Totally protected areas (World Conservation Union categories I–III) are those in which extractive activities are prohibited. These areas account for 5.7 percent of North America's landmass. Fifteen percent of the region's land area is protected according to categories I-VI (WRI et al. 1996).

Although there are fewer parks in the northern part of the continent, these comprise most of North America's larger parks. Map 12 shows the location of national, provincial and state parks. Biosphere reserves in Mexico are also shown, since most of Mexico's protected area falls within this designation. Biosphere reserves in Canada and the United States are legally protected as national or state/provincial parks. Their distribution is shown according to ecoregion. About two-thirds of these protected areas are located in three ecological regions: Eastern Temperate Forests, Great Plains and the Northern Forests. Note that the size of the parks is not portrayed.

The so-called "Mexican Modality" of Biosphere Reserves, is the key component of the Mexican Protected Area System (*Sistema Nacional de Áreas Naturales Protegidas*—Sinap). This concept includes one or more core areas where extractive activities are prohibited; a buffer zone where sustainable projects can take place; and an area of influence where activities are directed towards reducing human encroachment into the protected area. With the exception of a few Biosphere Reserves, until recently the protected areas in Mexico were considered "parks on paper." Although they had the legal protection of the presidential decrees that created them, they lacked the budget, the professional staff and the management practices to ensure actual protection.

A few years ago this began to change when Sinap—particularly 10 biosphere reserves—became the core of the conservation strategy in Mexico, receiving Global Environment Facility funds that were channeled though a private institution, the Mexican Conservation Fund (*Fondo Mexicano para la Conservación de la Naturaleza*—FMCN).

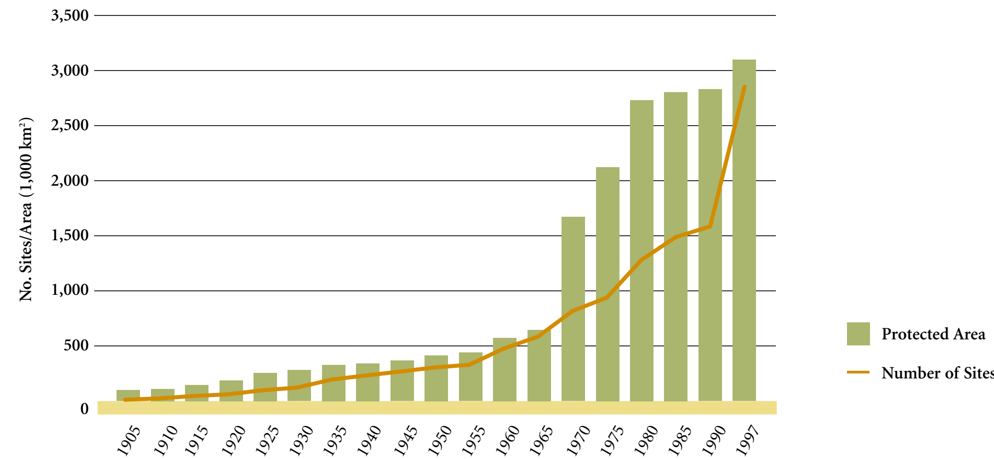
Organizational arrangements in the US also allocate important protection regimes to several agencies, especially the Bureau of Land Management (109.3 million hectares total area), the US Forest Service (77.3 million hectares), the Fish and Wildlife Service (36.8 million hectares), and the National Park Service (32.6 million hectares, including 1.1 million hectares in private ownership). Except for the national parks, only a small fraction of this total area is managed as wilderness. Deciding on appropriate uses for the remaining lands is an ongoing subject of debate.

The total percentage of legally protected wilderness areas in Canada is currently estimated at 6.4 percent, up from 2.6 percent in 1989 (WWF Canada 1999). Canadian protected area strategies are based on several concepts: representativeness of ecosystem types; a combination of federal, provincial, territorial, municipal and privately maintained areas; participation to a limited extent in internationally-guided efforts; and cooperation and negotiation with First Nations, and respect for their land claims.

In all three countries, large areas are also protected by other levels of government (state, provincial, and even municipal parks, nature preserves, and wildlife sanctuaries). Furthermore, NGOs play an important role in protecting areas for biodiversity conservation. The Nature Conservancy, for example, operates a private system of nature sanctuaries to safeguard imperiled species of plants and animals. It maintains more than 1,500 preserves of varying sizes in the United States. The organization protects and manages land it purchases or has received through gifts, exchanges, conservation easements, management agreements, debt-for-nature swaps, and through management partnerships (TNC 1997). Associated with The Nature Conservancy is the Mexican NGO, Pronatura, which also supports the

Figure 13

Number and Size of Protected Areas in North America, 1905–97

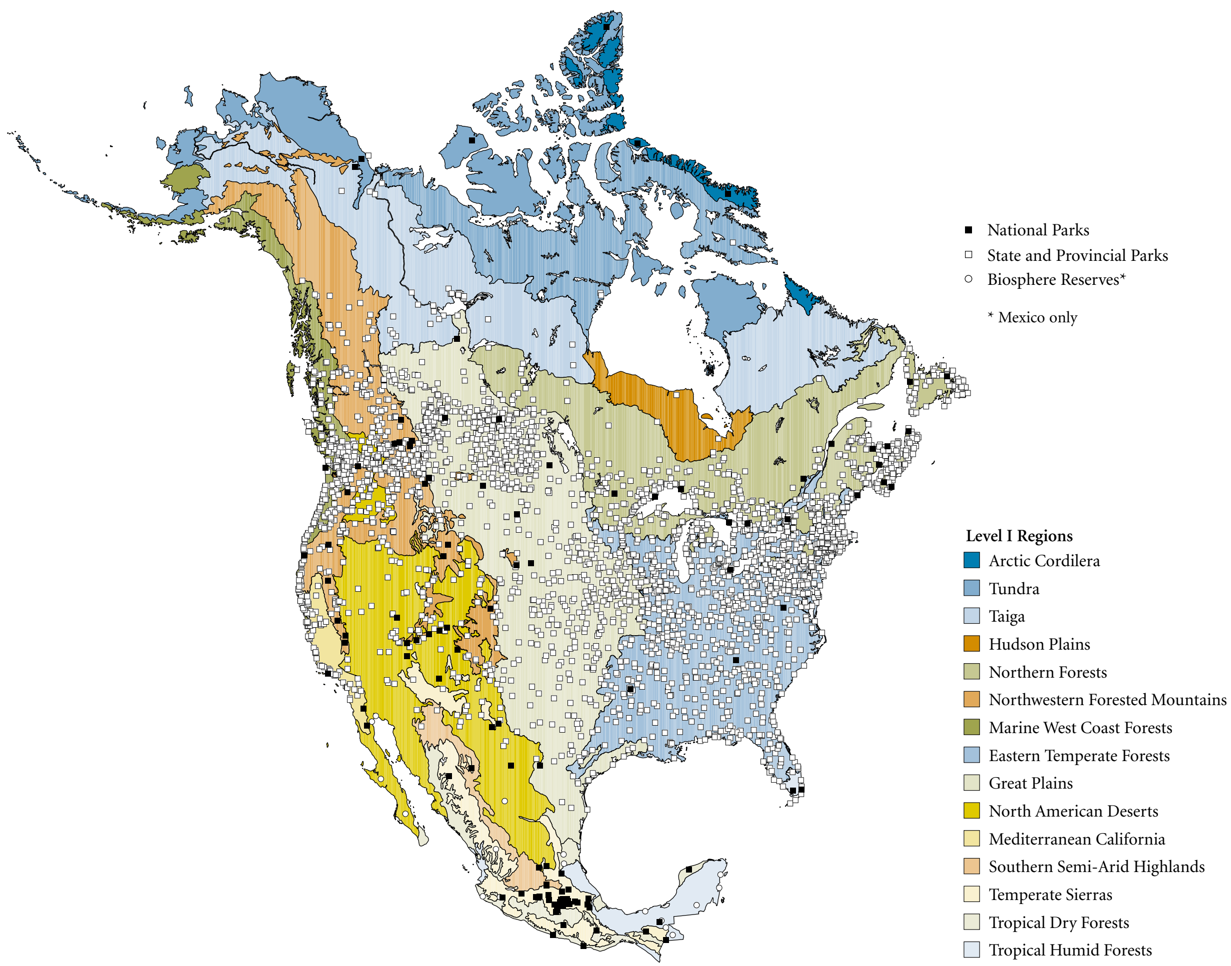


Source : Gordon 1995. Source of 1997 update: IUCN 1998.

Note: Protected areas according to IUCN categories I–VI*
*IUCN converted from a five-category to a six-category classification system in 1994.

Map 12

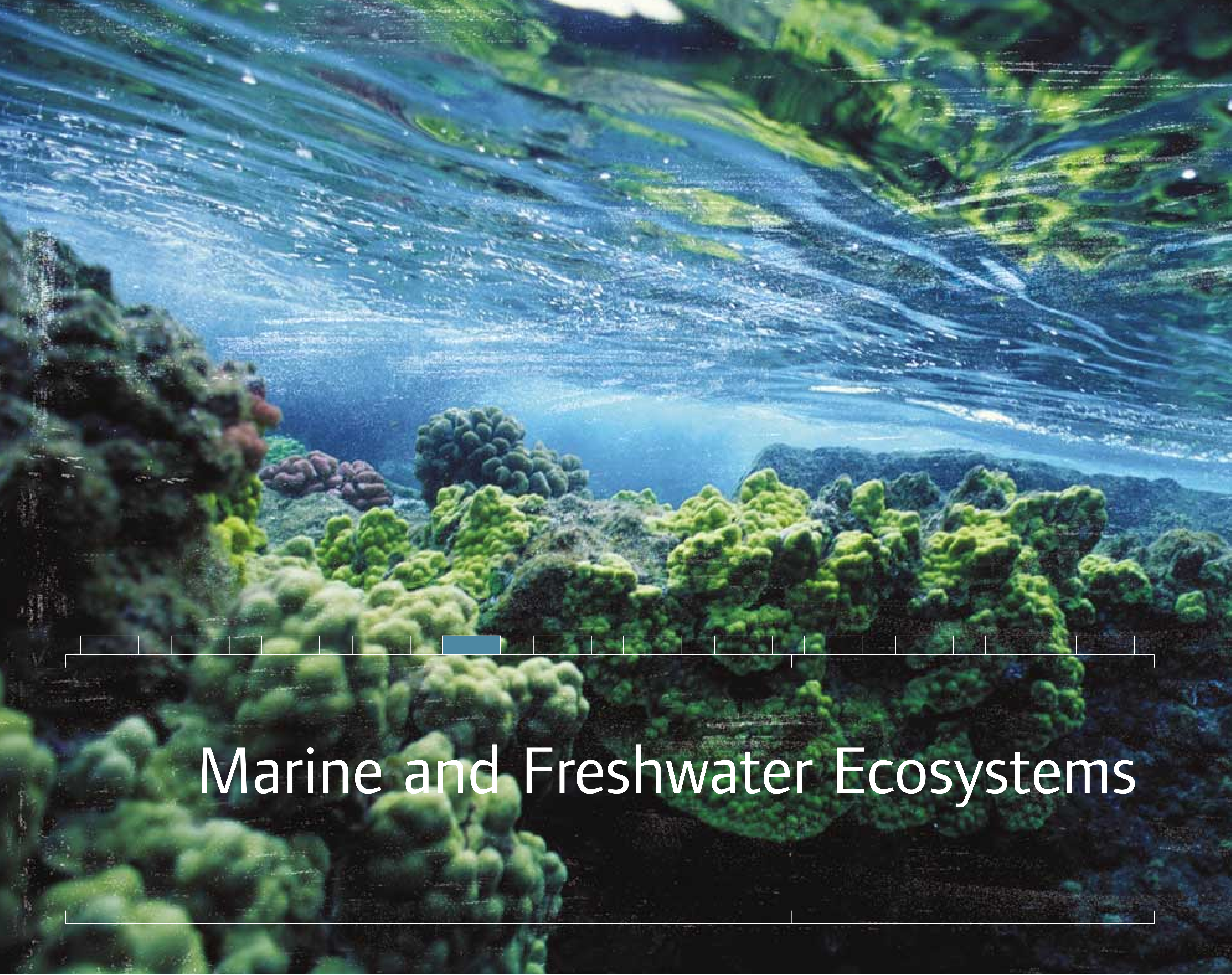
Protected Areas and Ecoregions of North America



Sources: Wiken and Gauthier 1996; Semarnap-INE-Conabio 1995. Based on maps by the Canadian Plains Research Center and the Canadian Council on Ecological Areas.

management of private lands for biodiversity conservation (Pronatura 1999). In Canada, the World Wildlife Fund maintains an 'Endangered Spaces Campaign,' the goal of which is to complete a national network of protected terrestrial areas by the year 2000, and a network of marine areas by 2010 (WWF Canada 1999).

Looming threats overshadow these positive achievements. Natural areas in all three countries are in danger of being overwhelmed by multiple factors. Success in attracting a broad range of visitors is putting stress on ecosystems. Insufficient funds have been allocated to properly manage parks for the maintenance of their natural values. Development outside parks is turning these protected areas into threatened islands. Surrounding land-use practices are often incompatible and unsustainable. Social pressures and consumptive demands for finite resources are increasing. Political pressure is increasing for demonstrable public benefits and short-term gains. And governments everywhere are looking for greater cost efficiencies and institutional streamlining (Reynolds 1995).



Marine and Freshwater Ecosystems

Marine and Freshwater Ecosystems under Threat

Oceans—which cover more than 70 percent of the planet's surface—shape our climate, provide a means of transport, and are home to an important part of the planet's biological diversity. North America's more than 400,000 kilometers of coastlines are marked by a vast array of marine ecosystems such as gulfs, harbors, bays, estuaries, salt marshes, swamps, mangroves, and coral reefs, as well as shallow and deep offshore waters. An enormous variety and quantity of marine and estuarine species inhabit the region's shores, with Mexico's biodiversity being especially rich. The number of known fish species in Mexico alone exceeds 2,100 (INEGI-Semarnap 2000).

Coastlines are attractive places to live. In the United States, more than half the population lives within 130 kilometers of an ocean, while some 23 percent of Canadians live in coastal communities (DFO 1997). Since 1960, the coastal population of the United States has increased by 40 million, and it continues to grow at four times the national average. By 2015, 35 million more people are expected to be living in US coastal areas (NOAA 1998a).

Of all the activities that take place in coastal zones and the near-shore coastal ocean, none is increasing in both volume and diversity more than tourism and recreation. In particular, the beauty, warm climate, and biological and cultural diversity of Mexico's Caribbean and Gulf coasts attract an increasingly heavy tourist trade. Clean water, healthy coastal habitats, and a safe, secure, and enjoyable environment are clearly fundamental to successful coastal tourism. Similarly, bountiful living marine resources (fish, shellfish, wetlands, coral reefs, etc.) are of critical importance to most recreational experiences. Security from risks associated with natural coastal hazards such as storms, hurricanes, tsunamis, and the like is desirable for coastal tourism to be sustainable over the long term.

Although vast in scale, the oceans and the life in them are vulnerable to changes from human activities. Marine and coastal habitats are being lost or degraded by increasing physical alteration of coastal areas, with the development of cities, ports, road networks, pipelines, and high-density

Map 13

Coastal Ecosystems Threatened by Development in North America

Source: Bryant et al. 1995. Mapping by World Resources Institute.

recreational use (map 13). Overdevelopment threatens the viability of the very resources to which people and industries are attracted (CEQ 1996; Bryant et al. 1995).

Marine ecosystems suffer from a growing tide of municipal, industrial, and agricultural wastes and runoff, as well as deposition from air pollution. Eighty percent of marine pollution in Canada, for instance, is from land-based activities, including industrial, chemical, and agricultural wastes (DFO 1997). Coastal waters in many areas continue to receive untreated or insufficiently treated municipal sewage, causing the closure of shellfish harvesting areas and beaches (CEQ 1996; EC 1996) (Box 6). Coastal areas are vulnerable to spills and discharges from the petroleum industry and illegal dumping of oily wastes from ships, leading to periodic large kills of seabirds. Added to these problems are poorly understood environmental fluctuations—potentially exacerbated by global warming.

Estuaries and coastal wetlands are among the most productive ecosystems in the world, both for the variety of life they support and for the important services they render. They provide habitat for commercially valuable fish and migrating waterfowl, and they perform essential ecological functions by filtering runoff from the land, stabilizing coastal lands, and providing nutrients for nearshore life (NOAA 1998a). About 75 percent of US commercial fish and shellfish depend on estuaries at some stage in their life cycle (NOAA 1998a). Some 23–29 percent of US estuaries have poor conditions for fish and bottom-dwelling organisms, and about 22–30 percent of US estuarine waters are not fit for some types of human use because of water turbidity, marine debris, biological and chemical contaminants, and contaminated fish and shellfish (EPA 1998a).

The Gulf of Mexico receives excess nutrients carried by the Mississippi River, which drains 40 percent of the continental United States. These nutrients contribute to conditions that cause a "dead zone" due to insufficient dissolved oxygen in the bottom waters. In 1998, the dead zone off the Louisiana coast was smaller than it had been in the five years following the 1993 Mississippi flood, but it still measured more than 12,400 square kilometers (EPA 1998b). Chesapeake Bay, the largest estuary in the United States and one of the most productive in the world, also suffers from excessive land-derived nutrient enrichment that contributes to anoxic or "dead" bottom waters. A large part of the nutrients come down the Susquehanna River, and most of them originate from intensively farmed cropland and livestock production. Nutrients have been reduced by cooperative efforts among federal and state governments and NGOs, but population growth and increased land development threaten to reverse the trend (EPA 1997a).

