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Trends in Canada's Natural Capital

Rose Anne Devlin
University of Ottawa

Quentin Grafton
University of Ottawa

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Trends in Canada's Natural Capital

1. Introduction

Historically, the well-being of a country has been measured in terms of the value of goods and services produced within its borders - largely ignoring environmental factors and natural resource wealth. To improve this situation, governments - and ours is no exception - have been actively engaged in trying to establish a system of "green" accounts which take stock of a country's natural wealth and how it changes over time. Norway was the first to introduce physical measures of the stock of natural resources in the national accounts and Canada has followed suit since 1986. Satellite accounts of the natural capital may also include valuations of resources and the environment as well as trace changes in the stocks of forests, minerals and agricultural land. Alternative measures of economic activity can also be derived which incorporate changes in natural capital by deducting expenditures made to reduce welfare effects of resource depletion and environmental degradation.

On the path towards a comprehensive evaluation of wealth, Canada identified and developed environmental "indicators" that assess how we are progressing (or regressing) over time. Since this process began a decade ago, statistics on some 17 key indicators in four key areas are currently available.[1] This list will grow over time. Because of the increased awareness of the importance of environment and resources to well being, a staggering quantity of data is now available on a large number of indicators.

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[1] The four areas (and indicators therein) are: Ecological Life Support Systems (stratospheric ozone depletion, climate change, toxic contaminants in the environment, acid rain, biodiversity change and marine ecosystems); Human Health and Well-Being (urban air quality, urban water, freshwater quality, urban green space); Natural Resources Sustainability (forests, marine resources and agricultural resources); and Pervasive Influencing Factors (passenger transportation, energy consumption, population grown and lifestyle patterns, and solid and hazardous waste generation).

However, while the current situation represents a vast improvement over previous years in terms of the availability of information, it remains difficult to sift through the deluge of figures to try to paint a portrait of the Canadian situation.

One of the main focuses of this paper is to try to present a clearer picture of the state and evolution of Canada's natural capital. Natural capital here is defined broadly in terms of environmental amenities and natural resources. The paper will thus add to the small body of literature that attempts to do just this, including a recent *Fraser Institute* (1997) document that examines various indicators in Canada and the U.S., and a *World Bank* (1997) document that takes account of the stock of natural resources in countries world wide.

The data used in this study come primarily from Statistics Canada's *Econnections* data base, CANSIM, and Environment Canada's *National Environmental Indicator Series.* The paper provides an overview of the available data articulated around three main themes: Natural resources; environmental degradation of air, water and land; and policy responses over time.

2. Natural Resources

Canada is one of the wealthiest in the world. And, once account is taken of our natural resources, the wealth of Canada becomes increasingly apparent. Indeed, in a recent World Bank study, Canada ranked **third** of 93 countries in terms of an estimated per capita value of "natural capital" (World Bank, 1997, p.34). To obtain these figures, this document employs a necessarily crude measure of what constitutes "nature capital" and how it is valued.[2] The problems associated with valuing a country's stock

[2] Natural capital, according to World Bank (1997, p.34) is measured as a sum of cropland, pastureland, timber resources, non-timber forest resources, protected areas and subsoil assets.

of natural resources are well documented. Heroic assumptions must necessarily be made in order to come up with figures that may be compared across countries. Rather than focusing on the validity of these assumptions - which is the subject of much debate and research - here we simply note that, in cross country comparisons, Canada is one of the wealthiest nations on earth.

Is our natural wealth growing or diminishing over time? One way to answer this question is to look at how the stocks of the various components of our natural resources have evolved. As straightforward as this may sound, it is actually rather complicated to determine what is the stock of natural resources. Aside from the obvious problems associated with determining how much of various minerals are under the ground (and here we speak only of those finds we know), it is extremely difficult to measure even those resources that are physically visible - like forests.

2.1 Forests

Looking at graph 1 we see that the total quantity of timber assets by province, measured in thousand cubic meters, has been slowly declining over time. For instance, in 1961 BC had 6195 million cubic meters of timber whereas this figure falls by 12% to 5432 by 1990. The story for Canada as a whole is very similar, as seen in graph 2. The value of timber stocks has fluctuated rather significantly since the late 1970s, as shown in graph 3. To put these numbers in context, note that in 1992 about 930,000 hectares were harvested, which represented about 0.8% of the managed forest area and about 0.4% of

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Canada, not surprisingly, is particularly rich in subsoil assets. Notice that this definition falls short of the definition to which we subscribe insofar as we include environmental amenities as part of a nation's natural capital.

Canada's total timber forest.[3] Of this figure about 90% of the area harvested each year represents forests that had not previously been commercially cut.

The quantity of timber harvested is affected by several factors - the amount of wood harvested, the age of the forest, the rate of forest regeneration, forest fires and disease. Different forests are affected differently by each of these factors. Typically, harvesting has replaced fire as the major cause of the decline in timber stocks, partly because of better fire management techniques.[4] Despite the upward trend in the annual volume of wood harvested from 1950 to 1992 - as shown in graph 4 - the total volume is also likely to decline in the next 10 years due to the falldown effect. This effect, more severe in British Columbia than other provinces, refers to the decline in timber supply associated with the transition from harvesting a mature and previously uncut forest to the sustainable harvesting of a rotational forest. In British Columbia, the falldown effect is expected to result in at least a 20 percent decline in the volume of timber harvested over the next few decades from its current level of 71.6 million to around 50-60 million cubic metres.[5]

2.2 Fisheries

Canada's fisheries encompass a vast area of water and include a range of species often grouped into four main categories. Groundfish species (such as cod and halibut) are caught near the ocean floor and have traditionally provided the greatest quantity of fish by weight, pelagic species (such as herring and capelin) are caught near the surface oftenat times often when the fish congregate to spawn, invertebrates

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[3] See Environment Canada (http://199.212.18.79/~ind/English/Forest/Bulletin/foind1_e.htm).

[4] See Environment Canada (http://199.212.18.79/~ind/English/Forest/Bulletin/foind1_e.htm).

[5] See British Columbia Ministry of Forests (http://www.for.gov.bc.ca).

(including crustaceans such as shrimp, crab, and lobster and shellfish) are caught in a variety of ways and often provide the highest value per weight of fish, and anadromous species (such as salmon) are caught both at sea and in rivers and are very important in terms of aboriginal and recreational fishing.

Given the immense variation in the habitats and life-cycles of the many different fish species, generalizations about the overall state of Canada's fish stocks are not possible. Nevertheless, within the different categories of species some noticeable trends are discernible over time. The most important change in the status of fish stocks in the past 25 years has been the collapse of the groundfish fisheries of Atlantic Canada. Many groundfish stocks have been affected and the most important stock has been the northen cod fishery located in the Northwest Atlantic Fishery Organization (NAFO) areas 2J3KL. The exploitable biomass, defined as the total weight of all fish which potentially may be caught, was at its highest level in 1962 at almost 3 million tons - graph 5. Due mainly to foreign exploitation the stocks fell to an estimated 526,000 tons by 1977. Following extended Canadian fisheries jurisdiction which began in 1977, the stock slowly recovered to over 1 million tons by 1984. However, despite a fishing moratorium which has been place since July 1992, the exploitable biomass has collapsed and was estimated to be as little as 21,000 tons in 1997 (Department of Fisheries and Oceans, 1998). The overall downward trend is repeated for other groundfish species in Atlantic Canada, although for most species the collapse has not been as dramatic as in the northern cod fishery. The net effect has been an almost 80 percent reduction in the total Atlantic catch of all groundfish from over 520,000 tons in 1972 to just over 110,000 tons in 1996[6]- graph 6

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[6] See Department of Fisheries and Oceans catch statistics at www.dfo-mpo.gc.ca/communic/statistics/landings.

A considerable fluctuation in abundance and catches is characteristic of pelagic species. In the Pacific, the Strait of Georgia herring fishery experienced a collapse in 1967 which led to a four year harvesting moratorium. Despite very significant fluctuations in the stock, the pre-fishery biomass which was estimated at 82,000 tons in 1998, is at one of its highest levels in three decades. By contrast, Canada's largest pelagic fishery - the Scotia-Fundy herring fishery - has experienced a decline in abundance in the 1990s. Landings of herring in Scotia-Fundy have fallen to 100,000 tons in 1997 from an average yearly harvest of 188,000 and 156,000 in the 1970s and 1980s. As a result, the total Canadian catch of pelagic species has fallen from around 460,000 tons in 1972 to some 320,000 tons in 1996.

Catches of invertebrates, in contrast to groundfish and pelagic species, have increased almost four fold in the past 25 years. The biggest increases have been in terms of crustaceans such as shrimp, crab and lobster. Despite the increases, evidence exists that some stocks may be in decline, including the important Atlantic lobster fishery.[7]

Anadromous species, such as salmon, are subject to very large fluctuations in catch from season to season. Thus overall trends in abundance are difficult to separate from annual fluctuations. Nevertheless, the stock of Atlantic salmon appears to have oscillated around a declining trend since the 1970s and some abundance measures have reached their lowest levels ever in the 1990s.[8] On the Pacific coast, five species of salmon (not including steelhead and cuthroat trout) are caught. In recent years, a dramatic decline in abundance of coho has been observed which has led to special conservation strategies to protect the species. The most important stock, in terms of catches, is the Fraser River sockeye which experienced

[7] Department of Fisheries and Oceans Stock Status Report C3-58 (1998).

[8] Department of Fisheries and Oceans Atlantic Salmon Abundance Overview for 1997.

large drops in catches in 1995 and 1996, and again in 1999.

Overall, several important fish stocks have declined over the past 25 years despite extended fisheries jurisdiction since 1977. Some of the declines are due to environmental factors but, at least in the case of many of Atlantic Canada's groundfish species, overharvesting has contributed to the decline in stocks.

2.3 Minerals

Canada is rich in several minerals, metals and ores - including coal, iron, potash, silver, uranium, crude oil and natural gas. For the sake of brevity, we concentrate on crude oil and natural gas and graph 7 shows the evolution in the stock of crude oil from 1961 to 1995. During the decade of the sixties, the known reserves steadily increased, whereas since 1970 they have been more or less on the decline. Further information can be obtained from looking at the *value* of crude oil reserves in Canada which takes account of the price of oil on the world market. From graph 8, we see that the value of oil reserves increased steadily and quite dramatically throughout the 1970s and early part of the 1980s - a period of rising or relatively high world oil prices. Since then, until 1995, the value of these reserves has fallen considerably; indeed, the value of reserves in 1995 is lower than it was in 1971 in real dollars.

The magnitude of natural gas reserves in Canada grew steadilyfrom 1961 to 1982, at which point they began to fall and have gradually declined until the end of our data in 1995, as shown in graph 9. Nevertheless, in 1995, the known reserves of natural gas were 67% higher than they were in 1961. By contrast, te value of the natural gas stock displays quite a different pattern over time, as seen in graph 10. Over the first half of the time period, from 1971 to 1983, its value was increasing; since then, it has generally declined. Once again, the importance of price in determining the value of natural resource stocks is underscored.

2.4 Wildlife and Biodiversity

One measure of the wealth of a country is the richness and diversity of its plant and animal life. Trying to determine biodiversity is an extremely complicated process - which certainly cannot be dealt with adequately in this current review. Nevertheless, because of its importance as a component of natural capital, we would be remiss to ignore this topic altogether.

We examine a couple of problem areas associated with determining the "stock" of wildlife and extent of biodiversity in Canada. To begin, it is useful to note that Canada is comprised of five distinct marine ecozones - Pacific, Arctic archipelago, Arctic basin, Northwest Atlantic, and Atlantic - and some 15 terrestrial ecozones.[9] Each ecozone has its own particular characteristics and its own ability to cope with environmental challenges. Table 1 presents a summary of the biophysical characteristics of these zones. Clearly, each area differs quite substantially in its plant and animal life. In some zones, like those in the arctic, seemingly small changes in environmental conditions may have a catastrophic impact on life within their borders. Other zones, especially in the south, can withstand much greater environmental changes.

Most of the Canadian population - 51% -lives in the Great-Lakes-St.Lawrence region which is the mixed wood plains ecozone. This zone comprises, however, only 2% of the total area of Canada. Table 2 provides a useful summary of the environmental and socioeconomic characteristics of our fifteen terrestrial

[9] Arctic Cordillera, Northern Arctic, Southern Arctic, Taiga Plains, Taiga Sheild, Taiga Cordillera, Hudson Plains, Boreal Plains, Boreal Shield, Boreal Cordillera, Pacific Maritime, Montane Cordillera, Prairies, Atlantic Maritime, and Mixedwood Plains.

ecozones.

Very little information is available over time concerning wildlife and biodiversity. Most of the available information is of a qualitative nature rather than quantitative. One exception is with respect to birds. Table 3 shows the percentage change in the population of breeding birds over the period 1966 to 1994. Overall, a small decrease in the number of such birds is observed - however, this result depends upon the terrestrial ecozone in question.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has compiled several lists of endangered species. In 1995, about 200 species were either endangered or threatened in Canada. Unfortunately, it is extremely difficult to get a consistent time series of consistent data reflecting endangered species in Canada. According to an official at COSEWIC, the lists of species that are endangered reflect largely the time and resources available to the team constructing the lists rather than the actual situation, *per se*. Budget and time pressures mean that accurate accounting is simply not available for our wild and plant life in Canada.

2.5 Remarks on our stock of Natural Resources

Canada is rich in natural resources. However, some resource sectors have experienced more difficulty than others. Part of this difficulty may be linked to property rights, the absence of which often leads to an overuse of the resource. For those resources where property rights have been well-established - like minerals, potash and ores - their extraction is relatively well-managed.[10] In others, like fisheries and forestry, serious problems have arisen with overuse.

[10] Although problems still exist in these resources, see Anderson (1991) especially chapter 8.

Canada's renewable resources have not been as well managed as its nonrenewable stocks. In particular, fishery resources have suffered from policies which have encouraged and even subsidized fishing leading, in some cases, to significant declines in important fish stocks. In the past three decades, hundreds of millions of dollars have been spent on federal deficiency payments and various subsidies to fishers (Crowley *et al.* 1993). Moreover, unemployment insurance benefits for self-employed fishers in Atlantic Canada in 1990 were on average over 80 per cent of the income they received from fishing - a level of support which has encouraged people to enter and remain in the industry. Policies which limit reduction in the total harvest, following a decline in the stock, have also been applied so as to avoid dislocations for people involved in the fishery.[11] Such approaches have contributed to the over exploitation of some groundfish stocks in Atlantic Canada. In fisheries where managers and fishers have set up systems to co-manage the resources, often with individual output controls, fisheries management has been much more successful.

In forest management, crown ownership of the lands means that appropriate prices have to be established for those who use the forests. Unfortunately, much conflict exists between those who harvest the trees for commercial use and those who would like to preserve them for future generations. Such conflicts have been most noticeable in British Columbia and have led to a major shift in forest policy and timber practices over the past decade. In addition, changes have occurred in the stumpage system---the amount charged harvesters for cutting trees on Crown Land. Until 1987, stumpage was calculated as a residual equal to the market value of timber (accounting for costs of delivery) less operating costs and an

[11] A useful discussion of policy instruments in the fisheries in contained in Anderson (1991, Ch.7).

allowance for risk. Such a system led to “highgrading” whereby firms harvest only those trees that provide a net return equal to or in excess of the stumpage, leaving (often damaged) trees behind. The new BC stumpage system avoids this problem but, in recent years, may have collected more rent than actually exists in the industry (Grafton *et al.* 1998).

In recent years, provincial governments (which own about 88 percent of commercial forest land in Canada) have begun to improve their tenure arrangements with timber companies. For example, Ontario’s *Crown Forest Sustainability Act* of 1995 has led to the use of sustainable forest licences which have a duration of 20 years. Increased security and length of tenure should, in turn, improve forest and management practices of licence holders. Similar tenure arrangements have also been introduced into British Columbia although harvesters are obliged to follow a sustained harvest level, called the annual allowable cut (AAC).

Because of marked differences in the stock of different natural resources, it is difficult ot summarize our current situation relative to earlier decades. Even our known non-renewable resources are not necessarily depleting as we become aware of new finds. Overall, the biggest problems seem to have arisen in our renewable resources, notably the fisheries and forestry sector.

3. Environmental Degradation

The topic of environmental degradation - pollution in short - is so multi-faceted as to render very difficult its treatment in a concise manner. We simply cannot do justice to every component of the problem in the space we have available. To frame our discussion, it may be useful to refer to the categorization used by Environment Canada in its National Environmental Indicator Series namely: stratospheric ozone depletion; toxic contaminants; acid rain; climate change; and urban air quality.

3.1 Stratospheric ozone depletion

The stratospheric ozone layer protects the earth from the sun's harmful ultraviolet (UV) radiation. UV-B intensities have been increasing on the earth's surface - growing some 10% over the decade 1986 to 1996.[12] Exposure to this radiation is linked to skin cancer, cataracts in humans, depression of the immunization system and is potentially linked to disruptions in crop yields and marine life. Several human-produced ozone-depleting substances have been identified as having an impact on the thickness of the ozone layer, namely: chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide and hydrochlorofluorocarbons (HCFCs).