Coral reefs are the most biologically diverse of all marine ecosystems and are home to one-third of all marine fish species. They also provide us with numerous benefits, including sources for new medicines, recreational value for the fast-growing tourist industry, and coastal protection by buffering shorelines from waves and storm action (Bryant et al. 1998). Their global extent is unknown, but probably exceeds 600,000 square kilometers or only a little more than 0.1 percent of the earth's surface (Bryant et al.1998; AIMS 2000). Yet coral reefs are among the richest centers of biodiversity, rivaling tropical rainforests.

Box 6
Emerging Trend: Rise in *Pfiesteria piscicida*

Pfiesteria piscicida is a dinoflagellate, a naturally occurring algae. During several stages in its life cycle, and in the presence of schooling fish, the organism emits a powerful toxin that kills fish (EPA 1998c). In recent years, there have been a number of major outbreaks of fish disease and fish kills along parts of the US East Coast, from Delaware Bay to North Carolina that may be related to these toxins. Other *Pfiesteria*-like organisms are found along the southeast coast from the Carolinas to the Gulf of Mexico. *Pfiesteria* has existed in the region for a long time, but human activities appear to have created environmental conditions that encourage its toxicity (NCSU 2000). These conditions stem from excessive nutrients in the water. Nitrogen and phosphorous come from both natural sources and human activities, such as sewage and animal waste disposal and fertilizer runoff.

Pfiesteria imperils not only the fish and other aquatic life in affected waters. Human health also appears at risk from exposure to *Pfiesteria* toxins. There have been reports of memory loss and confusion as well as respiratory, skin, and gastrointestinal symptoms (EPA 1998c). These symptoms can be severe with prolonged exposure, and can recur with even mild re-exposure years later.

In response to this new and troublesome problem along North America's eastern shores, intensive research is now being undertaken to identify the chemical toxins produced by *Pfiesteria* and to determine their effects on commercial fish stocks and human health. Monitoring programs have been set up to identify potentially toxic populations of the microbe. The public has been informed about how to avoid contamination, and hotlines have been set up to receive reports about fish kills or fish with lesions (Maryland DNR 1999; CBF 2000).

Coral reefs worldwide are increasingly threatened by global climate change and human pressures… 58 percent are threatened by human activities, and 27 percent are at high risk.

The United States has 16,100 square kilometers of coral reefs, of which 5,500 square kilometers are found in south Florida and the Florida Keys (NOAA 2000a). Mexico has coral reefs in both the Atlantic and Pacific. The largest of Mexico's system of coral reefs is the Great Maya Reef off the coast of Yucatán. It is part of the Meso-American-Caribbean coral reefs, which extend along the coasts of Belize, Guatemala, Honduras, and Mexico for about 1,000 kilometers. This is thought to be the world's second-largest coral reef, after the Great Barrier Reef of Australia (CCAD n.d.).

Coral reefs worldwide are increasingly threatened by global climate change (increasing greenhouse gases) and human pressures, such as siltation from shoreline construction and deforestation, industrial pollution, nutrient pollution from sewage, fertilizer and urban runoff, destructive fishing practices—trawling in particular—overfishing, careless pleasure diving, and dredging (NOAA 1998b; WRI et al. 1998). Globally, 58 percent of coral reefs are threatened by human activities, and 27 percent are at high risk (WRI et al. 1998). This is also true in North America, where degradation is outpacing protection strategies (Jameson et al. 1995).

The major threats are from siltation due to coastal development and tourist-related activities such as boating, fishing, and diving, which result in chronic abuse to the reefs due to the sheer numbers of participants. Destructive commercial and recreational fishing practices, nutrients from agricultural sources, storm runoff, and sewage discharge are additional threats (Bryant et al. 1995). Rising sea surface temperatures, as a result of global warming, are also emerging as a major threat. In 1998, unprecedented coral bleaching and die-off took place in all reefs around the world, except those in the central Pacific. In some parts of the Indian Ocean mortality reached 90 percent (Mathews-Amos and Berntson 1999).

Prior to the development of high-technology fishing methods, overharvesting of fish stocks was infrequent and local, except for certain marine mammals at times of high demand. Since the 1950s, however, modern fishing technology and expanding markets for seafood have combined to increase the demand placed on commercial fish stocks. Fishing boats equipped with greater power, radar, electronic navigation systems, and sonar have allowed crews to follow the fish throughout their annual cycle, day or night, winter or summer. According to the United Nations, about 60 percent of world fish stocks are currently either overfished or fully harvested. As the most desirable species—including salmon, cod, halibut, and swordfish—decline, some believe that we are now fishing down the food chain, in many cases, catching the food needed to rebuild depleted species.

The United States is the fifth-largest fishing nation, with its catch representing five percent of world totals (NOAA 1998b). Mexico ranked eighteenth in 1993 statistics, and in 1992, the value of Mexico's fish catch contributed 1.0 percent to its gross national product, although it has since increased in importance (Semarnap1996b). In 1996, the fishing industry contributed 0.35 percent of Canadian GDP, down from 0.75 percent in the early 1960s (Austin 1996).

Total fish catch in North America grew rapidly during the 1970s and 1980s due to improvements in technology and increased harvesting capabilities, along with supportive government policies. By the late 1980s, the total annual North American fish catch surpassed seven million tonnes before starting to level off (fig. 14).

By the end of the 1980s, a decrease in wild fish stocks, especially those in the Grand Banks of the north Atlantic, was becoming evident. The situation continued to deteriorate (fig. 15) and in 1992 Canada imposed an indefinite ban on the decimated northern cod, and subsequently on other groundfish species (Box 7). Nearly one-third of US federally managed fishery species for which there are adequate data are overfished (NOAA 1998b). In Mexico, fish catches declined in the early 1990s, due largely to the decrease in El Niño-induced sardine and anchovy catches. Landings of higher value fish subsequently increased, growing from 1.19 million tonnes in 1993 to 1.57 million tonnes in 1997 (INEGI 1995a).

It is not just the taking of fish from ocean to supermarket that depletes fish stocks, but also the manner in which the fish are caught. In the past, huge trawlers with massive dragnets indiscriminately scoured the ocean bottom. This practice damaged fish habitat and resulted in a large "bycatch" of fish that were commercially undesirable, or not allowed under government quotas. Over the past decade, efforts to improve gear selectivity and exclude certain species, international monitoring programs, and various codes of conduct have generally improved management of the east coast fishery.

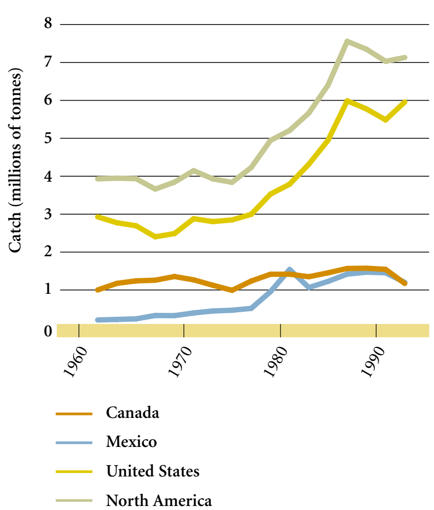
Salmon and other anadromous fish (species that migrate from fresh water to oceans and back to fresh water to breed) are also vulnerable to land-based development. Habitat degradation due to logging, mining, urbanization, migration hindrances such as hydroelectric power facilities, harvesting activities, and poor fish farming practices are the primary pressures. In the northwestern states and in British Columbia a large amount of inland habitat for Pacific salmon and steelhead has been lost, clearly posing a threat to the survival of these fish. And in the United States, five stocks of salmonids are listed as endangered and seven as threatened under the Endangered Species Act (NOAA 1998b).

Partly in response to declining wild fish stocks, more fish are now raised in hatcheries and released into nature, or put into fish farms, which are claiming an ever-growing share of the market. Aquaculture has developed significantly in North America, with harvests increasing from 375,000 tonnes in 1985 to 548,000 tonnes in 1995. In Canada, the industry grew by over 20 percent between 1984 and 1994 (FAO 1999). In the United States, which now produces less than three percent of the world's total value in aquaculture products, it is the fastest growing segment of food production (NOAA 1998b). Mexico's aquaculture production has fluctuated, but remained essentially stable during the 1990s (INEGI–Semarnap 2000). There is, however, strong growth in cultivating shrimp, and both the Mexican government and the World Bank have launched investment programs in this field (FAO 1997b).

Although aquaculture production provides more fish and seafood to the market, critics contend that it will not stop the decline in wild fish stocks. Fish farms exert their own pressures on coastal ecosystems. Constructing "farm" infrastructure may harm or destroy coastal vegetation. Waste products may raise nutrient levels in the water. And there is concern that diseases in farm-bred fish may harm indigenous species. Interbreeding with fish farm escapees also raises questions about biodiversity, especially if the farmed fish have been genetically altered (Brown 1998; Platt McGinn 1998).

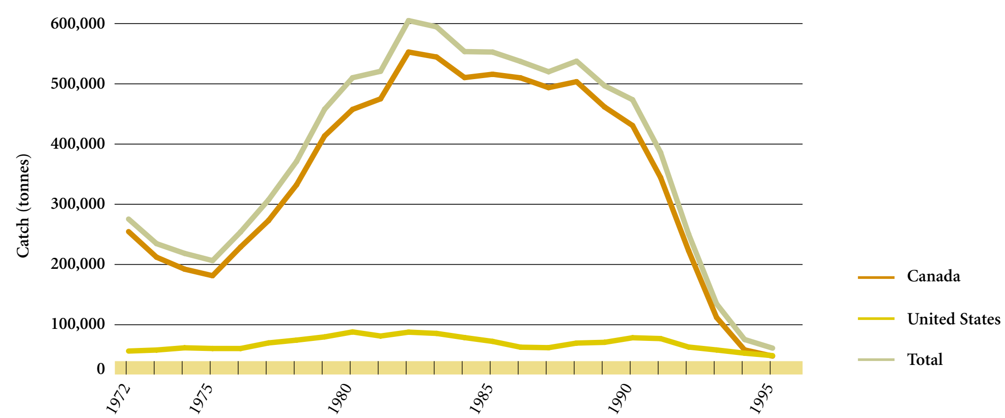
All three countries have taken measures to prevent overfishing and the decline in wild fish stocks, as well as to protect other marine species and their habitats. All three are signatories to the statement of principles contained in The Ocean Charter (UNESCO 1998). Canada and the United States have signed and ratified the 1982 UN Convention on the Law of the Sea and the subsequent Agreement relating to the Conservation and Management of Straddling and Highly Migratory Fish Stocks. Both documents articulate effective fishery management regimes and conflict resolution mechanisms (NOAA 1998b; UN 2000).

Figure 14
Fish Catch in North America, by Country, 1961–93



Source: FAO 1997c.

Figure 15
Atlantic Cod Landings, in Canada and the United States, 1972–95



Sources: DFO 1998; NMFS 1995.

Note: US data represent round weight; Canadian data represent live weight.

The United States and Canada responded to dwindling Atlantic groundfish stocks by extending to 200 miles their exclusive economic zones and banning foreign dragnet trawlers (Botkin and Keller 1995). Other regulations, such as shortened fishing seasons in deep offshore waters, stricter catch limits, and heightened monitoring of stocks, were also imposed. The Pacific Salmon Treaty between Canada and the United States has started to rebuild Chinook stocks. Closures of commercial fisheries and commercial license retirement programs in the Pacific Northwest have reduced harvesting capacity (EC 1996).

Nationally, the countries are also improving the management of their coastal and marine ecosystems and species. To implement its 1997 Oceans Act, Canada is developing an Integrated Oceans Management Strategy, based on sustainable and cooperative management. The US Sustainable Fisheries Act of 1996 also provides a new strategic direction in fisheries management. The US Endangered Species Act has enhanced levels of protection for selected marine species, particularly marine mammals, sea turtles, and salmonids (NOAA 1998b). And, the US National Estuary Program, which currently has 28 designated regions, has the goal of protecting the integrity of whole estuarine ecosystems, water quality and individual species. Mexico has instituted several programs, including legislation to protect marine turtles, marine mammals—including dolphins during tuna fishing—and the endangered vaquita. (Mexico's only endemic marine mammal, the vaquita is a harbor porpoise that lives in shallow coastal waters of the upper Gulf of California and is particularly vulnerable to adverse effects of human activity.)

Since 1986, conservation measures prompted by consumer demand for dolphin-safe tuna (tuna caught in the presence of dolphins but without serious injury to them) have led to a dramatic reduction in the number of dolphin deaths in the eastern tropical Pacific Ocean. Annual dolphin deaths have dropped to less than 2,000 in 1998 from over 133,000 in 1986 (NMFS 1999). In all three countries, natural resource managers and other stakeholders are adopting an integrated approach to managing fisheries and are working cooperatively to gather information, assess problems, and identify the means to solve them (DFO 1997; INEGI– Semarnap 1998; NOAA 1998b).

Freshwater species are much more vulnerable to extinction than marine species because, as with species inhabiting oceanic islands, physical barriers prevent them from escaping to new ecosystems when their own become destroyed or degraded. Figure 11 (above) shows the share of species type that is threatened in each of the three countries and illustrates the serious threat to freshwater fish. North America, and the United States in particular, is of global significance in its diversity of freshwater species. The United States contains the world's greatest diversity of freshwater mussel species, but more than 65 percent of these are extinct or threatened and 48 percent of crayfish species are at risk (fig. 12, above) (Master et al. 1998).

Amphibians have long been recognized as the "canaries in the mine"—keenly sensitive indicators of wetland ecosystem health since they spend time in both aquatic and terrestrial environments. They are also commonly

Box 7
Connections: The Human Cost of a Fishery Decline

A precipitous decline in the stocks of a number of demersal fishes (species that feed at or near the ocean bottom) off the northeast coast of North America provides one of the clearest examples of how unsustainable development affects societies. Cod, haddock, pollock, and other species have been fished to the point where some regional populations of these species have collapsed.

The story of the northern cod collapse off Newfoundland, Canada, is a textbook case of unsustainable fishing practices, both domestic and foreign. Excessive fishing has destroyed a major piece of the environment. In turn, that has destroyed part of the economy, and the result is severe social problems for the fishing-based society, including the accelerated departure of young people seeking work. In recent decades, governments encouraged large fleets and a high-capacity industry to help develop the regional economy. By the early 1990s, it was clear that the stocks were in steep decline and that the once-lucrative cod fishery was devastated. In 1992, Canada placed an indefinite ban on northern cod and subsequently on other groundfish species. In 1993, the US Congress also imposed stricter limits and shorter seasons and gave federal fisheries agencies the authorization to ensure uniform enforcement by states.

The decline of the northern cod and other groundfish stocks put tens of thousands of fishers and fish plant employees out of work in Atlantic Canada during the 1990s. The Atlantic Groundfish Strategy, or TAGS, was instituted to provide income support, reduce commercial fishing licenses, enable co-management with the fishing industry, and provide training for alternative employment. When the program began in 1994, 40,000 people were eligible. TAGS ended in 1998, and cost the Canadian government C$1.9 billion. A further three-year restructuring and adjustment measures program that started in 1998 had a budget of C$760 million (OAG 1997, OAG 1999).

In recent years, Canada has sought to introduce precautionary management strategies. Although most of the northern cod fishery has remained closed, the stock remains seriously depressed. Environmental factors appear to be part of the problem (EC 1996).

encountered by people, so developmental abnormalities are noticed quickly. Environmental pollutants have adversely affected many amphibian populations. A range of surveys, involving scientists, private citizens, and school children, are underway to ascertain the extent of these effects (MDNR 2000, NBII 2000).

Freshwater habitats are under severe threat as well. Often this habitat alteration results from land-based and atmospheric sources of pollution. Currently, about 2,500 US water bodies are under fish consumption advisories resulting from chemicals such as PCBs, chlordane, dioxins, and mercury (EPA 2000b).

Marine Protected Areas

Although national systems of parks and protected areas have concentrated on landscapes, growing awareness of the value and vulnerability of marine areas and crises such as fisheries closures have led governments to designate more marine protected areas. The goal is to help conserve marine biodiversity, maintain the productivity of marine ecosystems, and contribute to social and economic well-being. North America has 296 marine protected areas (Canada has 76; Mexico, 37; and the United States, 183) covering nearly 40,000 square kilometers, according to a definition given in an assessment by the World Bank, IUCN, and the Great Barrier Reef Marine Park Authority (WRI et al. 1996).

Each country, however, has its own system of marine protected areas. They establish different levels of protection for different sites, ranging from strict no-use zones to multiple-use areas. Some locations are designated to protect rare natural features, such as corals or underwater vents with rare ecosystems. Other areas protect cultural and historical resources or endangered species, such as the beluga whale. Educational and scientific pursuits, resource use, replenishment, and recreation are additional reasons given for protecting an area.

Parks Canada is developing a system of national marine conservation areas to represent each of Canada's 29 marine regions. Five of these regions are now represented by four sites, and there are plans to create another four by the end of 2000 (Parks Canada 1996).

Mexico has nine national marine parks, established under its General Law on Ecological Equilibrium and Environmental Protection, although in 1996 the category was changed to denote simply National Parks (INEGI-Semarnap 2000).

Under the US Marine Protection, Research and Sanctuaries Act, the United States has designated 13 national marine sanctuaries, from Hawaii to Lake Superior (NOAA 2000b). Twenty-five estuarine reserves have been designated under the US National Estuarine Research Reserve System (NOAA 2000b). In addition, President Clinton issued an executive order in 1998 calling on US federal agencies to develop a better understanding and protection strategy for coral reefs, the most biodiverse of all marine habitats (NODC 2000).

In 1995, the three North American countries participated with some 100 other nations in the negotiation and signing of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). GPA implementation task forces have embarked on a number of cooperative efforts, most notably two pilot projects in the Gulf of Maine and the Bight of the Californias, facilitated by the CEC. In addition to assisting with the implementation of the GPA in North America, the CEC initiated the mapping of North American marine and estuarine ecosystems, and helped to lay the groundwork for establishing a network of protected marine areas vital for the conservation of important ecosystems and marine life forms (CEC 1997b). These marine protected areas will be selected because of their shared ecological links (e.g., critical migratory habitat) across the three countries, and will be connected via the World Wide Web to coordinate conservation efforts, network-wide sharing of lessons learned, and increased access to timely information on emerging threats, new management strategies, and funding or outreach opportunities.