As a result of increased awareness of the importance of the ozone layer, the Vienna Convention in March 1985 set up a group to develop a protocol for the use of ozone-harming substances. The Montreal Protocol arose from this initiative and was adopted in September 1987. So far, some 162 countries - including Canada - have ratified the protocol and have begun to introduce measures to phase out the production and use of these substances.

Several problems are associated with pollutants like CFCs that result in a global externality. Clearly, international cooperation is essential in order to improve the situation. As long as some countries still permit the production of these products, international markets will flourish. For instance, a thriving

[12] See Environment Canada (http://199.212.18.79/~ind/English/Ozone/Bulletin/st_iss_e.htm).

black market in CFCs is now in operation into the United States for precisely this reason[13]. In Canada, criminal suits are now being successfully prosecuted for illegal trade in ozone-depleting substances.[14]

As a direct result of policy initiatives, new production of ozone-depleting substances has dropped substantially in Canada since 1987, as shown in graph 11. Note, too, that the fall in production of these substances is not the result of a fall in economic activity over the same period - as reflected in real Gross Domestic Product (GDP). Globally, the trend in the production of CFCs displays a similar drop since the late 1980s, as shown in graph 12. While global production is falling for certain substances, however, the stock of ozone-depleting chemicals continues to rise. As a consequence, global concentrations of the most abundant ozone-harming substances - CFC-11 and CFC-12 - have been increasing since measurements began in 1977 - although they appear to have leveled off somewhat in the early 1990s. By 1997, the stratospheric ozone level above Canada had improved since its worst measurement in 1993 but remains about 10% thinner than it was in 1980. Graph 13 shows the ozone levels above the City of Toronto from 1960 to 1995.

3.2 Toxic Contaminants

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[13] According to officials in Miami "CFCs are the port's second most profitable contraband after drugs" (*The Economist*, 9 December 1995, p.63).

[14] For instance, in a well-publicized case, a Fredericton automobile dealership was charged in May 1997 of ten counts of exporting CFCs without valid permits. The owner was also charged in the United States of illegally importing this substance. (CFCs are used in automobile air-conditioning units.) Several prosecutions have resulted in fines: for instance, in Ontario, Amcast Industrial Limited was fined $25,000 for selling a cleaning product that contained CFC 113 an ozone depleting substance, another company (Hi-line Manufacturing) was fined $100,000 for importing and selling CFCs. For further details see: www2.ec.gc.ca/enforce
/prosec/english/city_p_e.htm.

According to Environment Canada[15] more than 35,000 commercial chemicals are reported in use in Canada today. One group of substances that is associated with harmful effects on animals and humans are known as *persistent organochlorines* (POs). Organochlorines include the insecticide DDT, polychlorinated biphenyls (PCBs), and polychlorinated dioxins and furans. These substances are called "persistent" because they take a long time - sometimes centuries - to break down naturally. They thus tend to accumulate in the tissues of some animals - which may result in very high concentrations of POs in the top predators of the food chain. Two other groups of substances of concern to wildlife are heavy metals (lead, mercury and cadmium) and organophosphate and some pesticides.

One way to measure the extent of contamination - and the extent to which human health may be affected - is through wildlife. For instance, because of its broad distribution across southern Canada, where the Canadian population is most dense, and because it eats live fish, the double-crested cormorant is used to measure organochlorine levels (from DDT, PCBs, and some dioxins and furans).

An examination of double-crested cormorant eggs in four key regions in Canada[16] show that concentrations of DDE (the main breakdown product from DDT) have dropped significantly since DDT was banned in the early 1970s. Concentrations of PCBs have also fallen over the same period. However, some year to year variation in the measurement of both of these substances has occurred during the 1990s which suggests that Canada is still adversely affected by DDT and PCBs, possibly because of their use elsewhere or from the slow release of stored contaminants over time. Measurements of dioxins and furans

[15] See Environment Canada (http://199.212.18.79/~ind/English/Toxic/Bulletin/tx_iss_e.htm).

[16] These regions are the Strait of Georgia (British Columbia), Great Lakes (Ontario), St. Lawrence Estuary (Québec), and the Bay of Fundy (New Brunswick).

in these birds display a similar pattern.

Further evidence of the pervasiveness of POs in our environment can be obtained from human breast-milk samples. Periodic sampling has been reported from 1975 to 1992 with some relatively encouraging results. Graph 14 shows the parts per mililitre of PCBs in human breast milk for Canada, Ontario and Quebec. A significant drop was experienced over the decade 1975 to 1985 - not surprisingly given the controls that were put into effect over this period. Somewhat troubling, however, is the small increase in this measurement from 1985 to 1992. Like in the cormorant eggs case, this may be due to the use of POs in other countries and which may be contaminating our food chain or because of seepages from stored contaminants.

From graph 15 we can see that the level of DDT in human breast milk has fallen dramatically since the data became available in 1967. The ban on DDT in Canada is, no doubt, responsible for this massive decline. It is interesting to note, nevertheless, that small amounts of DDT were still discernible in human breast milk in 1992 - some twenty years since the substance was banned.[17] As a telling aside, the US Food and Drug Administration conducted tests on typical bundles of foods in 1995 and found that 25% of them contained DDT!

3.3 Acid Rain

[17] In spite of the international ban of DDT, several countries still use this pesticide - largely because it is effective and easy to make. India, for instance, as recently as 1997, still had not banned this substance. Furthermore, without enforcing the ban, many countries to continue to have problems with DDT. In 1995 in Bangledesh, where the substance is banned, large quantities of DDT were found in dried fish (some 100 times the allowed level when it was permitted). It was apparently put in the dried fish on purpose to help preserve them. In poor countries where food is scarce for large portions of the population, future well-being is often highly discounted in favour of present subsistence.

Acid rain refers to precipitation that is acidified by atmospheric pollutants. The principal culprits are sulphur dioxide (SO_2) and nitrogen oxides (No_x) which convert to sulphuric acid and nitric acid in the atmosphere. Although these substances occur naturally, over 90% of emissions are from human activity.[18] Acid rain was first considered a problem in Canada when fish populations were first discovered to be missing in acidified lakes in Northern Ontario.

The largest sources of SO_2 are in the smelting and refining of certain ores and in the burning of fossil fuels. No_x occur during the combustion of fossil fuels in vehicles, industrial processing, power generation and other activities. For geological reasons, much of Canada is unable to neutralize acid deposits adequately, which renders acid rain a particularly serious problem. Some of the consequences of acid rain and SO_2 and NO_x emissions include the destruction of trees and aquatic life, the deterioration of buildings, and respiratory problems in humans. Several policy responses have emerged to deal with the problem, including participating in numerous international accords designed to reduce the amount of SO_2 and NO_x emissions.[19]

Data from 1985 to 1993 reveal that SO_2 emissions in Canada have remained fairly constant; over the same period, the US experienced a small decline in emissions - see graph 16. In Eastern Canada,

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[18] See Environment Canada (http://199.212.18.79/~ind/English/AcidRain/Bulletin/ar_iss_e.htm).

[19] For instance, in 1979 Canada signed the United Nations Economic Commission for Europe Convention (UN ECE) on Long-Range Transboundary Air Pollution; in 1985 Canada signed the Helsinki Protocol agreeing to reduce national annual SO_2 emissions by at least 30% below 1980 levels by 1993; in 1988 Canada signed the UN ECE Sofia Protocol to limit NO_x emissions to 1987 levels by 1994 and in 1994 Canada signed the UN ECE Oslo Protocol which caps SO_2 in eastern Canada. For more details see: http://199.212.18.79/-ind/english/acidrain/bulletin/ar_iss_e.htm.

which generates the most SO_2[20], the trend is more encouraging; as depicted in graph 17, SO_2 emissions have decreased steadily since 1988 with the biggest drop registering in 1994, the most recent year for which data are available. The fact that Eastern Canada is emitting less SO_2 and the national trend is constant implies, however, that elsewhere emissions are on the rise. Data on Canada's NO_x emissions are less available. Measures for the three years 1980, 1985 and 1990 indicate that these emissions are fairly constant.

Overall, the emissions of SO_2 and NO_x have not changed significantly on a national basis since 1980. However, one can track the impact of the improvements in SO_2 emissions in Eastern Canada by looking at the acidity levels in lakes. 202 lakes in Ontario, Quebec and Atlantic Canada were monitored by Environment Canada from 1981 to 1994 of which 33% showed some improvement, 56% had stable levels of acid and 11% were deteriorating. These percentages, however, do not reveal the regional distribution of lake acidity. For instance, improvements were mostly observed in Sudbury, Ontario where stringent controls on SO_2 emissions from nickel smelters have been in place. Most of the lakes elsewhere showed little improvement - which has been attributed to transboundary emissions from the United States.[21]

3.4 Climate Change

Currently, high priority is being given by the government of Canada to the issue of climate change or "global warming". While high on the current affairs agenda, considerable disagreement exists regarding whether climate change is actually occurring and its impact on different regions of the world.

[20] The largest source of SO_2 emissions in Canada is smelting which accounts for 50% of Eastern Canada's SO_2 emissions.

[21] Environment Canada, http://199.212.18.79/~ind/English/AcidRain/Bulletin/arind4_e.htm).

Greenhouse gases (GHGs), which include carbon dioxide, methane, nitrous oxide, ozone, water vapour and CFCs, can accumulate in the atmosphere and help trap heat radiation coming form the earth's surface keeping it warmer than it would otherwise be. Without such gases the earth's average surface temperature would be about -6 degrees celsius instead of its current level of 15 degrees (Houghton, 1997). However, over the past two centuries concentrations of carbon dioxide, methane and nitrous oxide have increased significantly in the atmosphere - leading to, what is called the "enhanced" or human-induced greenhouse effect. The concern is that an enhanced greenhouse effect which will raise the average surface temperature and increase climate variability.

The most important GHG contributor to the enhanced greenhouse effect is carbon dioxide which accounts for as much as 60 percent of the increased radiative forcing. Given that emissions of GHGs have the same affect on temperature change no matter where they are emitted, addressing concerns of climate change is a world-wide issue requiring international cooperation. The Montreal Protocol of 1987 for CFCs, the 1992 Framework Convention on Climate Change and the 1997 Kyoto Protocol all set emission standards for signatory countries for greenhouse gas emissions. In the case of Canada, the Kyoto Protocol requires that by the period 2008-2012 quantified emissions must be 6 percent less than 1990 levels, and demonstrable progress towards this goal should be achieved by 2005.

Emissions of CO_2 have more or less risen steadily worldwide over the past several decades, as illustrated in graph 18. The recessions of 1982 and 1992 resulted in an almost imperceptible decrease of emissions for a couple of years - but not enough to dampen the clear upward trend. In Canada, this trend is different: emissions were clearly on the rise until the early 1970s when they reached a plateau, from this time emissions have fallen slightly then risen again - with 1995 levels being about 9% higher than those of

1990 (which is the base year for the Kyoto Protocol) - see graph 19.

As a result of the increased CO_2 emissions globally, global atmospheric concentrations of this substance have increased by some 4% from 1987 to 1996. Methane has increased by the same percentage over the same time period. In terms of average temperatures, the average global temperature has increased by about 0.5ºC since 1866. In Canada, the average temperature has risen about 0.4ºC since 1948. It should be noted, however, that scientists disagree about what exactly the "normal" temperature should be and how to take account of the regular cyclical variations in temperature that are normally observed. Nevertheless, in Canada not only has our "average" temperature changed but regional variations in average temperatures have occurred - with Western and Northern Canada attaining "higher" temperatures on average and the Great-Lakes-St.Lawrence area and Atlantic Canada experiencing lower temperatures on average.

3.5 Urban Air Quality

Several factors contribute to the deterioration of urban air quality. Air pollution is caused by burning fossil fuels, e.g., driving vehicles or fueling industrial plants, and various economic activities. The most common substances that pollute the air include No_x, carbon monoxide (CO), SO_2, particulate matter and volatile organic compounds (VOCs) which are found in solvents, oil-based paints and gasoline. Much of the Quebec-Windsor corridor and the Maritimes import poor air quality from their neighbour in the south. Frequently, airborne particles and ground-level ozone combine together, especially in summer, to produce smog.

The health effects of poor air are evident. Hospital admissions for respiratory problems, for instance, clearly rise with the amount of ground-level ozone. Materials like rubber, paint and plastic are affected also by the quality of air - leading to the deterioration of external structures and other problems.

Since the 1970s, when the problems associated with poor urban air became acute, much improvement has occurred. Several government policies have been enacted to deal with this issue. For instance, the Smog Management Plan introduced in 1990 has resulted in the introduction of catalytic converters in cars, cleaner gasoline and better industrial processes. Furthermore, urban centres report regularly on the quality of air in the region, providing advisories whenever conditions are below some benchmark. The National Ambient Air Quality Objectives (NAAQOs), which determine the "acceptable" level of the different air pollutants, are provided in table 4.

Graph 20 presents indicators of the five most common air pollutants from 1979 to 1993. In particular, this graph shows the percentage by which the pollutant exceeds its acceptable level, as defined by the NAAQOs[22]. A few points are worthy of note. To begin, a slight downward trend is discernible for three of these substances - SO_2, No_x and CO. Airborne particulates fell quite dramatically during the first half of the 1980s after which they have experienced some volatility - but the trend has been mostly downwards. By contrast, ground-level ozone measures have been exceeding the standard by an increasing rate, with only a few exceptions, throughout this period. Finally, it is worth noting that all five measures continue to exceed the national acceptable standard in spite of the plethora of government policies in this area.

Sometimes, looking at data on a national basis is not very informative given Canada's vast size. For instance, graph 21 presents the number of hours in which ground-level ozone measures exceeded the

[22] Average measures are calculated from various stations across Canada. See Environment Canada at http://199.212.18.79/~ind/English/Urb_Air/Tech_Sup/uasup2_e.htm for details.

acceptable standard for Canada as a whole. Here we can see that quite a bit of volatility is displayed in this figure from year to year, although in general the measurements in the 1990s are lower than those obtained in previous decades. If we decompose this national figure into four main regions - Windsor-Quebec City corridor, Prairies, Atlantic Canada and Lower British Columbia Mainland (graphs 22-25) - we can observe considerable interregional variation. The Prairies and Lower Mainland have experienced the cleanest air during the early 1990s. Interestingly, measurements in British Columbia were the highest of all regions in 1979 - but experienced a decline to the NAAQO by 1994. It is interesting to note that each region had at least one year of extraordinarily high ground-level ozone - but that this year differs from region to region. Overall, however, cities in Southern Ontario experienced the worst air quality.

Data on the number of days each year in which the measure of airborne particles exceeds the national standard are presented in graph 26. Again, the number of such days is considerably lower during the 1990s than during 1979 and the early 1980s. Airborne particles, as depicted in this graph, are those with a diameter at least 100 milimetres in size. In recent years, attention has been moving towards much finer particles with diametres of a millionth of a metre, and which may be the cause of much of the observed respiratory problems in humans. Because standards are yet to be created for these particulates, an indicator does not presently exist, but is expected in the near future.

4. Explaining Trends in Natural Capital

Several researchers have attempted to examine empirically the relationship between environmental degradation and human activity.[23] Typically, some measure of environmental degradation (like CO_2) is regressed on a number of variables that measure human activity - like per capita GDP, affluence, or per capita consumption. Cross-country studies seem to suggest a link between wealth or growth and environmental degradation.[24] In particular, researchers have found some evidence of a so-called 'Environmental Kuznet's Curve' (EKC) - fashioned after the result made famous by Kuznets that there appeared to be an inverted "U"-shaped relationship between economic inequality and economic growth (Kuznets 1955).

The EKC posits an inverted U-shaped relationship between environmental degradation and wealth or economic growth. Poor countries as they become richer tend to experience an increase in environmental degradation; whereas, once past a certain point, their environment improves. Thus, the EKC literature suggests that there is a threshold income beyond which a rise in wealth leading to a fall in environmental degradation.

Given the focus of this paper on the state of Canada's natural capital, we examine briefly whether a relationship exists in Canada between growth and environmental degradation. Part of our interest in this question, is with respect to the role of government policy is in promoting a healthy environment. If environmental degradation subsides as a result of economic growth, then why not focus attention on promoting growth and let the environment basically take care of itself?

Because of data constraints, we decided to use SO_2 emissions as a measure of environmental

[23]See the discussion in Rao (forthcoming).

[24] See, for instance, Dietz and Rosa (1997).

degradation - mostly because data were available, at least for Eastern Canada[25], from 1970 to 1994. Following the basic approach of other studies, we use population, per capita GDP, growth in per capita GDP, the growth rate squared (to take account of non-linearities), and time as our principal independent variables. In addition to using overall GDP, GDP in the manufacturing sector in Eastern Canada was added as another measure of economic activity in the region. Furthermore, metal production in smelters was added because of the clear relationship between smelter activity and SO_2 emissions.