Wetland Protection

Wetlands, including swamps, bogs, fens, and marshes, have been dismissed historically as wastelands to be dredged for ports and marinas or drained for farms, housing developments, and other uses. Yet wetland habitats are crucial to the survival of many of North America's threatened species, especially migratory birds.

Because there is no one agreed-upon definition of a wetland, comparable time-series data across the three countries is unavailable, making it impossible to calculate gains and losses for North America as a whole. In general, wetlands are areas of marsh, bogs, or fens with water that is static or flowing, fresh or salt. It is estimated that North America has 283 million hectares of wetlands (Dahl 1990, Davidson 1996; Wiken et al. 1998). According to the Ramsar Convention Bureau, North America has 56 Wetlands of International Importance, covering 14.9 million hectares and representing 22 percent of the world's important wetland areas (WRI et al. 1998). Wetlands on the Ramsar list are sites of international significance in terms of ecology, botany, zoology, limnology, or hydrology, with particular emphasis on the importance to waterfowl.

About 60 percent of North America's wetlands are found in Canada, which lays claim to almost 25 percent of the world's wetlands (table 5) (Government of Canada 1991). Only 1.4 percent of Mexico's land area is covered by wetlands, but these are essential to hundreds of migratory species in North America, while probably as many as 90 percent of Mexico's fish and crustacean species depend on wetlands during some part of their life cycle (Davidson 1996). The Directory of Neotropical Wetlands lists 65 of the country's wetland sites as being of special importance (Scott et al. 1986).

Except for those north of Canada's most populated areas and in Alaska, most of North America's wetlands have been commercially developed or converted to agriculture or other uses. About 85 percent of historical wetland drainage in Canada has been for agriculture, nine percent for urbanization and industrial development, and two percent for leisure and recreation property expansion (Rubec 1994). In both Canada and the United States, urban development has been responsible for most wetland loss during the past two decades. In the mid-1950s, agriculture was responsible for about 87 percent of wetland conversions in the United States. While, between 1982 and 1992, 57 percent of total wetland losses were attributed to urban development, only 20 percent to agriculture, 13 percent to deep-water conversions, and 11 percent to miscellaneous causes (USDA 1999).

Since the mid-1970s, wetland protection and restoration projects have slowed the conversion rate of remaining wetlands, although losses continue to outpace gains. The North American Waterfowl Management Plan has been instrumental in establishing more than a half million hectares of new wetlands and upland habitat. Overall, the use of two million hectares has been modified to support the plan, several duck species have begun to increase in number, and some 30 million more birds have flown north since the start of the program. Changes in commodity prices, a reduction in the area of wetlands that can be converted economically, and rising concern over the importance of wetlands have also influenced the rate of wetland conversions (Linton 1997).

Canada's vast freshwater wetlands fall under the jurisdiction of both federal and provincial agencies, the federal and provincial ministries of environment and natural resources, and the Canadian Wildlife Service. Many are located within national and provincial parks. The North American Wetlands Conservation Council of Canada is the senior body that advises the federal Minister of the Environment on all aspects of the development, coordination, and implementation of wetland conservation initiatives of national or international scope. This includes the habitat initiatives included in the North American Waterfowl Management Plan (NAWMP), a tripartite agreement between Canada, Mexico, and the United States to restore waterfowl populations to the levels of the 1970s. Related to the wetlands initiatives are several that strive to preserve riverine riparian areas—for instance, the Streambank Stewardship Program of the Saskatchewan Wetland Conservation Corporation.

Table 5

Wetlands in North America, by Country

	Wetland Area (1000 ha)	Percent of Total Land Area	Percent of North American Wetlands
Canada	169,075	18	60
Mexico	2,789	1	1
United States	111,104	12	39
North America	282,968	10.3	–

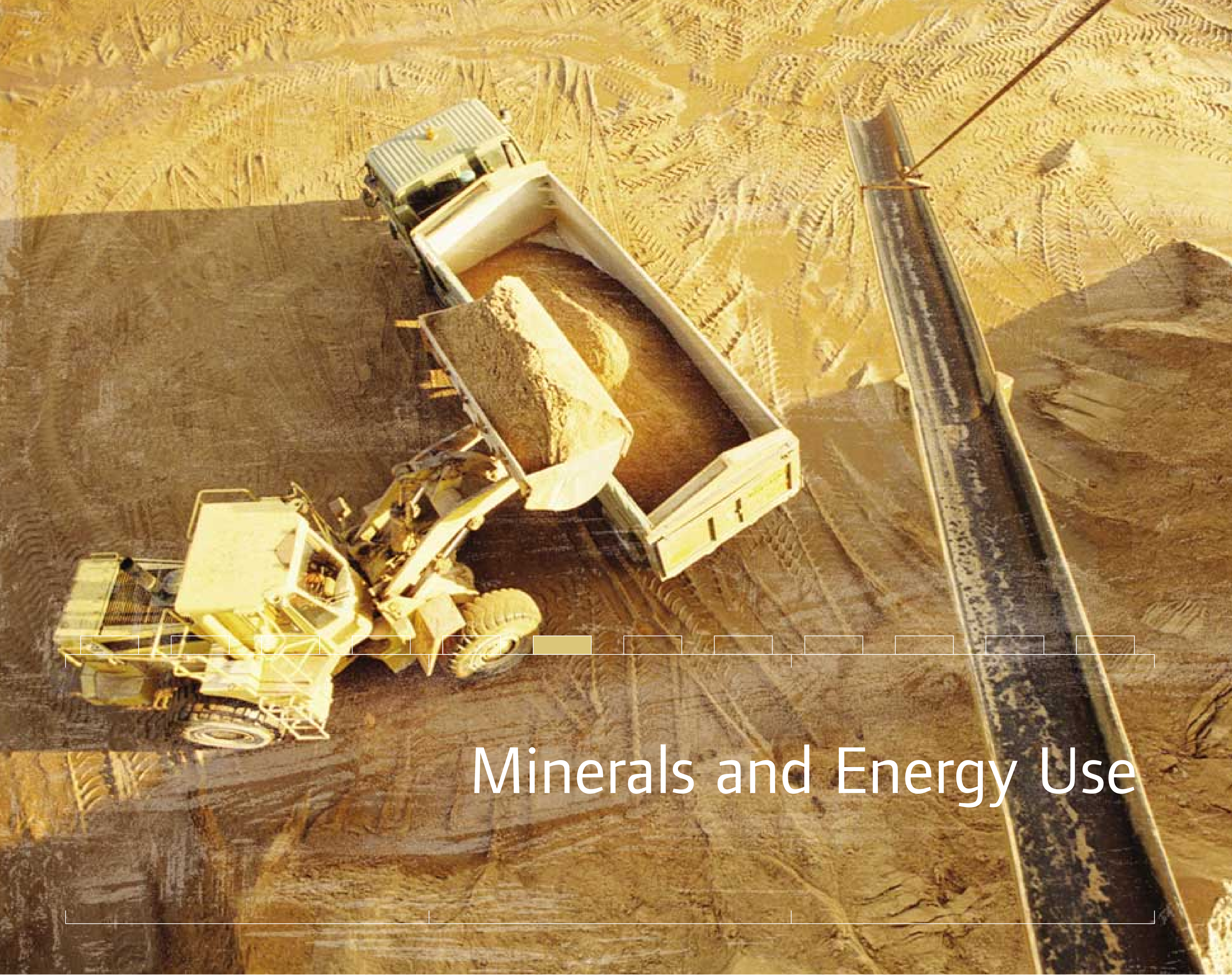
Sources:
Canada Wiken et al. 1998.
Mexico Davidson 1996.
United States Dahl 1990. (Note: data fluctuate with restoration and conversion activities such that there was little change between 1990 and 1998 (Wilen 1999)).

Nongovernmental organizations are actively concerned with Canada's wetlands as well. Groups such as Ducks Unlimited Canada, Wetlands International, and Ecoscope have made major contributions to public education about the value of wetlands and to their conservation.

In the United States, the Emergency Wetland Resources Act of 1986 mandates that the US Fish and Wildlife Service produce information on the characteristics, extent, and status of US wetlands and deepwater habitats. Thus far, the National Wetlands Inventory (NWI) has mapped 89 percent of the lower 48 states and 31 percent of Alaska. The NWI is also producing statistically valid estimates of wetland losses at 10-year increments, which began in 1990. All data, species information, and digitized maps are available for download from the Service's home page (FWS 2000). Administration of wetlands and freshwater resources, however, is spread over many agencies and departments, from the US Army Corps of Engineers and the Bureau of Reclamation to the North American Wetlands Conservation Council and the US Department of Agriculture's voluntary Wetland Reserve Program. Some well-known freshwater areas actually fall under the purview of the US Forest Service's National Wilderness Preservation System, which includes the Boundary Waters Canoe Area (a joint wilderness area with Quetico Provincial Park in Ontario).

Nongovernmental organizations, too, play a valuable role in wetland acquisition and conservation. Various state chapters of the international organization, The Nature Conservancy, are especially active in wetland preservation, as is Ducks Unlimited.

Multinational efforts to monitor and protect freshwater and marine ecosystems showcase the advantages of international cooperation when dealing with an interconnected environment. Collaboration is essential to ensure effective protection and restoration of resources that cross international boundaries or that are subject to transboundary environmental threats.



Minerals and Energy Use

Minerals and Mining

North America has one of the world's major mineral resource bases, producing about 48 percent of the world's molybdenum, 40 percent of its sulfur, 34 percent of its selenium, 32 percent of its silver, and 29 percent of its zinc and copper (INEGI 1995b). Mining was responsible for 4.1 percent of Canada's GDP in 1997 (EIU 1998a), for 1.8 percent of US GDP in 1995 (DOC 1996), and for one percent of Mexico's in 1998 (EIU 1998b). Within North America, the United States produces the most gold, lead, copper, molybdenum, and sulfur, while Mexico is the major producer of silver, and Canada of zinc, selenium, and cadmium (fig. 16).

The greatest impacts from the mining, smelting, and refining of minerals and metals are related to the generation of hazardous and solid wastes, water and air pollution, and habitat disturbance. Cyanide, ammonia, and a number of organic compounds used to extract metals from rock can contaminate surface and groundwater, as can the lead, cadmium, and other minerals contained in mining waste. When land is disturbed and not reclaimed after it is mined, it becomes aesthetically degraded and unusable for most purposes.

Mining generates enormous quantities of waste, placing it second to agriculture as the largest waste producer in North America. Much of this waste is made up of mine tailings, the finely ground rock that remains after the valuable product is extracted. At many sites, tailings have been piled in huge mounds, upon which—if not reclaimed in some way—nothing will grow for generations. At other sites, slurries containing tailings are flushed into large open ponds, where the hazardous metals or chemicals they often contain can threaten local aquifers. For instance, in the South Fork of the Coeur d'Alene River Basin in Idaho, nicknamed the "Valley of Death," some 70 million tonnes of tailings have been dumped over the past century (Watkins 2000).

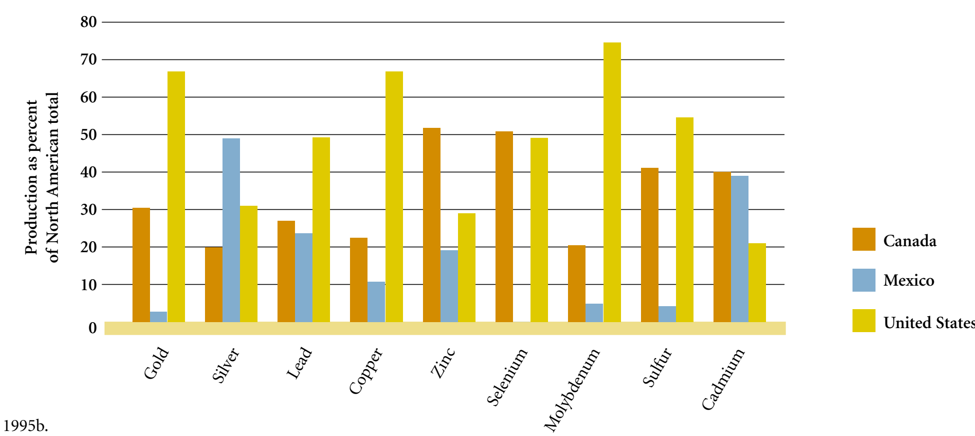
Historically, mining legislation such as the General Mining Law of 1872, which is still on the books in the United States, assigned no responsibility for the environmental consequences of mining. As a result, some 16,000 abandoned mining sites in the western US pose serious water contamination problems, but they may never receive remediation (Watkins 2000). The largest recent sites are receiving attention under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (the "Superfund Act") and must be cleaned up until they meet EPA's approval. At the largest such site, the former Anaconda copper mine complex that runs for about 225 kilometers along the Clark Fork River outside Missoula, Montana, the total cleanup bill will easily surpass half a billion dollars.

The magnitude of toxic releases from mines is such that the Toxics Release Inventory (TRI) for 1998, the first year for which hardrock mining industry data are included, reveals that mines release more toxics than any other industry in the United States (MPC 2000b). The Environmental Protection Agency's 1998 TRI data show, for instance, that one Nevada mine reported releasing more than 36,000 kilograms of mercury, with over 4,100 kilograms released directly into the air, and one Arizona copper mine released twice as much toxic waste (56 million kilograms) as was released that year in the entire state of New York (27 million kilograms) (EPA 2000a).

In Canada, as in the United States, the "polluter pays" principle for managing cleanup costs has achieved only marginal success thus far. Canada has at least 10,000 mine sites that are either abandoned, or where the owner is unable or unwilling to pay for clean up (MPC 2000a). In these cases, when public pressure demands the mine sites be rehabilitated to pre-disturbance levels, it is generally the government that must respond, at taxpayer expense. Although there are Canadian laws and environmental guidelines relevant to mining, critics contend there is no adequate law to force mining companies to rehabilitate old sites and reduce the impact of new mines (MiningWatch 1999a). The situation is said to be further

Figure 16

Mineral Production in North America, by Country



Source: INEGI 1995b.

complicated by the lack of provincial legislation and/or regulations to require mining companies to meet environmental standards or to provide enforcement oversight (MiningWatch 1999b).

Fossil Fuels

Most energy consumption in North America involves burning nonrenewable fossil fuels—coal, oil, and natural gas. The continent ranks first among the world's regions in terms of total oil consumption. Oil, among the region's most significant natural resources, is most abundant in Mexico, which has more than twice the reserves of the United States and over 10 times those of Canada (table 6) (DOE 1995a). More than half the region's proven reserves of natural gas are found in the United States, but much of its natural gas supply is currently not accessible for environmental reasons. In the case of Mexico, there are large reserves, but the country lacks the pipeline infrastructure to transport gas to consumers.

The importance of natural gas as a fuel in North America is expected to grow in coming decades (DOE 1995a) because it is cheaper than oil and cleaner burning than oil or coal. Coal is the region's third most significant fossil fuel. It is less expensive than oil or natural gas, and almost all North American coal consumption is for electricity generation (DOE 1995b). Between 1985 and 1995, North American production and consumption of coal and natural gas generally increased, while production of crude oil declined (figs. 17-22).

Burning fossil fuels for power generation, however, has several direct, deleterious environmental and health effects. Nitrogen and sulfur oxides, especially sulfur dioxide from coal-fired power plants, and acid aerosols combine with water vapor in the atmosphere to form "acid rain," which damages forests and other plant life, acidifies bodies of standing water, and attacks stone and concrete structures. Particulate matter and aerosols, when taken into the lungs through respiration, have negative effects on human health. Carbon dioxide acts as a greenhouse gas that plays a role in global climate change, since it helps reflect outbound terrestrial radiation back toward the earth, warming it (other greenhouse gases are water vapor, ozone nitrogen oxides and methane). Sulfur oxides tend to have the opposite effect, reflecting solar radiation back into space, but their resultant cooling effect is overshadowed by the warming caused by greenhouses gases, since the latter stay in the atmosphere for decades or even centuries, whereas sulfur oxides tend to be leached out of the atmosphere in a few weeks.

Global warming (see also the sections below on Air Quality and Climate Change), along with deleterious environmental and health effects, are powerful reasons why policies for satisfying North Americans' energy dependence need to shift more in the direction of renewable, environmentally friendly methods of power generation.

Table 6

Fossil Fuel Energy Stocks in North America, by Country

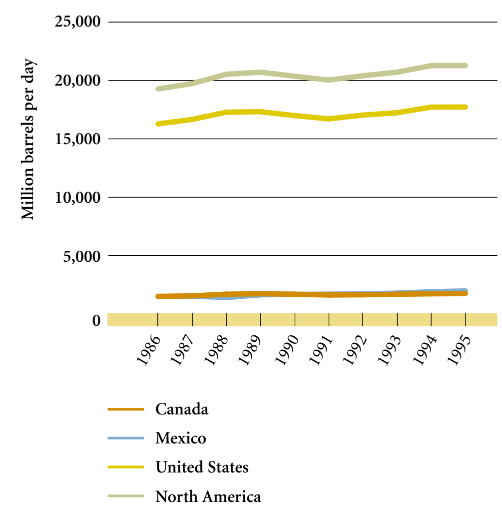
	Crude Oil (billion barrels)	Natural Gas (trillion cubic meters)	Coal (billion tonnes)
Canada	4.7	17.3[1]	8.62
Mexico	28.3	8.6[1]	1.18[2]
United States	21.8	47.3[1]	243.60
North America	54.8	73.2[1]	253.40

Source: DOE 2001.

Note:
[1]Proven reserves
[2]Recoverable coal

Figure 17

Crude Oil Consumption in North America, by Country, 1986–95



Source: DOE 1995a.

Note: The graphs in figures 36–41 have different units and scales.