Table 5 reports the estimated coefficients obtained from the simple model proposed. These results typify the findings from several variants of the model. Three points are worthy of note. First, smelter production always exerts a positive and statistically significant effect on SO_2 emissions in Eastern Canada. Looking at the last column of table 5, which presents the elasticity of each variable measured at their mean, we see that a 1% increase in smelter production leads to a 1.3% increase in SO_2 emissions, *ceteris paribus*.

The second point to note is that the coefficient on the time trend variable is always negative and statistically significant. We may interpret the sign and magnitude of this coefficient in several ways. The most obvious one is that it reflects a general trend towards less SO_2 in the environment. Why this is the case, however, cannot be answered by the simple model above. One possible explanation points to the increasing public awareness of the importance of the environment, and the resulting public policies which have emerged in the area. Without further analysis, one simply cannot say with any degree of certainty why the state of the environment, as reflected in the SO_2 levels, appears to be improving over time.

[25] Eastern Canada here is defined as all provinces east of Manitoba.

The last point of interest arising from these results is that economic growth appears to have no effect on SO_2 emissions. Our measure of growth is the percentage change in manufacturing output in Eastern Canada each year. Manufacturing was chosen in order to account of the fact that the service sector - the sector which has experienced the greatest relative growth over the past two decades - typically contributes little to environmental degradation. In the version of the model reported in table 5, growth squared was also added as a regressor on the grounds that the relationship between emissions and growth is likely to be non-linear. The same results were obtained when we used total (per capita) GDP. It would appear that for Canada, wealth, or economic activity in general, does not contribute significantly to explaining SO_2 emissions.

5. Public Policy and Natural Capital

Any discussion of Canadian natural capital and environmental amenities must necessarily recognize the role played by public policy. To begin, it is remarkable to note that, in Canada, less than 10% of land is owned privately--- 50% of land is owned by provincial or territorial governments and 40.3% of land is federally owned.[26] This fact alone implies an extraordinary role for government in the management of our natural resources. In addition, because everyone is affected by environmental degradation - and no one "owns" the environment *per se* - environmental protection becomes necessarily the domain of government.

Much has been written regarding the types of instruments available to government to manage resources and the environment. With the risk of trivializing this important area, there are essentially four

[26] See, Table 10.8, Statistics Canada, *Econnections* data base.

main categories of policies available: command and control, taxes and subsidies, tradeable allowances (licenses), and legal liability. We have seen throughout the analysis of this paper, command and control type policies - in which government policy basically dictates a course of action - have been very successful in certain areas, especially when it comes to restricting the production and use of particular hazardous substances. Clearly, banning DDT, CFC production and use has had a profound impact on their presence in our environment. They have been less successful in other spheres of activity. For instance, in the fisheries, government regulations concerning the size of the fishing vessel and the length of the season have been circumvented by fishers employing different technologies and fishing more efficiently in a shorter period of time. In other words, sometimes the government can successfully implement regulations and other times individuals and firms can successfully by-pass them.

The other three classes of government policy are considered to be "economic" instruments which are designed to overcome the problems associated with the circumvention of conventional regulations. Again, the fisheries provide us with a good case in point. Implementing a policy of tradeable licenses in the fisheries has met with relative success in comparison to command and control regulations. In other words, giving fishers the economic incentive to behave (i.e., fish) appropriately taking into account the impact that over-fishing has on everyone seems to be a more effective strategy when compared to traditional regulations. Such an approach requires well-designed policies to help devise the right mix of property rights and incentives, and is as important for fisheries as it is for forests and other environmental assets.

Public policy is this area is complicated tremendously by the fact that it is not the sole purview of the federal or provincial governments. Often regulations are set federally, but it is up to the provincial and territorial governments to determine how they are implemented and monitored. Much debate has ensued as to the appropriate division of powers in these instances. Environmental regulations fall into this category, as do several other key regulations dealing with environmental concerns. As a crude measure of the magnitude of the problem of managing the environment, it is interesting to note that Environment Canada currently solely administers fourteen federal acts[27], including the *Canadian Environmental Protection Act* (CEPA); administers part of seven other acts, and helps eleven other government departments in administering their acts. In short, the range of activity which has an impact on the environment is enormous.

Clearly, government policies abound in this area and we cannot hope to cover all of them in this brief discussion. One piece of information rarely examined, but which may be of interest to a discussion of public policy, is government expenditures in the area of natural resources and the environment. The use of such expenditures is fraught with complications. First, it is very difficult to obtain figures of actual spending on natural capital even by the federal government - hindered, in no small measure, by the fact that spending in this area crosses several governmental departments.[28] Further, much expenditure takes place at the provincial, territorial and local government level. Finding the required information for a long enough period of time to make some intertemporal comparisons is difficult. It is also extremely hard to make intertemporal comparisons because of the potential relationship between government policy and the *need*

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[27] These are: *Canadian Water Act; Canadian Wildlife Act - Regulations; Canadian Environmental Assessment Act - Regulations; Canadian Environmental Protection Act - Regulations; Canadian Environment Week Act; Department of the Environment Act - Regulations; Lac Seul Conservation Act; Lake of the Woods Control Board Act; Migratory Birds Convention Act - Regulation; National Round Table on the Environment and the Economy Act - Regulations; National Wildlife Week Act; Weather Modification Information Act - Regulations;* and the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act.*

[28] One need only look at the plethora of acts managed by Environment Canada - as detailed in the previous footnote - to get some sense of the magnitude of the impact of environmental concerns.

to spend money on the environment. For instance, once an environmental problem has improved, it may not be necessary to continue to spend money on trying to solve it.

Notwithstanding the above caveats, graph 27 displays all government expenditures in real dollars on the environment and natural resources from 1980 to 1996.[29] It is interesting to note that these expenditures rose quite dramatically during the early to mid-1980s, and then declined equally dramatically during the last half of that decade. While Public Accounts data end in 1996, information from Environment Canada estimates suggest that spending on the environment at least has continued to fall from 1996 to 1998.[30] Graph 28 presents the expenditures on the environment and resources as a percentage of Canadian GDP in order to put these figures into some sort of context. Again, we see that expenditures in this area are relatively smaller in 1995 compared to 1980.

Without an in-depth analysis, it is difficult to know how to interpret these government expenditure figures. They certainly could provide ammunition for activists who think that the government is not committed enough to environmental concerns. Others may argue that environmental problems are improving and hence less money needs to be spent in this area. Not much information is available over time on the expenditures by private business on pollution control. We do, however, have relatively detailed information on such expenditures in 1994. For instance, we know that in 1994 some $1.6 billion was spent on capital abatement expenditures and some $2.06 billion was spent on operating expenditures for

[29] These data were obtained from Public Accounts.

[30] See, *Gallon Environment Letter*, Vol.2, No.14, June 5, 1998.

abatement.[31] For the same year, most of the capital and operating expenditures where geared towards end-of-pipe facilities - which comprised some 50% of total business expenditures on abatement. Environmental monitoring also made up over 10% of business expenditures on abatement. Table 6 provides a summary of the operating and capital expenditures on environmental protection by activity for 1994.

It is also interesting to note the expenditures on environmental protection by industry. Table 7 provides expenditures by thirteen industries. In terms of capital expenditures, the pulp and paper industry spends by far the greatest amount on abatement control - not surprising when one considers how much this industry emits each year. The second highest capital spender on pollution abatement controls is the mining, crude oil and natural gas industry which also spent the most in 1994 on operating abatement expenditures.

6. Concluding Remarks

The paper was brings together the available data on the environment and resources to provide a picture of the state of Canada's natural capital, and how it has evolved over time. The review indicates that although much data are now available thanks to several government departments, many data gaps remain. One important gap concerns wildlife and biodiversity for which consistent and reliable data are difficult to obtain. Moreover, very little has been done and is available on the cost of environmental and resource policies. In order to determine if environmental policies are as effective as possible, it would seem reasonable to determine how much is spent in this area. In this paper, we employed a crude measure of

[31] See tables EXPOI.IVT, EXPCP.IVT in Environment Canada's *National Environmental Indicators Series*.

these expenditures which suggests that expenditures by governments on natural capital are on the decline.

Finally, the paper indicates the paucity of empirical analysis of environmental policies in Canada. A gap which presumably can be filled as more and better data are become available.

Notwithstanding the lacunae identified in the paper, several comments may be made regarding the current state of Canada's natural capital. The portrait painted in this paper certainly suggests that Canada continues to be rich in natural resources. It is clear, however, that government policy is necessary in the area of renewable resources, although it has not always been effective. The fact that certain policies have been shown to be effective in the management of some resources suggests that resource problems can be improved over time.

The state of Canada's environment also depends upon the particular aspect under investigation. By and large, air and water qualities are better now that they were a couple of decades ago. Environmental policies and controls are likely to be the cause of this improvement. It is clear, for instance, that the ban on DDT has had a significant impact on the pervasiveness of this substance in our environment. However, degradation continues to be a problem in several key areas. The stratospheric ozone layer above Canada is still 10 per cent thinner than it was in 1980. Air pollution remains a problem in certain regions. Lakes continue to acidify, although fewer lakes acidify now in comparison to earlier years. Carbon dioxide levels are still high, keeping the threat of the dire consequences of global warming on the public agenda. In short, while our environment is much improved in important areas in comparison to earlier years, work remains to be done. It would seem that the next step should be to examine in greater detail the impact that certain government policies have had on specific environmental targets, as well as the costs of these policies, in order to determine where to proceed from here.

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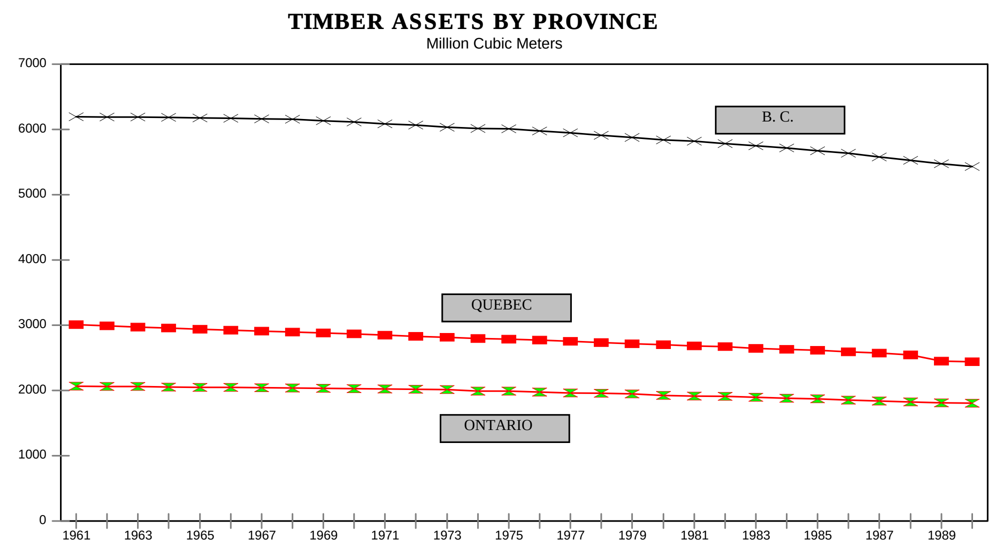
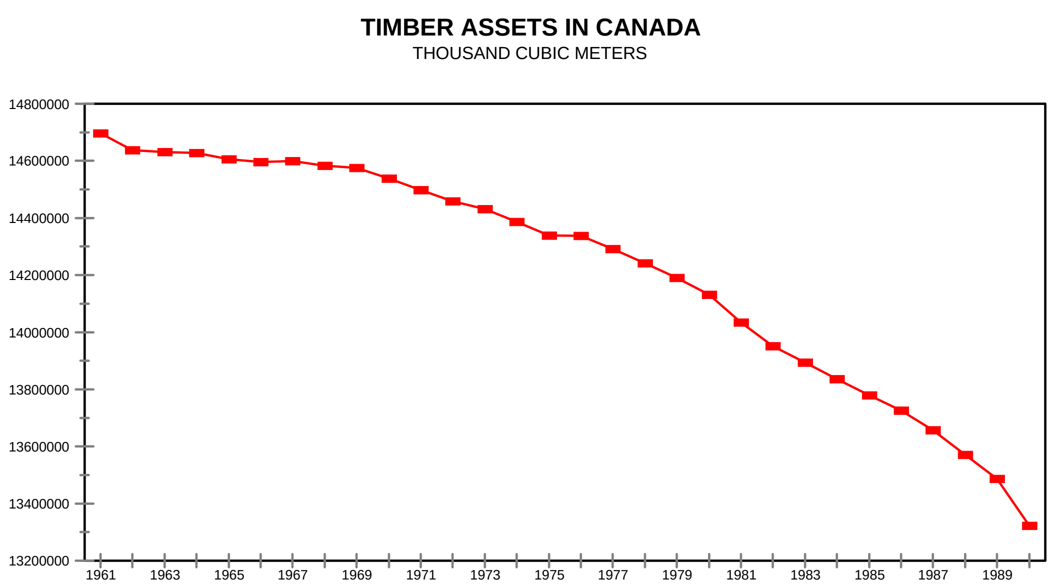
Graph 1



Source: Econnections: Linking the Environment and the Economy (CD Rom), Statistics Canada

Graph 2



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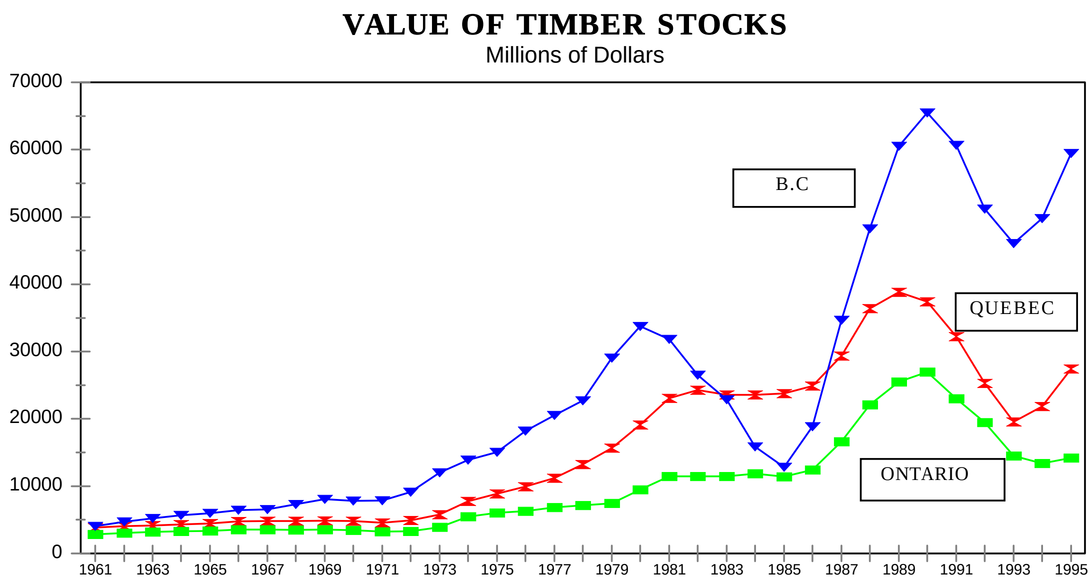
Graph3