Renewable Energy

Interest in various forms of renewable energy is growing throughout the region. Since the oil price shocks and emerging environmental awareness of the early 1970s, renewable energy has been slowly penetrating the market. In 1993, 7.8 percent of the energy consumed in North America was produced by renewable energy sources, primarily hydroelectric power (table 7) (WRI et al. 1996). Given the region's diverse geography and the many sites at which low-impact hydroelectric, geothermal, solar, and wind power can be developed, this energy pathway holds much future promise.

Underlying pressures that create barriers to commercializing renewable energy include the high cost of capital, poorly developed infrastructure, lack of awareness among customers, and a disadvantageous energy pricing regime (EC 1996). Both solar energy and wind power, although virtually limitless and nonpolluting, require supplemental technologies to make energy available when generation does not coincide with demand. Interest and investment in renewable energy resources tends to rise in times when fossil fuels are expensive, and to decline at other times.

Renewed interest in developing renewable energy in the 1990s was stimulated by a growing awareness of the climatic effects of carbon emissions from conventional fuel sources. Recent technological developments are making renewable energy sources increasingly reliable and cost-effective, and production is increasing (fig. 23).

Table 7

Renewable Energy Consumption in North America, by Country

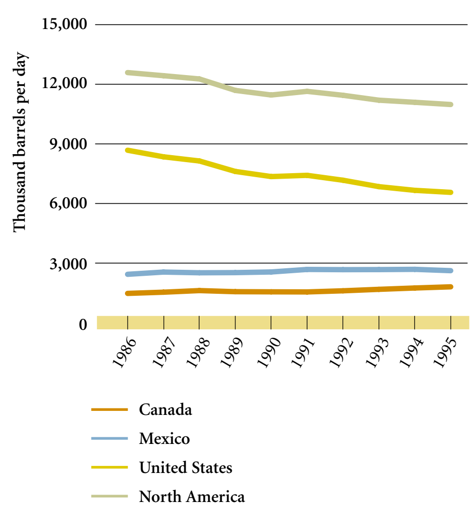
	Renewable (petajoules)	Share of Total Energy Use (percent)
Canada	1,166	9.6
Mexico	331	4.1
United States	1,670	8.2
North America	3,167	7.8

Source: WRI et al. 1996.

Note: Renewable sources include geothermal, wind and hydro power and the measure is for primary electricity, assessed at the equivalent of 100% efficiency for hydroelectric and wind generation, and 10% efficiency for geothermal generation.

Figure 18

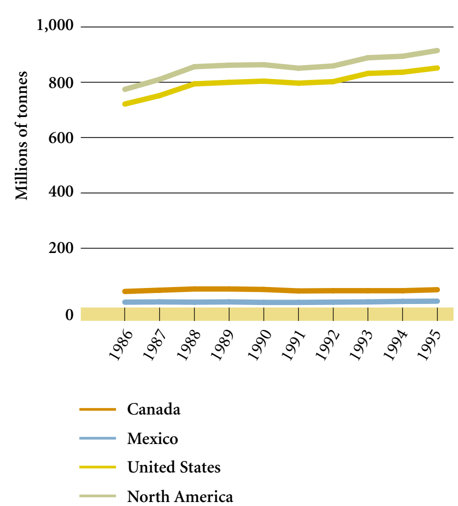
Crude Oil Production in North America, by Country, 1986–95



Source: DOE 1995a.

Figure 19

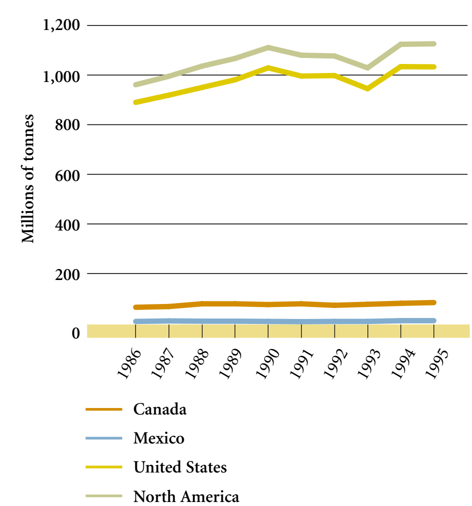
Coal Consumption in North America, by Country, 1986–95



Source: DOE 1995ab.

Figure 20

Coal Production in North America, by Country, 1986–95



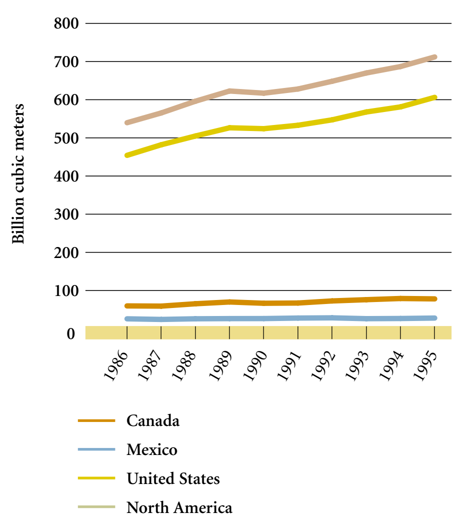
Source: DOE 1995ab.

Some speculate that restructuring in the electricity-generating sector, led by recent initiatives in the United States, could encourage investment in renewable energy technologies as well as in more efficient and less polluting technologies using natural gas. Solar electricity is gaining a foothold in some areas of the United States due, in part, to more competition between electric utilities, but also because consumers are voicing their preference for "green products" (O'Meara 1998b). Wind power is making significant inroads in the Central and Western United States and in Alberta, Canada. Eleven US states have recently adopted some type of "renewable portfolio standard," requiring that a gradually increasing percentage of a state's electricity be generated from renewable resources (GDS 2000).

Meanwhile, critics of deregulating the electricity-generating sector fear that such a policy will have significant negative effects on air quality, as deregulation could encourage utilities to extend the operating lifetime of older, coal-fired utility boilers that are cheaper to operate but emit more pollution. Early signs indicate that electricity production from coal burning is on the rise in North America and that this increase has in fact been stimulated by deregulation and competition.

Figure 21

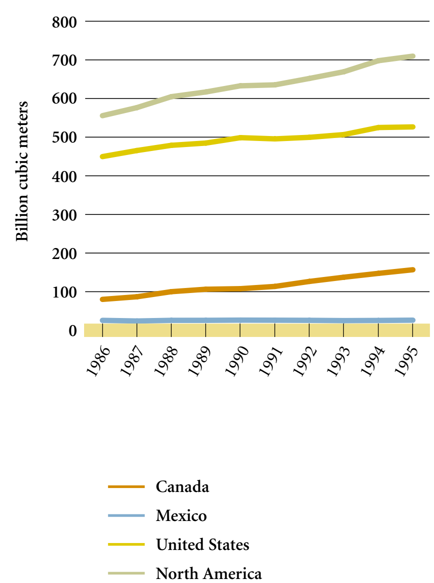
Dry Natural Gas Consumption in North America, by Country, 1986–95



Source: DOE 1995a.

Figure 22

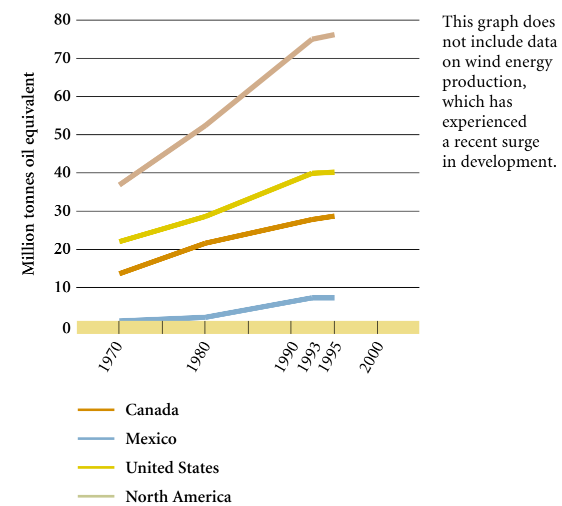
Dry Natural Gas Production in North America, by Country, 1986–95



Source: DOE 1995a.

Figure 23

Renewable Energy Supply in North America, by Country, 1970–95



Sources: OECD 1995a; OECD 1997.

Note: Sources are hydro, geothermal, and solar energy.

Transportation

The transportation sector is one of the largest consumers of fossil fuels in North America. In addition to depleting this nonrenewable resource, emissions from burning fossil fuels contribute to local air pollution, climate change and acid rain.

Transportation is vital to the social and economic structure of North America. Vehicles—especially automobiles, trucks and planes—and their related infrastructure, affect human health and the environment in many ways. The transportation sector is one of the largest consumers of fossil fuels in North America. In addition to depleting this nonrenewable resource, emissions from burning fossil fuels contribute to local air pollution, climate change and acid rain. The effects of these damaging pollutants result in harm to humans, other species and the ecosystems upon which we depend. In addition, transportation expropriates extensive areas of land for roads and parking, displacing other valuable uses such as agriculture, wildlife habitat, and housing (EC 1998a; CEQ 1996).

The increasing number of motor vehicles on North America's roads is directly related to population growth, higher incomes, and land-use decisions that promote urban sprawl. Nearly 90 percent of US and Canadian households and more than 30 percent of Mexican households own automobiles. In 1997, there were almost 17.5 million cars registered in Canada (Statistics Canada 1999b), while there were 208 million in the United States in 1995 (CEQ 1996). In the last 25 years, Canada's population increased by one-half, but the number of automobiles doubled (Good 1999). In Mexico, there were 43.9 million passenger cars in 1994, compared with an estimated 28.8 million in 1984 (INEGI 1995a).

Only a few large cities have extensive public transportation systems, so more than 80 percent of all commuting trips in Canada and the United States are by private automobile. Transit use (as measured by passenger-kilometers) remains static at less than five percent of motorized travel in urban areas of Canada (EC 1998a). In the United States, the total passenger-kilometers by transit, rail, and intercity bus has dropped by half since 1970 (CEQ 1996).

North American dependence on the automobile feeds into a cycle that reinforces suburban development and demands for roads and parking, and leads to a decline in public transit services and the vitality of urban cores. Citizens of Canada and the United States travel greater distances than residents of other countries with comparable standards of living. The largest proportion of travel is within cities and their suburban surroundings (EC 1996).

Subsidies for gasoline, roads, and parking make automobiles artificially inexpensive to operate. This encourages commuting, and acts as one of the underlying pressures driving suburbanization in North America. In addition, municipal planning biases tend to promote heavy use of cars by favoring more and bigger roads over the creative management of public transportation (Gardner 1998). A wave of concerns over sprawl led US voters to approve a record number of land-use measures and conservation initiatives in recent elections.

In the United States, transportation accounts for two-thirds of the nation's oil consumption, (CEQ 1996), while in Canada passenger vehicles account for more than half of the fuel consumed and carbon dioxide emitted from the transportation sector (EC 1998a). Significant improvements have been made in the energy efficiency of North American motor vehicles in the last 30 years. However, these efficiency gains have been off-set by the increasing number of vehicles, the greater distances traveled and increasing vehicle size. The 1980s trend toward smaller vehicles has reversed. Sport utility vehicles and light trucks, which are not subject to fuel efficiency standards, now account for about half the vehicles sold in the United States. The result of these trends has been a marked increase in fuel consumption, leading to greater impact on the environment and human health (Brown 1998; Dunn 1998; FOE 1998). Changes in production processes are adding to motor vehicle traffic as factories move to just-in-time deliveries that favor transport trucks rather than slower but more fuel-efficient trains.

Of the other forms of transportation that affect the North American environment, marine transportation is increasingly important. The United States is the world's largest trading nation and accounts for nearly 20 percent of world maritime trade. More than 95 percent of US foreign trade, excluding that with Mexico and Canada, is conducted by sea. With the relaxation of trade barriers, it is expected that international trade will triple by 2020, with 90 percent (by weight) moving via the ocean. The nine million barrels of oil imported daily to the United States, largely by water, is the largest single commodity handled anywhere (NOAA 1998c).

Oil spills account for only five percent of the oil entering the ocean every year, but these concentrated events have significant environmental and social impacts at local and regional levels. Although increased trade can potentially lead to more oil spills, prevention and preparedness capabilities have improved along North America's coasts. A significant decline in the number of oil spills along US beaches has been attributed to a combination of political, economic, and regulatory measures (US Coast Guard 1995). Despite the reduction in risk, however, large-scale releases of oil continue to occur in the marine environment (NOAA 1998d).

Air Quality

City centers and surrounding suburbs have historically borne the brunt of air pollution. Yet, despite overall air quality improvements since the Clean Air Act was adopted in the United States in 1970, a disturbing new trend is emerging. In both 1998 and 1999, average rural ozone levels were greater than the average observed at urban sites.

The quality of the air we breathe is affected by decisions regarding modes of transportation, what fuels to use, pesticides to spray, and laws to pass and enforce. The burning of fossil fuels—in electric power plants and in the expanding transportation sector—together with the burning of municipal and medical waste and the smelting of sulfur-bearing metal ores, produce large quantities of air pollutants.

The United States emits far more air pollutants than the other two countries, largely because it is the most populous. Canada and the United States are among the highest air pollution emitters in the world. This is due to several factors, chief among them is the fact that these two countries are the highest per capita consumers of fossil fuels.

Hidden subsidies to the energy sector encourage the development and burning of fossil fuels and polluting industrial activities. Zoning regulations that promote urban sprawl and roadways lead to increases in vehicle traffic and emissions.

Air pollution became a serious health problem in the late nineteenth century, peaking with a major smog episode in London, England, in 1952 that killed 4,000 people (Campbell et al. 1995). Measures to restrict coal-burning improved air quality significantly in the following decades. In the 1970s, acid rain emerged as a new air pollution issue with the discovery of dying lakes and forests in central and eastern North America. Consequently, the concern shifted from human health to the environment. Some of the more significant effects of acid rain include the destruction of local vegetation and declines in the health of more distant forests, acidification of lakes and streams and associated die-offs of freshwater biota, and increased leaching of metals from rocks, soils, and building materials.

Elevated levels of urban air pollution have shifted the focus of concern back to public health and, increasingly, the role of the automobile. Impaired air quality in urban centers contributes to one of the most direct and harmful effects of North America's dependence on motor vehicles. Vehicle exhaust contains a variety of pollutants, including carbon monoxide, oxides of nitrogen, sulfur dioxide, volatile organic compounds, and small airborne particles. Ground-level ozone and smog develop when these common air pollutants are "cooked" by sunlight.

According to a study by the Ontario Medical Association, ground-level ozone (smog), acid aerosols, and airborne particles have created a serious health problem in North America. These pollutants are implicated in both respiratory and cardiovascular dysfunction (OMA 1998). Children and the elderly are particularly sensitive, as are those with pre-existing respiratory ailments (OMA 1998; Health Canada 1997). Ontario's Ministry of Environment has estimated that smog causes about 1,800 premature deaths per year in Ontario (CEC 1997a). Despite improvements in air quality, approximately 62 million US residents lived in counties with pollution levels above the national air quality standards in 1999. This rises to 125 million if an eight-hour ozone standard is used (EPA 2000b).

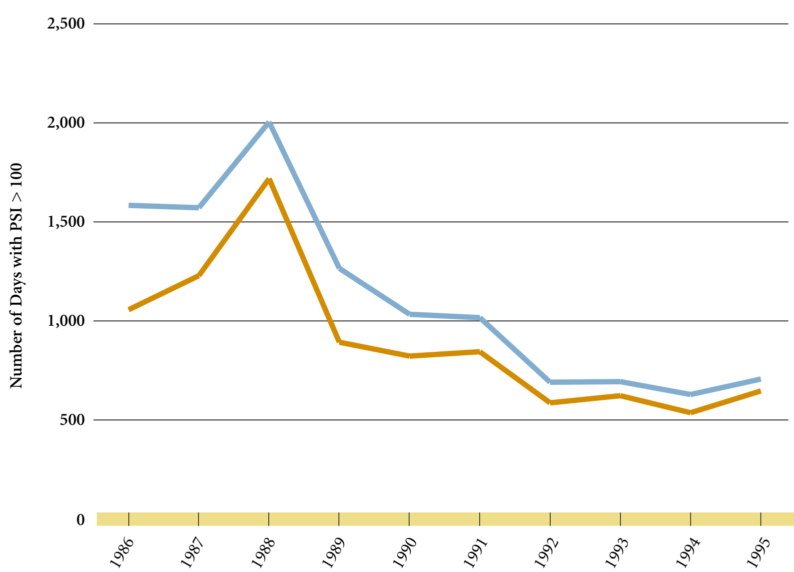
Public concern about the health effects of air pollution, particularly urban smog, has led to a wide array of air pollution abatement measures, ranging from industrial controls to improvements in automobile efficiency. While these clean-up measures continue, some of the successes have been offset by increases in industrial output and the steady rise in the number and size of motor vehicles, and the distances they are driven. Between 1970 and 1999, US population increased 33 percent, while vehicle miles traveled increased 140 percent, and gross domestic product increased 147 percent. At the same time, total emissions of the six principal air pollutants decreased by 31 percent (EPA 2000b).

City centers and surrounding suburbs have historically borne the brunt of air pollution. Yet, despite overall air quality improvements since the Clean Air Act was adopted in the United States in 1970, a disturbing new trend is emerging (fig. 24). In both 1998 and 1999, average rural ozone levels were greater than the average observed at urban sites. Visibility is being impaired across large areas, including many of the nation's most treasured parks and wilderness areas. In addition, ground-level ozone has been estimated to cause over US$500 million in annual reductions of agricultural and commercial forest yields (Sawyer 1996). Efforts by the Environmental Protection Agency to control ozone levels and particulate emissions have been stymied in the courts (EPA 2000b). In Canada, rising ozone levels in the 1990s roughly parallel developments in the United States (fig. 25). Urban sprawl development patterns and the resulting increase in vehicular traffic threaten to unravel decades of progress in controlling air pollution.

The huge and rapidly increasing population of Mexico City and the associated vehicle traffic, combined with the frequent occurrence of temperature inversions that trap pollutants, have created a severe air pollution problem in that city (fig. 26). In the mid-1990s, suspended particulate matter from vehicles and other sources contributed to the deaths of about 6,400 people per year in Mexico City, and about 29 percent of all children had unhealthy amounts of lead in their blood (WRI et al. 1996). Responses are being implemented. Unleaded gasoline was introduced in 1990 and, starting in 1991, all new cars have been designed to run on unleaded fuel. A mandatory emissions testing program for vehicles is being strengthened. Restricted driving days require vehicles to be left at home one or two days a week. Improved emission control technologies for vehicles are being adopted. Industries and the service sector are working to reduce emissions. The public transportation system is being improved and expanded. And rezoning of urban areas is underway to reduce travel distances between land uses.

Figure 24

Metropolitan Air Pollution Trends in the United States, 1986–95



Notes:
This graph shows that ozone increasingly accounts for those days with US Pollutant Standard Index values greater than 100 (which is the federal standard) and reflects the success in achieving lower CO concentrations in US cities.

PSI - Pollutant Standard Index:
0–50=Good
51–100 = Moderate
100 = Federal Standard
101–200 = Unhealthful
138–200 = Health Advisory (Ozone only)
200–275 = Very unhealthful
275+ = Hazardous

Trend in the number of days with PSI values greater than 100 summed across the nation's 94 largest metropolitan areas (those cities with total 1990 population greater than 500,000).

Source: EPA 1996b.

Significant reductions have been made in the atmospheric concentrations of sulfur dioxide, carbon monoxide, and lead concentrations and in the levels of total suspended particulates. However, the condition of Mexico City's air remains critical. Ground-level ozone and nitrogen dioxide concentrations are still well above acceptable health standards. Without serious measures to restrict polluting activities, Mexico's poor air quality will increasingly impair human health.

The air we breathe is not limited by political boundaries. In fact, many pollutants of concern to human and ecosystem health are transported tens or even thousands of kilometers (CEC 1997a). In general, prevailing winds in North America tend to transport air pollutants northeastwards. The exception is northern and central Canada, where prevailing winds are generally from the northwest or the west (CEC 1997a).

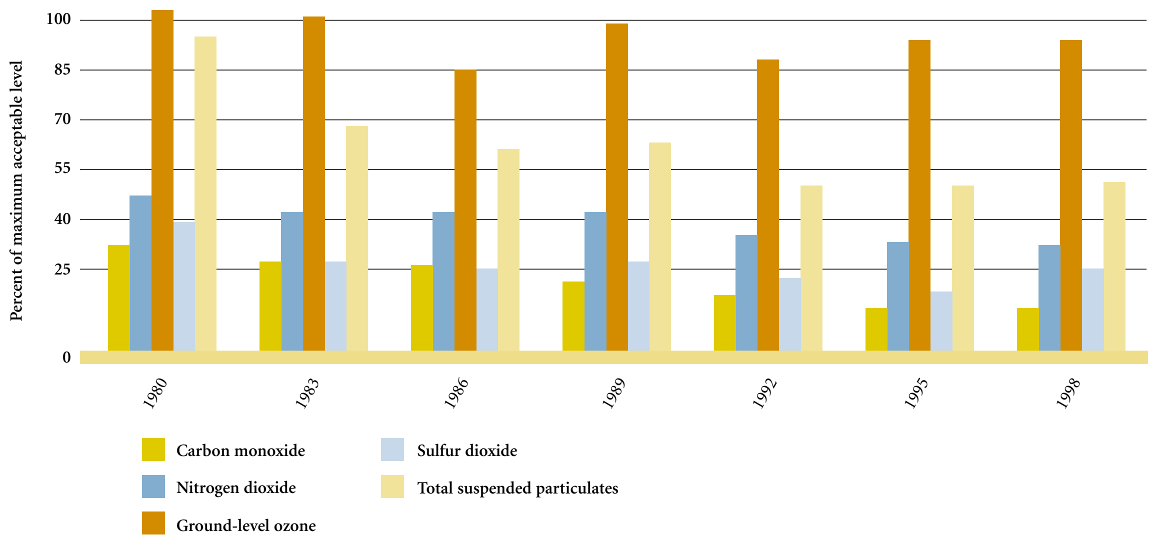
Recent studies have shown that a number of serious pollutants cross the boundaries of Canada, the United States, and Mexico. Transboundary pollution is typically from Mexico into the United States and from the United States into Canada (CEC 1997a). However, there are clear examples where the opposite occurs, most notably when emissions from south-central Canada are transported to the northeastern United States.

Transboundary pollutants of concern in North America include: sulfur dioxide, nitrogen oxides, mercury, particulates, ozone, persistent organic pollutants (POPs) and volatile organic compounds (VOCs) (CEC 1997a).

In 1993, more than half the pollutants that cause acid rain in Canada (principally sulfur and nitrogen oxides) originated in industrial areas of the United States. These emissions and the resulting deposition of sulfates in eastern North America have decreased dramatically in the past decade (map 14), thanks to aggressive reduction targets and coordinated strategies in both countries. Canada has worked with the provinces to achieve significant reductions in sulfur dioxide emissions from major sources in eastern Canada, particularly from nonferrous metal smelters and coal-burning power

Figure 25

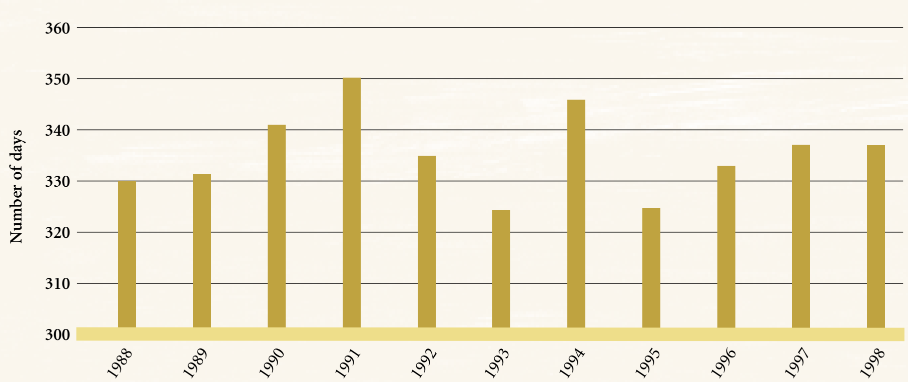
Common Air Contaminants in Canada, 1980–98



Source: Data from Tom Furmanczyk, Statistical Officer, Pollution Data, Environment Canada.

Figure 26

Days Exceeding Standards for Ozone Concentration in the Valley of Mexico Metropolitan Zone, 1988–98



Sources: INE 1999c; INEGI-Semarnap 2000.

Note: Maximum acceptable frequency according to criteria for air quality standards: once every three years.

plants. The US Acid Rain Program, implemented in 1995, will reduce annual sulfur dioxide emissions by 10 million tons from 1980 levels by 2010. The program sets a permanent cap on the total amount of sulfur dioxide that may be emitted by power plants nationwide at about half the amount emitted in 1980. An emissions trading program is in effect to achieve the required reductions cost effectively (EPA 2000b). Despite major achievements in reducing the emission of acid rain precursors in North America, evidence suggests that further reductions of 50 percent are needed (EC 1997).

In southern Canada, transboundary smog has emerged as an important issue, with estimates that over half of Toronto's ground-level ozone originates in the United States (CEC 1997a). The same sources (coal-fired plants in the Ohio Valley) are also blamed for elevated smog levels in the northeastern United States. Aircraft measurements and other studies have shown that ozone can travel hundreds of kilometers—and harm the health of people far from the source of the pollution.

Canada and the United States are cooperating to reduce transboundary air pollution, including air toxics and ground-level ozone, through the International Joint Commission and the 1991 Air Quality Agreement. In December 2000, an Ozone Annex was added to the 1991 Agreement. It commits both governments to significantly reduce the creation of smog-causing nitrogen oxides and volatile organic compounds (VOCs) over the next 10 years (EC 2000). The eastern provinces of Canada and the New England states have also worked together to combat the long-range transport of mercury (CEC 1997d).

Other transboundary problems include air quality deterioration along the industrial belt of the US-Mexican border and in the Arctic, which receives air pollutants from industrialized areas far to the south as well as from the Eurasian continent. Elevated mercury levels in fish and marine mammals in the Arctic are thought to pose a human health risk during fetal development because offspring are exposed to the accumulated lifetime mercury stores of the mother (INAC 1997).

Map 14
Wet Sulfate Deposition in Canada and the United States, 1980–84 and 1991–95

Source: EC 1999.

Note: The area receiving average wet sulfate deposition>20 kg/ha/year declined by 61 percent between 1980–84 and 1991–95. Mexican data are not available.

Dioxin deposition in the Canadian polar territory of Nunavut comes primarily from North American sources that account for 85 to 98 percent of the total toxicity. Modeling indicates that US sources contribute 74–85 percent of the deposition, Canadian sources contribute 8–21 percent, and Mexican sources, 4–9 percent. Municipal waste incineration is the largest source category, accounting for 37 percent of total emissions (CEC 2000a).

Climate Change

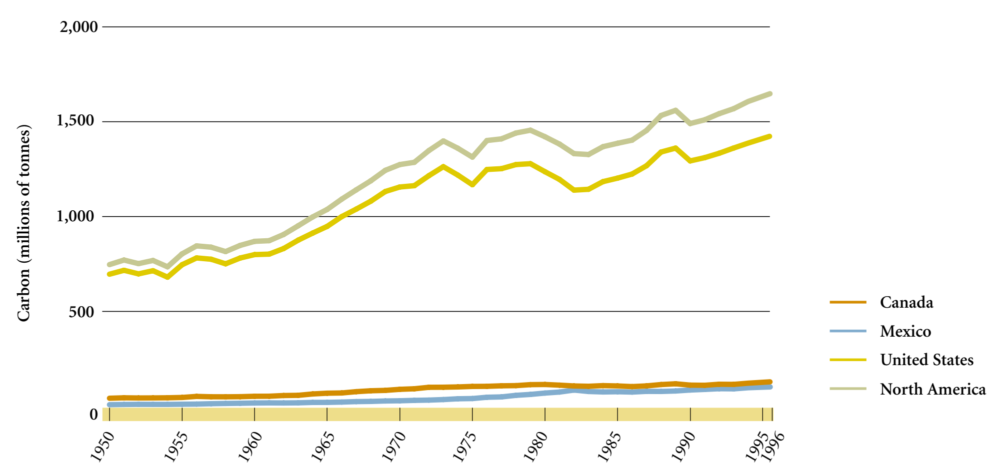
North America's high and increasing level of greenhouse gas emissions runs counter to the aim of stabilizing emissions agreed to by most countries at the UN Conference on Environment and Development in 1992. As of this writing, national programs are only now beginning to emerge in any of the three countries to deal with what has to be considered a global challenge of unprecedented magnitude.

Most greenhouse gases, such as carbon dioxide (CO_2), water vapor, nitrogen oxides, and methane, enter the atmosphere from natural sources such as plants, animals, and microbes. A balance in their concentration is maintained by natural processes such as photosynthesis. The result is an insulating blanket of gases that keeps the planet at a habitable temperature. Humans are tipping this balance by altering the concentration of atmospheric gases. The release of carbon from fossil fuel burning is compounded by the destruction of natural ecosystems such as tropical rainforests that would otherwise remove carbon dioxide from the air.

North Americans, especially people living in the United States, Canada, and Mexico's urban centers, are major global emitters of greenhouse gases, releasing billions of tonnes to the atmosphere per year—more than in any other region except Asia. These emissions are strongly influenced by the United States, which is the largest single source of fossil fuel-related CO_2 emissions in the world (fig. 27). The United States and Canada lead other regions in terms of per capita CO_2 emissions, with consistently high levels amounting to almost 15 times the per capita emissions from the Far East. This is primarily due to reliance on fossil fuels to power cars; heat, cool, and light buildings; and produce and use consumer goods. Combined, the three countries of North America emit the equivalent of about five tonnes of carbon per person per year (fig. 28). Furthermore, North America emits significant amounts of other greenhouse gases, including methane, nitrogen oxides, and chlorofluorocarbons (table 8). Methane is a

Figure 27

CO_2 Emissions from Fossil Fuel Consumption and Cement Production in North America, by Country, 1950–96



Sources: Boden 1997; Marland et al. 1999.

Note: To convert these data to the actual mass of CO_2, multiply by 3.664—the ratio of the mass of CO_2 to that of carbon.

highly potent greenhouse gas, with 24.5 times the heat absorption capacity of CO_2 per molecule. It originates largely in landfills and agricultural activities.

Scientists are increasingly tying these emissions to predicted rapid changes in the global climate, illustrated by a recent rise in average global temperatures, both atmospheric and oceanic (the 1990s was the warmest decade on record in North America). This effect has been studied and modeled extensively, most notably by the Intergovernmental Panel on Climate Change (IPCC)—several hundred of the world's best climatologists comprising three working groups, organized under the auspices of the United Nations. At five-year intervals they publish their findings. The third and most recent report, issued at the beginning of 2001, is a sobering statement that we stand on the edge of a global cataclysm (IPCC 2001).

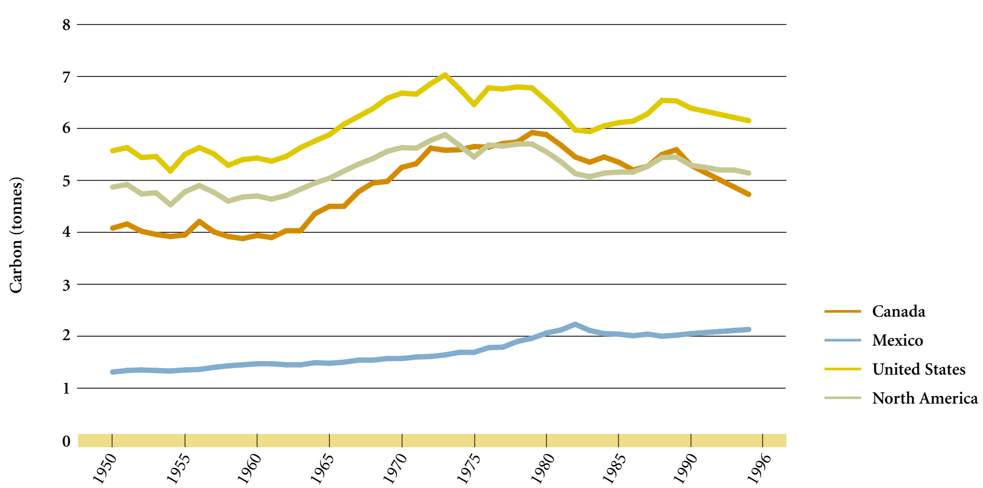
Using six different projection methods about how large economies grow and how fast they might make the transition to substantial use of non-carbon sources of energy, the new report predicts that the average global temperature will increase between 1.5 and 6.3°C in this century, a forecast significantly more pessimistic than the 1.3 to 3.5°C predicted by the IPCC report only five years ago (IPCC 1996). Even at the low end, these increases will spell disaster for crop yields in tropical and semi-tropical regions where food is now scarce. In addition, the models predict that one result of the warming of the atmosphere will be a change in global climate and weather patterns. Among the effects predicted by the IPCC and other researchers are more frequent and extreme events, such as heat waves, floods, a rising sea level, droughts, severe storms, and more pronounced events from weather cycles like El Niño (Watson et al. 1998, 1997).

Even relatively small changes in average temperatures can result in much more extreme events. At the beginning of the new century, observers point to the disappearance of mountain glaciers on all continents, the receding polar ice-caps and increasingly early appearance of free water in the Arctic (McKibben 2001). Ironically, in the initial phases of global warming, portions of the United States and southern Canada may experience lengthened growing seasons. Over the longer term, however, scientists warn that there will come a dramatic point beyond about 1.5ºC of warming, where crop yields would start to decline rapidly. And if the sea level rises as expected (1.5 meters at the low end of the predicted temperature increase, as much as 3.5 meters with more extreme warming), storms and flooding along coastal areas will become much worse, causing property damage and loss in the billions of dollars (White and Etkin 1997). At the higher end, the rise in sea levels would be sufficient to permanently flood low-lying regions such as southern Florida (up to perhaps 50 km north of Miami), the Mississippi delta in southern Louisiana (up to perhaps 100 km upstream from New Orleans), and coastal North Carolina (Lemonick 2001). Currently low-lying islands like Cozumel would all but disappear. And the effect on already impressive tides in places like the Bay of Fundy would be unimaginable. In addition, a warmer climate will alter the range and transmission of vector-borne and contagious diseases, such as malaria and dengue fever (Box 8).

Longer-term effects are more difficult to predict. One possibility is that, if global warming were to reach the IPCC's worst-case scenario and continue for hundreds of years, the vast ice sheets in Greenland and Antarctica might melt (these ice sheets contain enough water to raise world sea levels by some 70 meters—see IPCC 2001, report of working group I, section F). This could dilute the salt content of the oceans and slow or even stop major ocean currents

Figure 28

Per Capita CO_2 Emissions from Fossil Fuel Consumption and Cement Production in North America, by Country, 1950–96



Sources: Marland et al. 1999.

Note: To convert these data to the actual mass of CO_2, multiply by 3.664—the ratio of the mass of CO_2 to that of carbon.

Box 8

Emerging Trend: The Potential Health Consequences of Global Climate Change

Direct effects:

Deaths, illness, injury due to increased exposure to heat waves (also some possible reductions in cold-related diseases and disorders)

Respiratory effects, including climate-enhanced exposure to pollens and air pollutants

Deaths, illness, injury due to extreme weather events (cyclones, floods, fires, etc.)

Skin cancers, eye disorders (cataracts etc.), and immune suppression due to increased exposure to ultraviolet radiation

Indirect effects:

Altered range and transmission of vector-borne infectious diseases (malaria etc.)

Altered transmission of contagious diseases (cholera, influenza, etc.)