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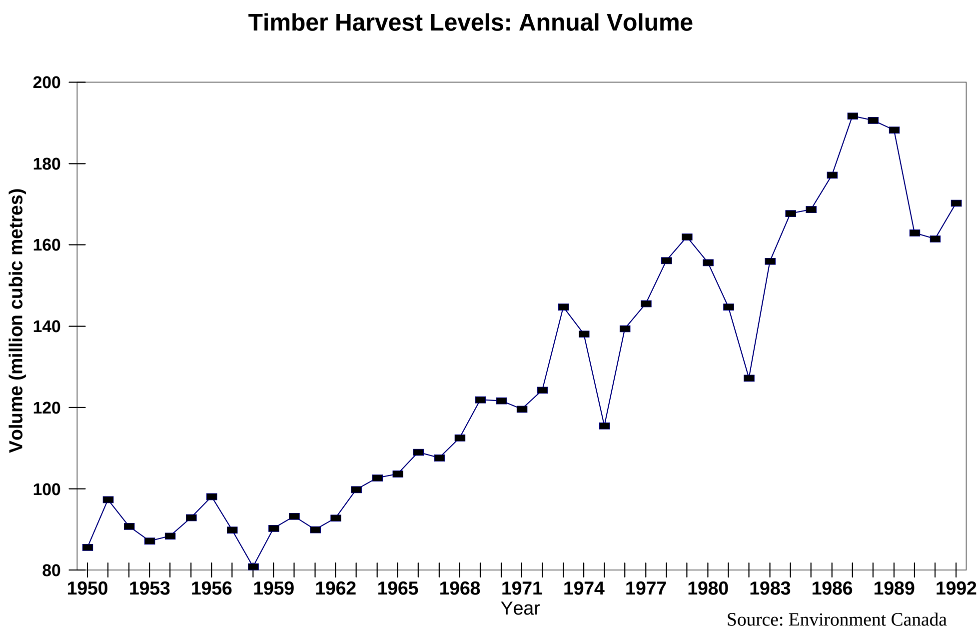
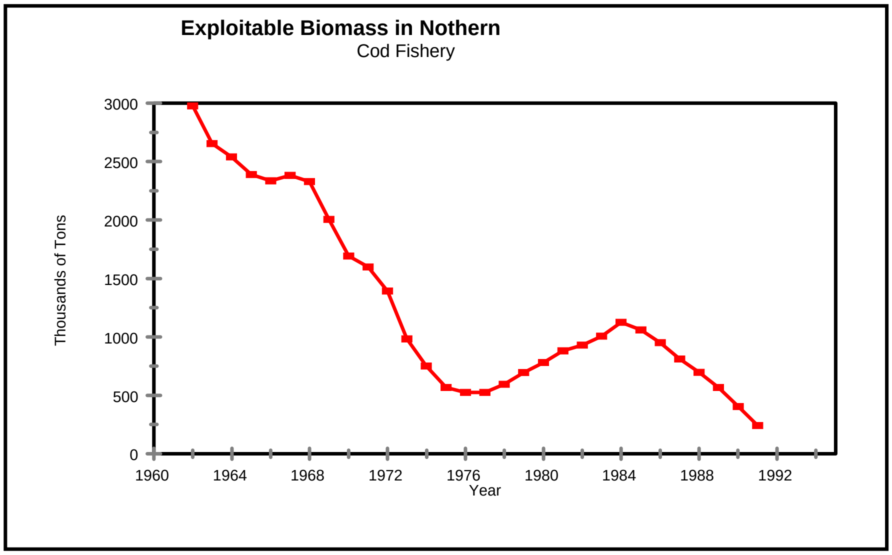
Graph 4

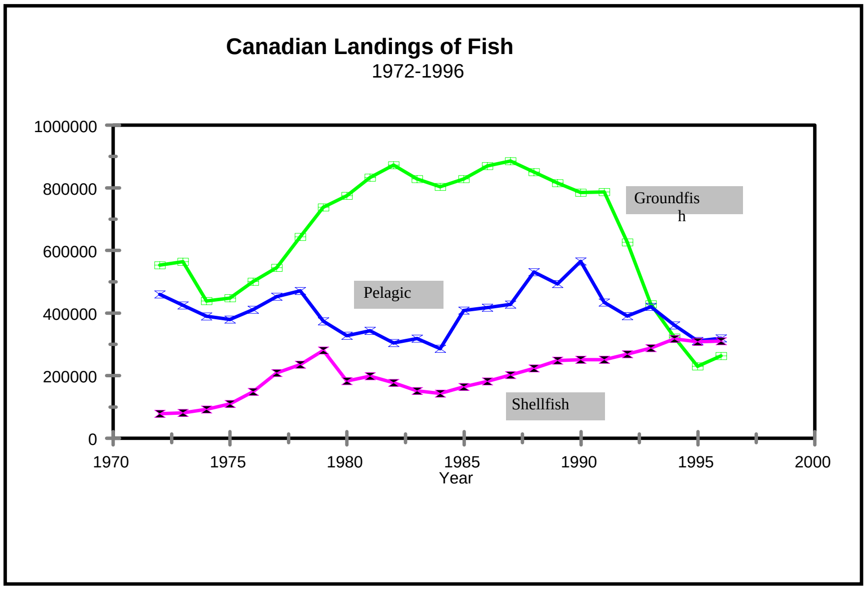


Graph 5



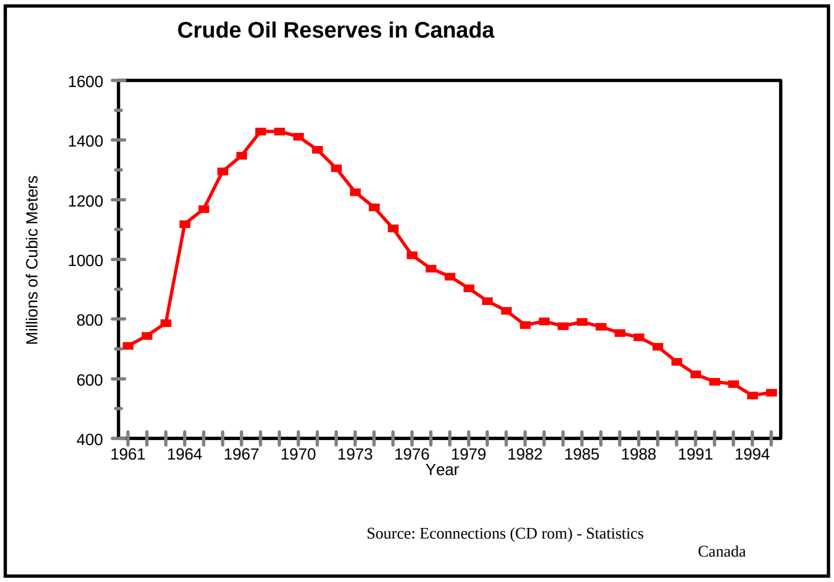
Source: Department of Fisheries and Oceans