Impact on food production (especially grain crops and the marine food chain) due to changes in temperature, precipitation, and biological systems from pests, diseases, etc. (also, ultraviolet radiation may impair photosynthesis)

Consequences of sea-level rise: increased flooding, disrupted sanitation, salinization of soil and fresh water, and increased breeding sites for infectious disease vectors

Demographic displacement and crowding due to "environmental refugees"

Source: McMichael and Martens 1995.

The Environment Leaders of the Eight in their 1997 Declaration on Children's Environmental Health stated that children will be among the most susceptible to the health effects associated with anticipated changes in the global climate due to human actions. Such changes include more severe heat waves, more intense air pollution, and the spread of infectious diseases (Anon 1998).

like the Gulf Stream, which warms the North Atlantic and Europe, as happened in prehistoric times. This, paradoxically, might help throw the planet into another ice age. Alternatively, if the northern peat bogs and Arctic permafrost warm enough to start releasing the methane stored within them, global warming might well quickly surpass even the bleakest current predictions (Lemonick 2001).

North America's high and increasing level of greenhouse gas emissions runs counter to the aim of stabilizing emissions agreed to by most countries at the UN Conference on Environment and Development in 1992. As of this writing, national programs are only now beginning to emerge in any of the three countries to deal with what has to be considered a global challenge of unprecedented magnitude.

Table 8

Approximate Amounts of Non-CO_2 Greenhouse Gas Emissions in North America, by Country

	Methane (1,000 tonnes)	Nitrous Oxide (1,000 tonnes)	CFCs (1,000 tonnes)
Canada	3,514	111	5
Mexico	3,642	12	15
United States	28,171	359	60
North America	35,327	482	80

Source for methane and nitrous oxides for Canada and the United States: WRI et al. 1998; data are for 1994.
Source for Mexico: INE-Semarnap 2000. Methane and nitrous oxide data estimates for early 1990s.
Source for CFCs for Canada, Mexico and the United States: OECD 1997; data are for the mid-1990s. CFC values refer to their total apparent consumption controlled by the Montreal Protocol.

Natural Disasters

The number and cost of natural disasters—worldwide and in North America—have increased enormously….The cost is rising not only because of the increased frequency and severity of natural disasters, but also because of the growing tendency of people to live in high-risk areas.

Throughout a long and continuous cycle of response and recovery, mitigation and preparedness, North Americans have tried to reduce their risk of and consequences from disasters. Recent experience, however, suggests that disasters are becoming more frequent and expensive in spite of advanced technology.

The number and cost of natural disasters—worldwide and in North America—have increased enormously (Changnon et al. 1997). The list of events is long: the Mississippi flood of 1993 (Box 9), the Mexico City earthquake of 1985, the ice storm in eastern Canada and the northeastern United States in 1998, and such costly and sometimes lethal hurricanes as Camille (1969), Gilbert (1988), Hugo (1989), Andrew (1992), Pauline (1997), and Floyd (1999). And the cost is mounting. The single most costly disaster insurance year on the record was 1998. The cost is rising not only because of the increased frequency and severity of natural disasters, but also because of the growing tendency of people to live in high-risk areas (Changnon et al. 1997). Government post-disaster aid and property insurance that covers extreme weather probably contribute to this tendency.

Certainly the El Niño episodes of the last two decades have been the strongest of the past 120 years. And, as the Americas are greatly affected by El Niño cycles, it is perhaps reasonable to expect that the storms it influences might be similarly extreme (D'Agnese 2000). A number of scientists now think that recent climatic changes have already increased the frequency and severity of some types of natural disasters, such as hurricanes, tornadoes, droughts and floods, but the extent of this link is not yet known (Etkin et al. 1998).

Migration is a significant factor associated with disastrous events. Since hurricane-prone coastal areas increasingly attract new and expanded settlements, people may live in high-risk areas because they do not know or care about the risk of infrequent catastrophic events, because they do not fully understand the risks, or because poverty or other societal factors limit their choices. In the United States, damage, injury, and death from hurricanes, tornadoes, and particularly from the storm surges they generate can occur in heavily populated regions. Hurricanes and tornadoes occur most frequently in the central United States and Florida (Parfit 1998) (map 15).

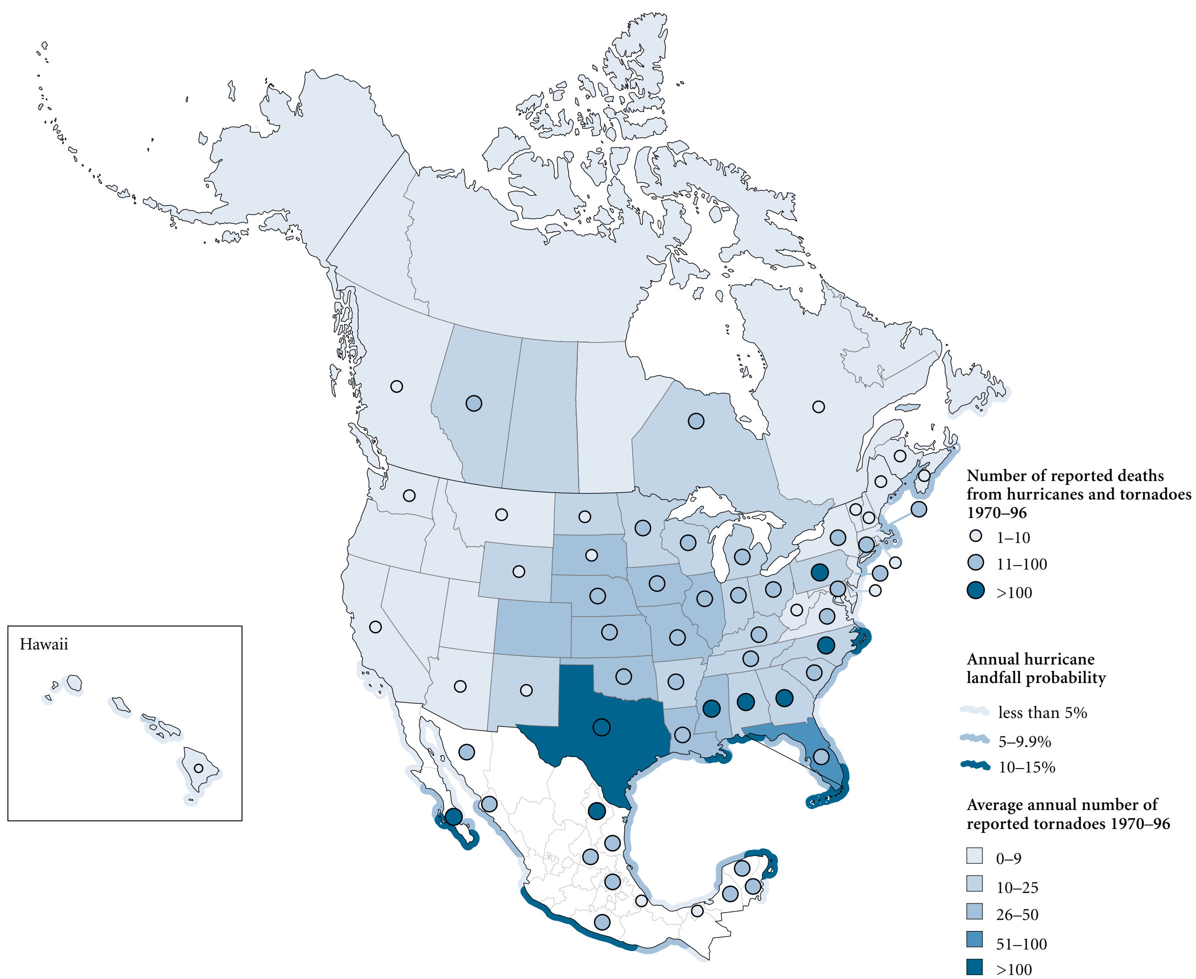
Our current understanding of disasters reflects to a much greater degree the importance of the human pressures that lead to unsafe conditions. Natural events are the triggers that create disasters, but the occurrence of disasters is just as much a function of society as it is of nature (Abley 1998). Canada, Mexico, and the United States have all suffered from short-term environmental thinking, which permitted activities that exacerbated the effects of some types of natural disasters. Widespread deforestation, for example, removes a watershed's ability to soak up rainfall, thus causing floods far downstream during heavy rains. Engineering waterways to make them more navigable creates deeper and straighter channels, which often allow flash floods to move faster and in greater volumes, with disastrous effects.

Building in riverine floodplains and along hurricane-prone coasts virtually guarantees extensive property damage in times of disaster. Nonetheless, if insurance coverage and comprehensive disaster relief are available, such practices will continue. Subsidized agriculture, flood insurance, and the promise of governmental disaster relief have long encouraged people to settle in the Mississippi floodplain (Searchinger and Tripp 1993; Rasmussen 1994). In addition to causing human suffering, extreme events can wreak havoc on ecosystems, triggering a domino effect of further environmental damage. Droughts, for example, can lead to dust storms, soil erosion, and forest fires.

North American governments are beginning to step up programs to better inform the public of natural hazard risks and to reduce the risk of loss of life, injuries, economic costs, and destruction of natural and cultural resources. Land-use planning that designates low-risk uses for areas that are most vulnerable to natural hazards is an effective method for mitigating impacts, but the practice is far from

Map 15

Hurricanes and Tornadoes in North America, 1970–96: Frequency and Resultant Loss of Life



Source: NG Maps 1998.

Note: No tornado data available for Mexico.

Box 9

Connections: The Mississippi Flood

To minimize recurrent flooding and encourage settlement, a series of levees and dikes were built along the Mississippi River over many decades. The purpose of the structures was to confine the river to a more stable channel. Though seemingly successful during most years, the system has proved inadequate and even harmful during exceptional floods. In 1993, for example, property damage and erosion were more severe than they would have been without the controls (Searchinger and Tripp 1993).

By cutting the river off from the floodplain, the levees prevented water from spilling over into bordering wetlands. These wetlands and temporary lakes that formerly acted as storage areas for excess water were now inaccessible to the main channel of the river. Flooding tributaries had nowhere to go but the river proper. In many places, the levees have also destroyed wetlands and their rich web of life.

Among the major policy questions raised by the 1993 disaster was how the United States could shift to more appropriate uses of flood-prone lands (Changnon 1996; Bhowmik and Demissie 1996; Rasmussen 1994; Philippi 1996). An interagency review committee set up to address the long-term future of the Mississippi basin recognized the need for a more sustainable approach to development and considered a variety of nonstructural alternatives, including resettlement projects and wetland restoration (Rasmussen 1994).

routine. At a time of growing populations and deregulation, it is harder to stop development in areas that are only occasionally flood-prone.

Since the frequency and ferocity of natural disasters is likely to be altered in unclear but significant ways as a result of future climate change, societies striving for sustainability must learn to become more flexible. Past experience is one useful guide that often tends to be overlooked. And precautionary approaches may be able to dramatically mitigate the severity of future effects. Land use planning that encourages disaster-resistant buildings and transportation networks in less vulnerable locations is one promising strategy. Upholding national commitments to reduce greenhouse gas emissions is another. Clear contingency plans, outlining what to do and how or whether to rebuild after disaster strikes, are also important. Becoming a more resilient, nimble, and sustainable region will likely require unprecedented levels of cooperation among diverse disciplines and multiple levels of government.

Wastes

One of the byproducts of our current high-consumption society is a vast amount of waste. Disposal is becoming an ever more difficult problem.

One of the byproducts of our current high-consumption society is a vast amount of waste. Disposal is becoming an ever more difficult problem. Many wastes are too toxic to release into the environment, so they must either stop being made or safe disposal methods must be found. When municipal landfills run out of space, it is hard to find acceptable new sites. And nobody wants an incinerator in his or her neighborhood. The three Rs—reduce, reuse, and recycle—have been in our lexicon for several decades, but progress in implementing them is uneven at best. Some companies have made impressive progress in minimizing their wastes when there has been supportive leadership and large-scale employee participation. Many municipalities have improved their waste reduction and recycling programs, especially along the west coast of the United States and Canada. However, the cost of discarding many nonhazardous wastes is still relatively low, and ours is a throwaway society.

Industrial Wastes

North America produces over 227 million tonnes of hazardous waste each year (table 9). These are wastes that are ignitable, corrosive, reactive, or toxic as defined by the Basel Convention, an international agreement on hazardous wastes.

In recent years, it has become easier for governments, community residents, environmental organizations, and trade associations to monitor hazardous waste output at individual industrial facilities. Prior to passage of the US Emergency Planning and Community Right-To-Know Act of 1986, even the clean up crews at industrial accidents were often unaware of the types and combinations of chemicals they would encounter. When the Toxics Release Inventory (TRI), a component of the legislation, was first implemented, many companies were surprised to learn how much and what types of waste they generated and the manner in which it was handled. They had never measured before. Canada followed in 1993 with its National Pollutant Release Inventory (NPRI). Mexico is now implementing its *Registro de Emisiones y Transferencia de Contaminantes* (RETC). Collectively, these databases are referred to as pollutant release and transfer registers (PRTRs).

In an effort to compare waste generation and handling practices across North America, the Commission for Environmental Cooperation publishes an annual report, called *Taking Stock*, which analyzes the publicly available hazardous waste data from Canada and the United States. (Mexico's pollutant-specific data are not yet comparable, although the Mexican government has announced that a legislative proposal would be submitted to Congress in fall 2001 to make reporting to the RETC mandatory.) The most recent assessment, on 1998 releases, analyzed 165 chemicals from nearly 22,000 manufacturing, electrical utility, and hazardous waste management/solvent waste facilities, and coal mines (table 10). These chemicals accounted for 65 percent of the total releases and transfers reported in Canada and 60 percent of those in the United States. Air emissions constituted 53 percent of total releases by weight (CEC 2001a and b).

Table 9

Production of Hazardous Waste in North America, by Country

	Year	Generation (million tonnes)
Canada	1991	5.896
Mexico	1997	8.000
United States	1993	213.620
North America	–	227.516

Source: OECD 1997.

Note: Hazardous waste refers to waste streams classified as such by the Basel Convention on Transboundary Movements of Hazardous Wastes and their Disposal.

Four US states (Ohio, Texas, Michigan and Indiana) and one Canadian province (Ontario) each reported more than 180 million kilograms of releases and transfers. In Canada, the 50 top-reporting facilities accounted for 55 percent of all on-site releases. This included 86 percent of all on-site land releases and 98 percent of underground injection. In the United States, the 50 top-reporting facilities accounted for 31 percent of all on-site releases. This included 60 percent of all on-site land releases, 53 percent of on-site underground injection, 31 percent of on-site surface water discharges, and 18 percent of on-site air emissions (CEC 2001a).

For the two countries, just two manufacturing industries (primary metals and chemicals) reported more than 600 million kilograms each in total releases and transfers—41 percent of the North American total reported amounts in 1998. Hazardous waste management and solvent recovery facilities were the fourth-largest sector for total reported amounts and for total releases of chemicals in North America in 1998. Sixteen of the 50 facilities in North America with the largest total reported amounts of releases and transfers were in this industry sector.

One-third of total releases were metals and their compounds, and 15 percent were of known or suspected carcinogens (amounting to 250 million kilograms). Fifty facilities in North America accounted for one-third of total releases of carcinogens (CEC 2001b).

In previous years, slightly over half of all releases and transfers in the matched data set were of five chemicals: methanol, zinc (and its compounds), nitric acid and nitrate compounds, manganese (and its compounds), and toluene (CEC 2000b). Of these, methanol and toluene have shown substantial decreases in use from 1995–98 (14 and 25 percent, respectively) and the others, substantial increases (zinc and its compounds, 35 percent, nitric acid and nitrate compounds, 18 percent, and manganese and its compounds, 38 percent) (CEC 2001b). From 1995–98, total on-site releases declined by 12 percent and transfers off-site to disposal increased by 35 percent (total releases, both on- and off-site, have decreased four percent over the period). During the same period, the transfer of metals for off-site treatment/sewage/disposal increased by 41 percent.

Current pollutant release and transfer registers are clearly limited. Only a small number of the tens of thousands of chemicals estimated to be in commercial use must be reported. Non-point or diffuse sources, such as transportation and agriculture, and small sources, such as service stations and dry cleaning establishments, remain exempt. However, the existence of these registers has already resulted in a dramatic decline in toxic waste generation

Table 10

On- and Off-site Releases in Canada and the United States, 1995–98

	Canada, NPRI*						United States, TRI*					
	1995	1996	1997	1998**	Change 97–98	Change 95–98	1995	1996	1997	1998**	Change 97–98	Change 95–98
	number	number	number	number	%	%	number	number	number	number	%	%
Total facilities	1,302	1,355	1,445	1,488	3	14	20,136	19,804	19,499	19,193	-2	-5
Total forms	4,164	4,324	4,632	4,797	4	15	61,334	59,767	59,403	58,814	-1	-4
	tonnes	tonnes	tonnes	tonnes			tonnes	tonnes	tonnes	tonnes		
On-site releases	**92,672**	**83,080**	**79,569**	**76,903**	-3	-17	**842,276**	**801,408**	**772,438**	**749,591**	-3	-11
Air	67,039	64,060	62,172	58,764	-5	-12	541,545	504,340	451,115	424,620	-6	-22
Surface water	12,331	5,128	4,038	4,344	8	-65	76,796	79,128	96,361	96,882	1	26
Underground injection	3,557	4,812	4,198	3,701	-12	4	85,430	72,700	77,178	72,903	-6	-15
Land	9,608	8,950	9,032	9,972	10	4	138,504	145,239	147,784	155,187	5	12
Off-site releases	**26,114**	**27,479**	**34,309**	**29,264**	-15	12	**140,118**	**152,956**	**199,836**	**195,978**	-2	40
Transfers to disposals (except metals)	4,242	2,283	2,533	2,567	1	-39	18,623	14,785	17,436	20,568	18	10
Transfers of metals***	21,872	25,196	31,776	26,698	-16	22	121,495	138,172	182,400	175,410	-4	44
Total releases On-site and Off-site	**118,786**	**110,559**	**113,878**	**106,167**	-7	-11	**982,394**	**954,364**	**972,274**	**945,570**	-3	-4

Source: CEC 2001a.

Notes: * The sum of air, surface water, underground injection and land releases in NPRI does not equal the total on-site releases because in NPRI on-site releases of less than 1 tonne may be reported as an aggregate amount.
** New TRI industry sectors not included for 1998.
*** Includes transfers of metals and metal compounds to energy recovery, treatment, sewage and disposal.

(EPA 1999). The transparency of the reporting process has also led to more informed dialogue and goal setting regarding emission reduction priorities.

Municipal Wastes

North Americans are among the largest producers of municipal solid waste in the world. In per capita terms, US and Canadian citizens produce about twice the municipal waste of Mexicans (table 11) (OECD 1997, Statistics Canada 2000). As the volume of such waste continues to grow, so does the problem of how to dispose of it. The growth in waste generation in North America is illustrated by the trend in the United States (fig. 29).

Over the past decade, the number of solid waste landfills has decreased in Canada and the United States. In Mexico, where the bulk of waste has traditionally been disposed of in open dumps, there has been an increase from 16 regulated sanitary landfills in 1994 to 46 in 1997 (EPA 1993; OECD 1995b; Resource Integration Systems Ltd. 1996; Sedesol-INE 1994). Since the 1980s, there has been a decline in the use of incineration for waste disposal in North America due to concerns about air pollution.

Recycling and other forms of waste reduction, including composting, are beginning to have some impact. In the early 1990s, about 70 percent of North America's municipal solid waste was disposed of in landfills, while between 13 and 21 percent was recycled (EC 1996; OECD 1995a, 1995b; Sedesol-INE 1994). In 1992, the United States recycled 19.4 percent of its municipal solid waste, while Canada recycled 14.9 percent. Only 2.4 percent of such waste was recycled in Mexico in 1994, but this figure does not include the materials collected and recycled by workers at landfill sites (Sedesol-INE 1994).

An increased commitment to recycling, as well as community opposition to new landfills and incinerators, increased US recycling rates to 27 percent by 1996. This was accomplished largely by instituting curbside recycling programs, covering 51 percent of the US population. In the densely populated Northeast, 83 percent of residents had access to curbside programs, while in the South only 35 percent of the people had access to curbside pickup of recyclables (DOC 1999). In some states, such as California, the goal is to divert 50 percent of the solid waste stream from landfills by the year 2000. Efforts by households and businesses to reduce their wastes and reuse materials are not well captured in national statistics.

Table 11

Production of Municipal Solid Waste in North America, by Country

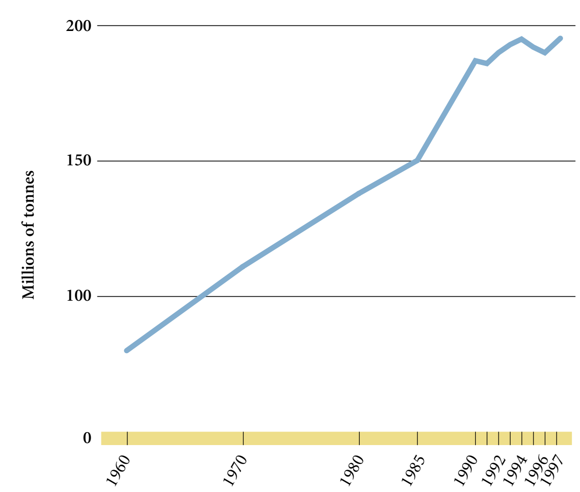
	Total Amounts (million tonnes)	Per Capita (kg)
Canada	20.600	690
Mexico	30.510	320
United States	189.696	730
North America	240.806	625

Source: OECD 1997 for Mexico and the United States. Statistics Canada 2000.

Note: Data for 1995 or latest available year.

Figure 29

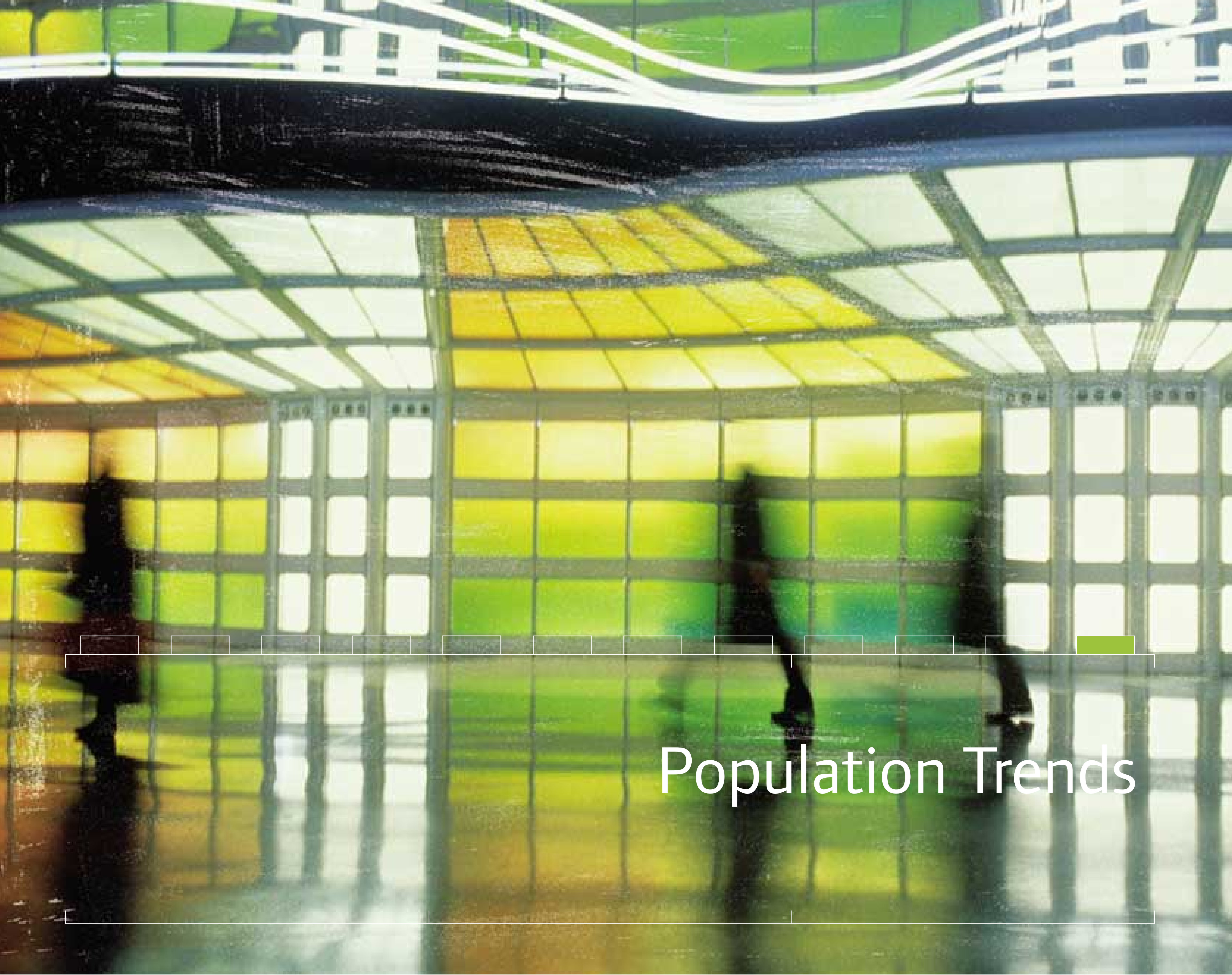
Waste Generation in the United States, 1960–97



Sources: DOC 1995; DOC 1999.

Note: Covers post-consumer, residential and commercial solid wastes, which comprise the major portion of typical municipal collections.

Population Trends



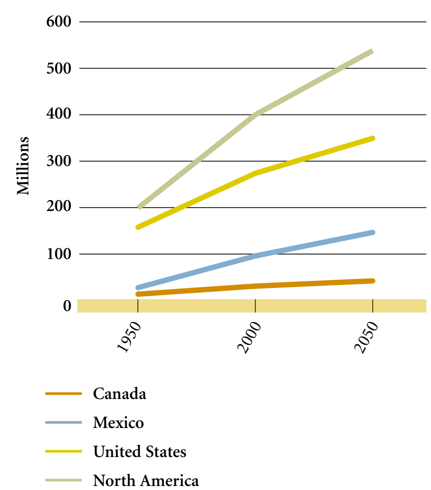
Total environmental impact…is a combination of population growth, consumption levels, and the types of technologies used.

One reason that human effects on the environment have increased in pace and scale over the past century is rapid population growth. Total environmental impact, however, is a combination of population growth, consumption levels, and the types of technologies used.

As more and more people become able to buy cars and other goods, pressure on the environment increases. This illustrates a dilemma within the idea of sustainable development. Because, in addition to environmental protection, the concept calls for improved living standards for the less fortunate. Traditional economic growth, however, increases total environmental impact (Botkin and Keller 1995). Fortunately, many technological innovations and creativity, along with substitutes and alternatives for some resources, are now helping to relieve the environmental consequences of economic activity (Livernash and Rodenburg 1998).

Figure 30

Projected Population Growth in North America, by Country, 1950–2050



Sources: UNICEF 1996; US Census Bureau 1999. 1998 and 2050 data estimates: POPIN 1998.

In 1998–99, North America's population was close to 394 million, which amounted to 6.8 percent of the world's total. Of North America's total population, the United States had 69 percent (271.9 million), Mexico 23 percent (91.2 million), and Canada eight percent (30.3 million). By 2050, North America's population is expected to be about 538 million (fig. 30). Average population density in North America is 26 persons per square kilometer, with Canada's density only 3, compared with 28 in the United States and 47 in Mexico (map 16).

In the three decades following the Second World War, North America experienced economic growth that enhanced the general quality of life: better nutrition, higher levels of education and literacy, and increased longevity (figs. 31 and 32). This trend continued in the 1980s and 1990s as fertility and infant mortality rates continued to decline (fig. 33) and life expectancy improved.

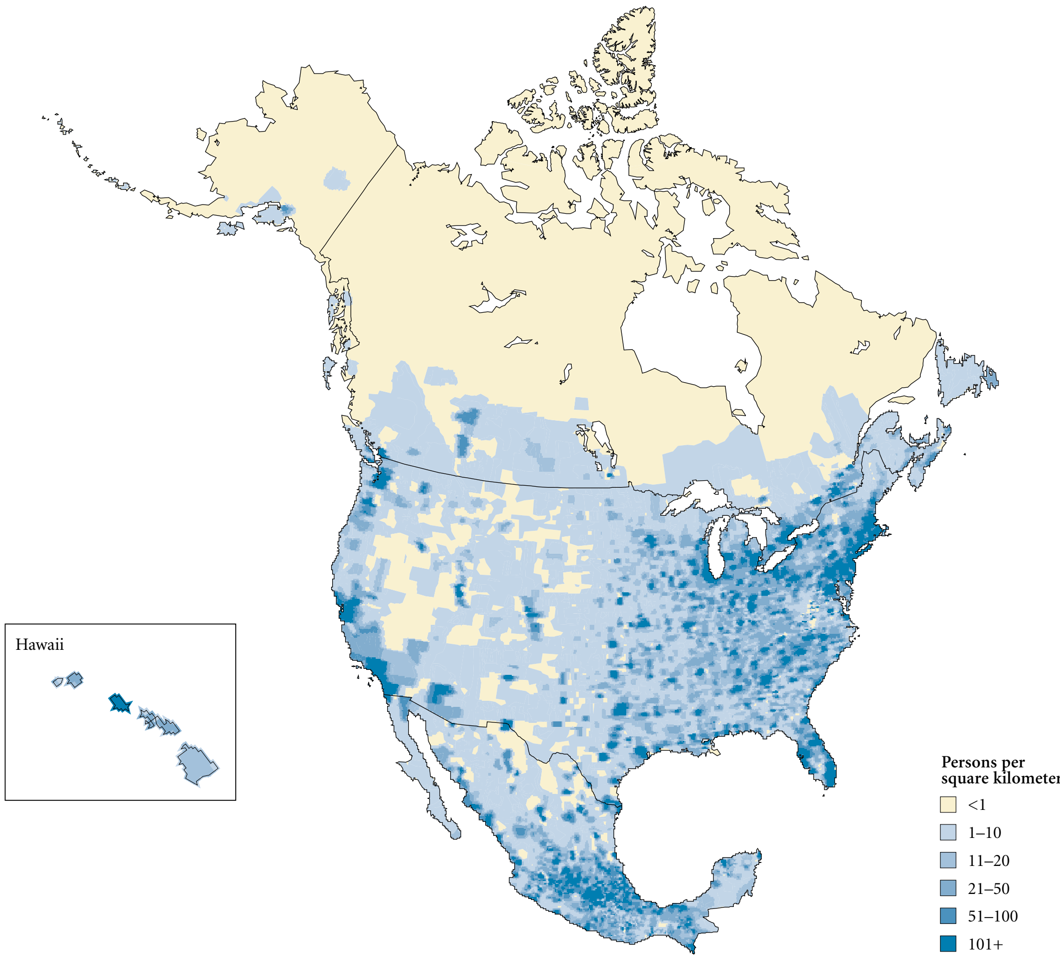
Yet, among industrial countries, the United States and Canada still have some of the highest rates of population increase, with annual growth rates of 0.9 percent and 1.1 percent respectively. The US rate of natural increase (the excess of births over deaths) is 0.6 percent and accounts for two-thirds of the growth, while net immigration (the excess of people arriving in the country over the number leaving) contributes about one-third (POPIN 1998). In Canada, the bulk of population growth is from immigration.

Because of aging baby-boomers, the share of the population aged 65 and older in Canada and the United States will continue to grow in the near future. By 2050, from 10 to 15 percent of their populations will be in the 65-plus group (UNFPA 1998). Mexico is a country with a high rate of population growth (annual growth rate of 1.94 percent), with about one-third of its population under age 15 (WRI et al. 1998) (fig. 34).

Populations are becoming increasingly concentrated in North America, and the number and size of urban areas is growing (fig. 35). Over 70 percent of the population live in urban areas of more than 2,500 people, while 30 percent

Map 16

Population Density in North America



Source: CIESIN 1997.

Populations are becoming increasingly concentrated in North America....Over 70 percent of the population live in urban areas of more than 2,500 people, while 30 percent are in areas... of 100,000 or more.

are in areas with populations of 100,000 or more (DOC 1995; Statistics Canada 1994). In the United States and Canada people are moving away from urban cores to suburbs and small or intermediate-size cities, contributing to the pattern of urban sprawl. In Mexico, migration to urban areas remains more prevalent.

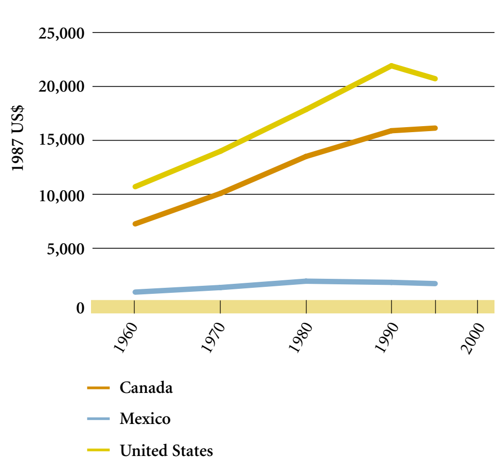
There is a growing recognition that urban sprawl is harmful to the environment and to the economic vitality of communities. New development on the outskirts of metropolitan regions often takes the form of low-density, detached housing with high infrastructure costs. Homes are separated from retail outlets and retail is separated from office space. The automobile is often the only way to travel. This growth pattern increases impervious land cover, resulting in increased stormwater runoff, a leading source of water pollution, and less groundwater recharge to aquifers that supply drinking water. In some regions, rapid and extensive housing developments are exerting pressure on local water supplies. Air quality suffers from increased traffic and congestion.

Sprawl development exerts pressure on productive agricultural lands, prime wildlife habitat, wetlands and aquatic systems, and other important components of local and regional ecosystems. When adjacent to national parks and other scenic areas, development imposes settlement pressures on protected areas. Urban sprawl is estimated to have consumed about 1.7 million hectares of prime or unique farmland in the United States between 1982 and 1992 (Sorensen et al. 1997).

While metropolitan areas have obvious environmental impacts in terms of energy consumption, waste generation, and smog, improving the livability of already-concentrated developments can reduce urban sprawl and enhance economic vitality. In some cities, urban planners are encouraging higher densities, in part to save surrounding land from being paved over. Reduced commuting distances and the density to justify transit save energy and reduce air pollution. "Smart growth," which emphasizes town-center, transit, and pedestrian-oriented development, provides a solution that serves the economy, the community, and the environment. Twenty-four hour cities, such as Boston, New York, San Francisco, and Toronto demonstrate the appeal of high density, mixed use developments. Protecting greenspace, reducing traffic congestion, offering more transportation choices, strengthening regional cooperation, and improving quality of life are priorities shared by most North American communities.

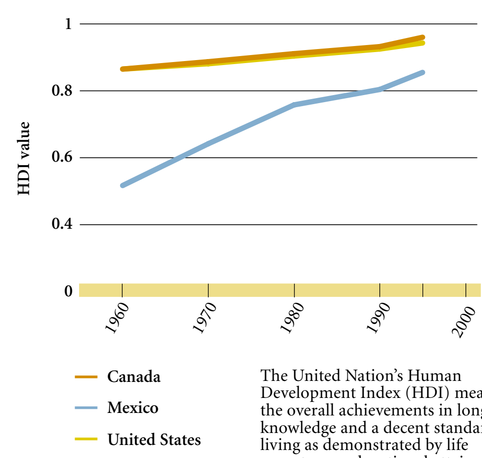
Economic differentiation based on race, sex, or ethnicity is declining in North America, but people in the lowest income quintile are still more likely to belong to racial minorities

Figure 31
Per Capita GDP in North America, by Country, 1960–95



Source: UNDP 1998.

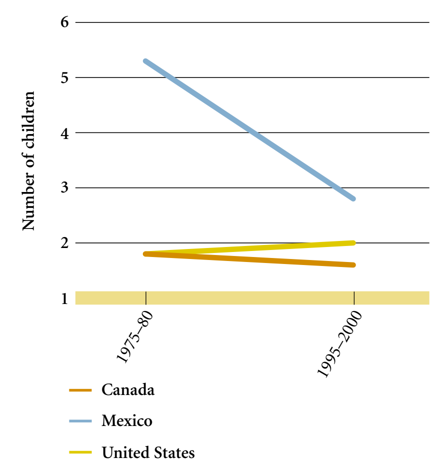
Figure 32
Human Development in North America, by Country, 1960–95



The United Nation's Human Development Index (HDI) measures the overall achievements in longevity, knowledge and a decent standard of living as demonstrated by life expectancy, educational attainment [adult literacy and combined primary, secondary and tertiary enrollment] and adjusted income.

Source: UNDP 1998.

Figure 33
Total Fertility Rate in North America, by Country, 1975–80 to 1995–2000



Source: WRI et al. 1998.

Note: The total fertility rate is an estimate of the number of children an average woman would have if current age-specific fertility rates remained constant during her reproductive years.

Box 10

Emerging Trend: Environmental Justice

North America's poor are disproportionately affected by environmental ills. Research in the United States suggests that poor working people and people of color move into industrial zones because housing is cheaper and they cannot afford better. Polluting facilities are sited near these communities because their residents are least able to resist them politically and economically (Szasz et al. 1993).

The Council on Environmental Quality found that minority and low-income neighborhoods in the United States face disproportionate environmental risks (CEQ 1996): African Americans and Hispanic-origin populations are more likely than whites to live in areas with reduced air quality. Low-income residents living in older, poorly maintained buildings are more likely to be exposed to dangerous levels of lead.

Migrant farm workers are more likely to be exposed to hazardous levels of pesticides and less likely to have access to adequate protective clothing. In some areas, Navajo land and water supplies are contaminated with uranium, which may be contributing to the high incidence of organ cancer among Navajo teenagers.

The possibility that citizens are exposed to environmental hazards in an uneven manner came to the attention of the US public through the siting of toxic waste disposal facilities. A landmark 1987 study found there were nearly twice as many minorities in communities with hazardous waste facilities as in communities without (CEQ 1996). In response, a grassroots movement grew to promote environmental justice. It strives to obtain protection under environmental laws and regulations for all people, irrespective of race, ethnicity, or socioeconomic status (Szasz 1994; University of Michigan 1997).

In 1994, President Clinton issued an executive order instructing all federal agencies to develop strategies for achieving environmental justice. The Office of Environmental Justice was created within the Environmental Protection Agency, replacing the Office of Environmental Equity established in 1992. In Canada, environmental justice has rarely been an issue, partly because visible minority populations are smaller and less concentrated than in the United States. An exception is indigenous communities, which have been concentrated on reserve lands that in some cases have experienced severe pollution problems.

The environmental justice movement in Mexico is in its infancy. In 1998 it was sparked by plans to build a nuclear waste site in south-central Texas. Under an agreement known as the Texas Compact, a nuclear waste facility was planned at Sierra Blanca to accept the wastes from Texas, Maine, and Vermont. Grassroots opposition in Texas and across the border at Ciudad Juarez in Mexico led to amendments to the Compact. They include the right of local residents to bring civil action against the Compact based on a community's composition, be it race, color, national origin, or income level (SBLDF 1998).

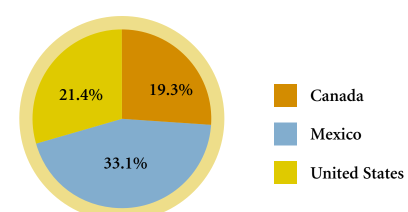
and households headed by females. Declining or stagnating real wages mean that middle-class families in North America rely increasingly on more than one income (Beveridge et al. 1997). In some spread-out metropolitan regions, families now spend a greater share of their income on transportation than on housing.

Although poverty receded and well-being increased overall in North America during the postwar period, this occurred at different rates and from very different starting points in each country. Despite continued economic growth, there is evidence that income inequality has widened in all three North American countries since the 1970s (Beveridge et al. 1997; Eisner et al.1997).

Income and social inequality combined with other pressures, undermine sustainability. People on the lowest social and economic rungs are also disproportionately influenced by environmental problems (Sachs 1996) (Box 10). In a number of aboriginal communities, notably in the Great Lakes basin and in the Arctic, wild foods form an important part of the diet and the local economy, and are a fundamental part of the culture. Some of these foods are now so contaminated by pollution that they are unsafe to eat or pose a significant health risk. Across the continent,

Figure 34

Share of Population under the Age of 15 in North America in 2000, by Country



Source: WRI et al. 1998.

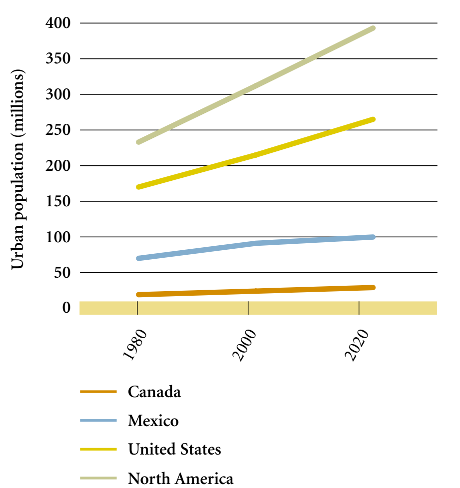
forest clearcutting, resource extraction, industrialpollution, and overfishing often take the greatest toll on low-income communities.

Furthermore, the more disadvantaged citizens are, the fewer resources they have to deal with the health consequences of the pollution or environmental disturbance to which they are exposed. Affluent people, on the other hand, have the resources to fight potentially unhealthy development projects and to protect and beautify their physical surroundings. They tend to value wilderness areas and can afford to make use of them for recreational activities.

Yet there is no doubt that affluent North Americans have a far greater impact on the global environment than poorer segments of society and than residents of other countries.

Figure 35

Growth in Urban Population in North America, by Country, 1980–2025

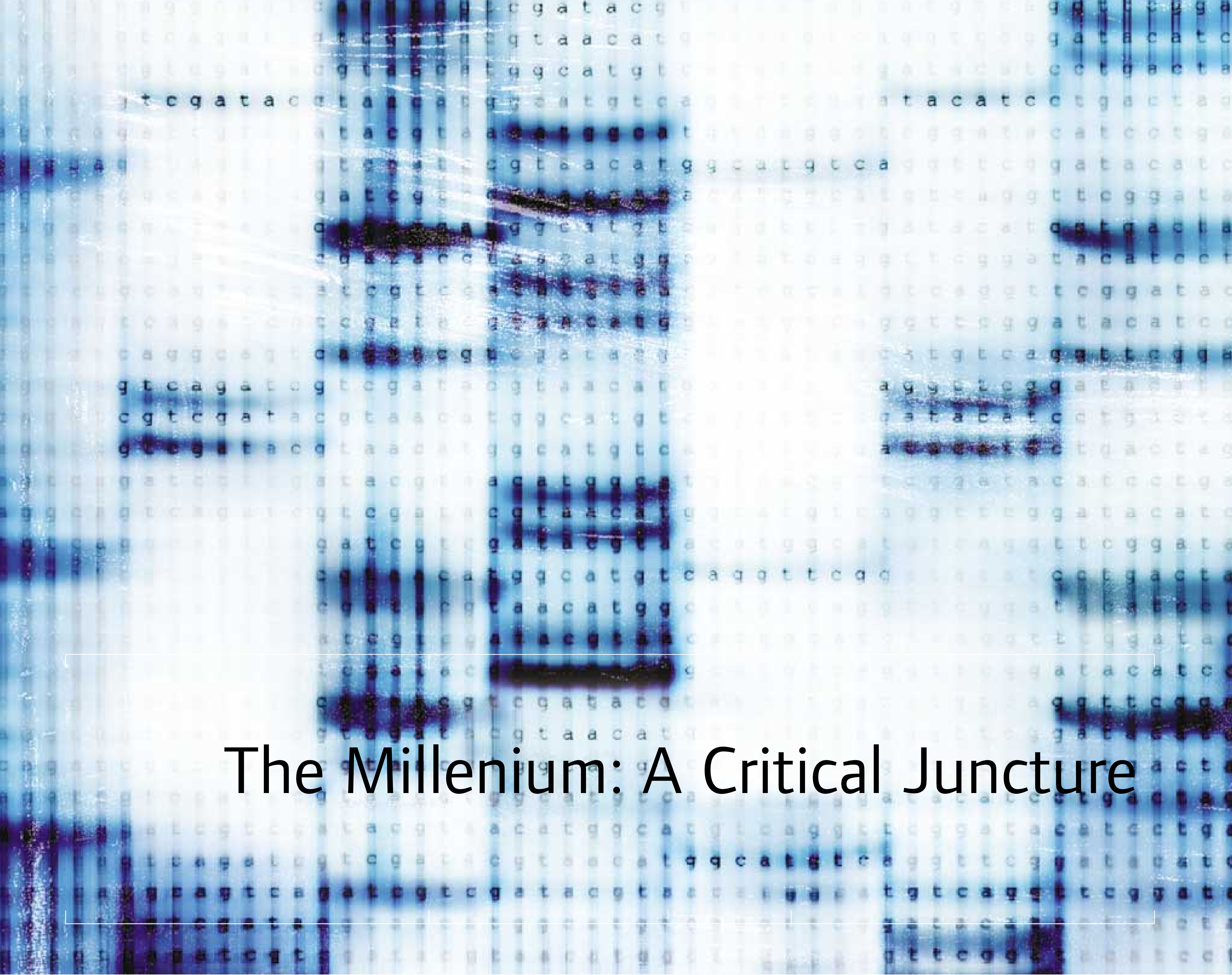


Source: WRI et al. 1998.

Note: Urban population refers to the census population of areas defined as urban in each of the countries.

Affluent Americans appropriate larger amounts of natural resources, use more energy, and generate more waste (Flavin 1997). The ecological footprint of the average US or Canadian citizen is also far larger than that of the average Mexican, as illustrated in figure 1 on page 4 (Wackernagel et al. 1997).

As humans are a dominant part of the North American ecosystem, maintaining their health and well-being while reducing their environmental impact is a very important component of maintaining ecosystem health.



The Millenium: A Critical Juncture

Humankind has reached a critical juncture at the close of the millennium. On one hand, we have evolved a pattern of development and lifestyles in which growing numbers of people consume great amounts of materials and energy, releasing large amounts of pollutants. On the other hand, we see increasing evidence of environmental limits.

Humankind has reached a critical juncture at the close of the millennium. On one hand, we have evolved a pattern of development and lifestyles in which growing numbers of people consume great amounts of materials and energy, releasing large amounts of pollutants. On the other hand, we see increasing evidence of environmental limits. We are challenged to set mutually compatible environmental and economic goals that will ensure the sustainability of nature's assets and provide fair opportunities for improving human health and welfare into the next century and beyond.

Equipped with a better understanding of the relationship between our actions and the world we inhabit, North Americans have the potential to make responsible decisions and adopt practices that are more compatible with ecologically, socially, and economically sustainable development.

The path is fraught with contradictions. Public concern is thwarted by institutional impediments. There is an increasing mismatch between ambitions and resources. Even during an era of prosperity, subregions, sectors, and population groups face economic difficulty. Social and fiscal policies have not adequately addressed the widening gulf between the haves and the have-nots. Some traditional social safety nets have broken down, and social fragmentation appears to be increasing.

Given the environmental, economic, social, and institutional trends outlined in this report, it is clear that considerable progress is required to put North America "on track" toward sustainable development. The prevailing emphasis on consumption—with high levels of energy use, waste, and greenhouse gas emissions—jeopardizes the capacity of natural resources and systems to support future generations. On both a North American and a global scale, economic activity in Canada and the United States is exerting disproportionate environmental pressure. With by far the largest population and the strongest economy of the three countries, the United States dominates the region's portrait of environmental trends. While North America's traditional emphasis on economic growth has had notable benefits, the need for a more balanced, socially equitable, and integrated approach is apparent.

When faced with clear evidence of the need to change, such as the impact of chlorofluorocarbons (CFCs) on stratospheric ozone, North Americans can be quick and efficient in remedying their problems. In the past 10 years, production of ozone-depleting substances has declined

Sustainable development ensures that the use of ecological resources and ecosystems today does not damage the prospects for their use by future generations.

Canadian Council of Resource and Environment Ministers

Sustainable development makes satisfaction of social aspirations and the needs of today compatible with the maintenance of biophysical and social balances indispensable for the particular process of present and future development.

Mexico's Environment Program 1995–2000 (INE 1999b)

A sustainable activity is one that can be continued indefinitely without harming the environmental, economic, or social bases on which it depends, and without diminishing the opportunities of future generations to enjoy resources and a quality of life at least equal to our own.

President's Council on Sustainable Development (PCSD 1996c)

dramatically due largely to commitments made under the 1989 Montreal Protocol. Progress is also being made on acid rain, the cleanup of the Great Lakes, and reductions in the use and discharge of many toxic substances.

A range of encouraging trends can be identified that may enhance the region's progress toward sustainability. They include an accelerated regional convergence of environmental policies reflecting trinational commitments to sustainable development. Sustainable forestry and agricultural practices are being adopted more widely, and there are promising developments in renewable energy.

Over the past few decades, Canada and the United States have devoted considerable political will and resources to tackling environmental problems. Government action was prompted largely by increased public awareness and expectations, and by pressure from NGOs. Scientific evidence of a decline in the health of North America's environment has been an immensely important catalyst. Responses to the most pressing problems of the past have been instituted through the establishment of environmental agencies at many different levels, and through passing laws and regulations aimed at cleaning up the damage, protecting resources, and preventing further destruction.

In response to the environmental and human health problems associated with urban developments, a number of North American cities are developing and implementing plans for sustainable long-term growth, prompted by the goals in Agenda 21, the agreement that emerged from the 1992 UN Conference on Environment and Development. Through Green Plans and sustainability initiatives, governments across the continent are starting to reverse negative trends in air and water pollution, waste generation, and the availability of green space.

In the past decade, sustainable development has become a widely accepted and continuously evolving concept, highlighting the linkages between human and economic development and the environment. The term started to enter common parlance following the 1987 report of the World Commission on Environment and Development. Our Common Future, states that sustainable development should "meet the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

Since the release of Our Common Future, government discourse has taken a noticeable shift toward the stated goal of sustainable development as a way to resolve conflicts between the environment and the economy. Yet relatively few concrete strategies exist to achieve sustainable development.

One encouraging sign is that many businesses have begun to reorient themselves toward more sustainable forms of development, convinced that the move makes good business sense. Some are redefining their mission to focus on providing a service rather than a product. This typically entails a longer-term, more holistic approach to the marketplace. Many companies have committed to eliminating virtually all waste as a means to increase profits, reduce potential liabilities, and protect the environment.

Applying sustainable development goals, both nationally and internationally, has profound implications for economic systems and national economic accounting. If assets—capital goods and natural resources—are consumed faster than they are replenished, the continued well-being of future generations cannot be guaranteed. Devising better methods to monitor these changes, and establishing maximum acceptable thresholds of activity, poses an enormous challenge.

Achieving a more equitable distribution of wealth among generations, regions, and societies, and opening up opportunities for social mobility, participation, and empowerment will also be a challenge.

A major transformation is called for to shift the "model of progress from ever-increasing growth in consumption, to a culture of material sufficiency and the growth of quality values" (Raskin et al. 1996).

We can expect that coping with a number of these challenges will be made even more difficult by the course of global warming over the next several generations. Our success—or lack of it—in addressing that looming threat will have much to do with our ability to ensure adequate supplies of freshwater for all areas, maintain productive cropland, forestry, and fishery resources, protect vulnerable wild species, improve the economic status of disadvantaged citizens of the three countries, and encourage sustainable development of our current, rich resource base. Absent a consensus on how to address this problem, it is hard to be optimistic about our chances.

How we respond to these challenges will determine North America's success in moving toward a more sustainable future. The transition will not be easy. It will require adapting policies, institutions, technologies, and lifestyles. It will mean altering deep and enduring attitudes, values, and behaviors that underlie our economic and social systems. Economic development and lifestyle choices that impose unacceptable burdens on the environment will have to be discouraged, and incentives offered to make more sustainable choices.

North America is often looked to as a model for prosperity and progress. We can become a model of environmental stewardship and social equity.

Our global future depends upon sustainable development. It depends upon our willingness and ability to dedicate our intelligence, ingenuity, and adaptability—and our energy—to our common future. This is a choice we can make.

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<http://www.rds.org.mx/>

Earth Council
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Environment Canada
<http://www.ec.gc.ca/>

Food and Agriculture Organization of the United Nations
<http://www.fao.org/>

Forest Service, US Department of Agriculture
<http://www.fs.fed.us/>

Instituto Nacional de Ecología, Semarnap
<http://www.ine.gob.mx>

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International Boundary and Water Commission
<http://www.ibwc.state.gov>

International Institute for Sustainable Development
<http://iisd.ca>

International Joint Commission
<http://www.ijc.org/ijcweb-e.html>

IUCN: The World Conservation Union
<http://www.iucn.org/>

National Park Service, US Department of the Interior
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National Round Table on the Environment and the Economy
<http://www.nrtee-trnee.ca>

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Organisation for Economic Cooperation and Development
<http://www.oecd.org/>

President's Council for Sustainable Development (United States)
<http://www.whitehouse.gov/PCSD/index.html>

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