Graph 6

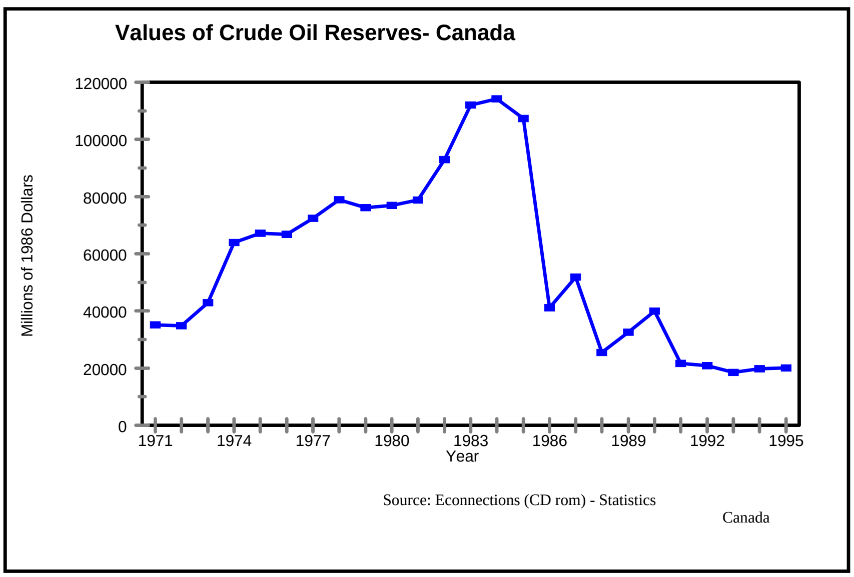


Source: Department of Fisheries and Oceans

Graph 7



Graph 8



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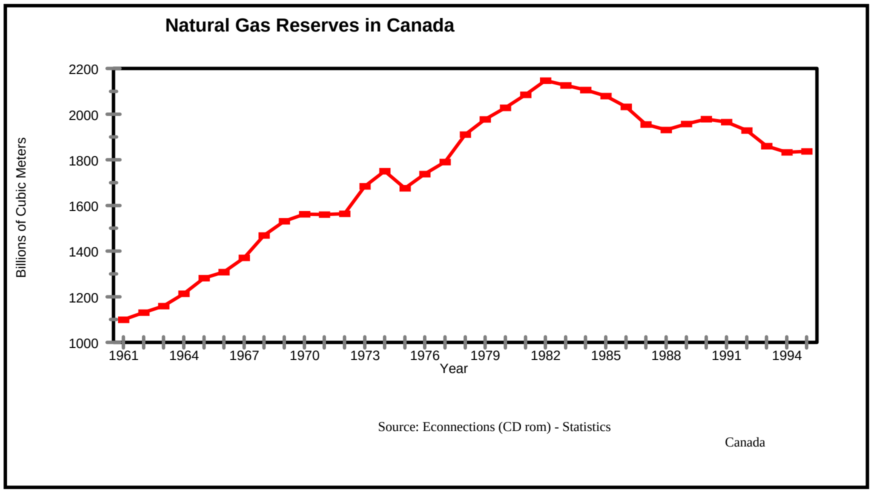
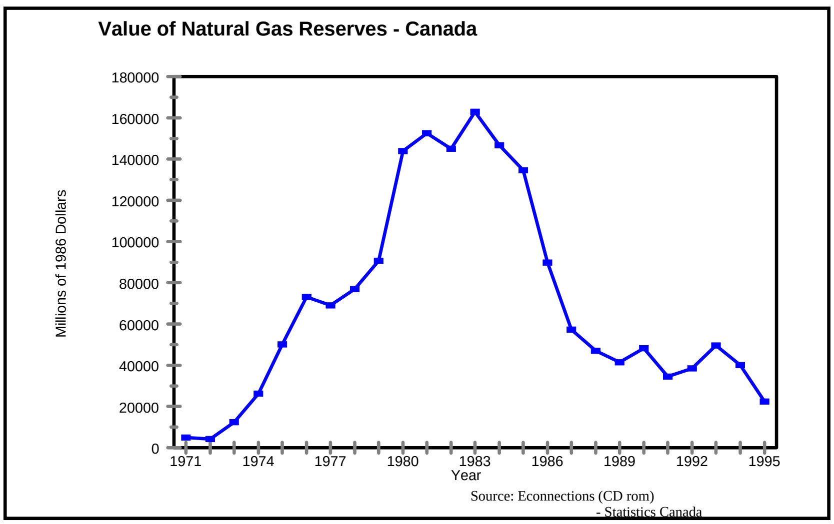


Graph 10



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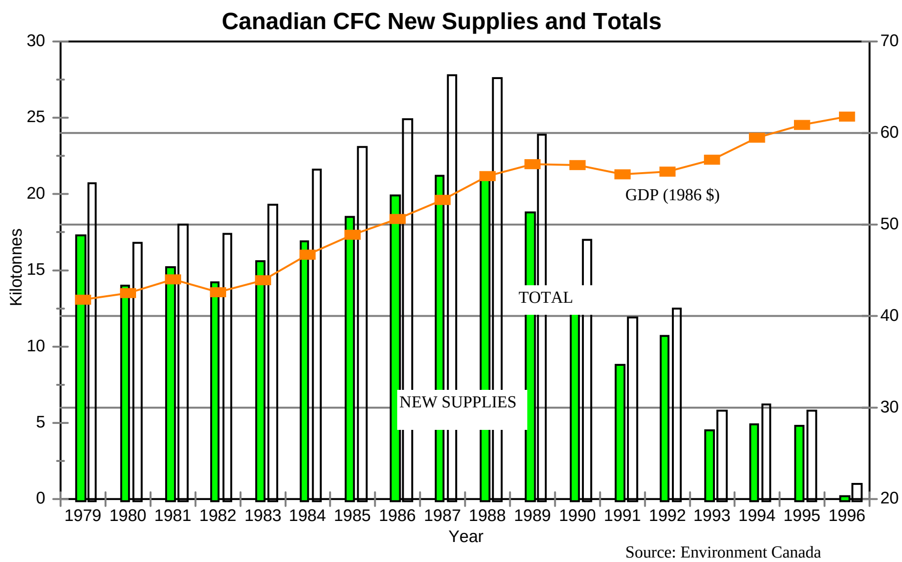
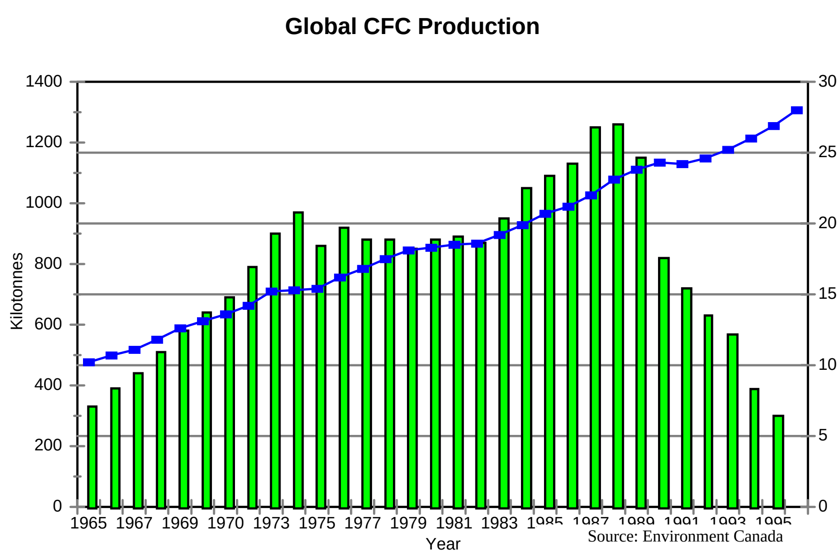
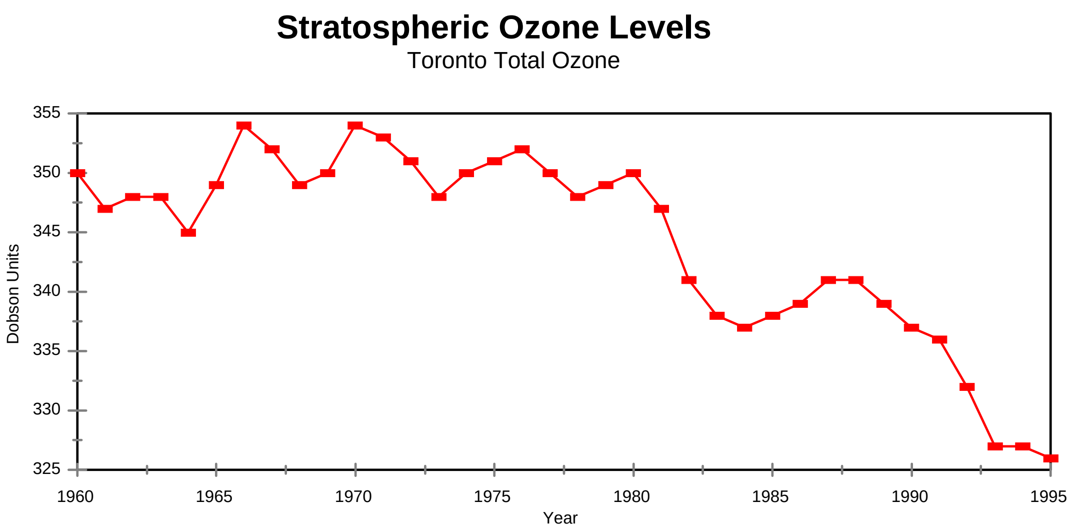


Graph 12

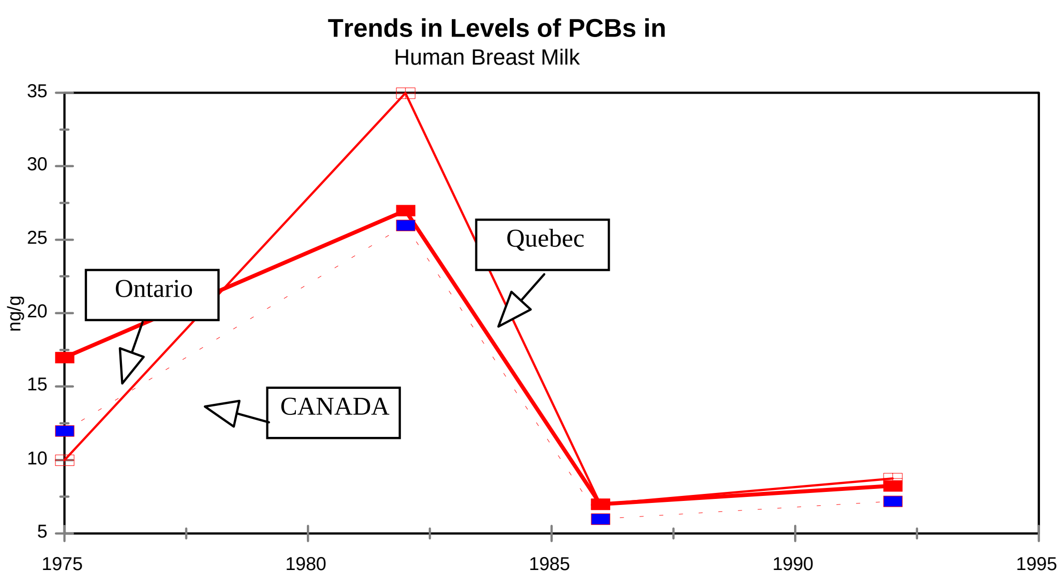


Graph 13



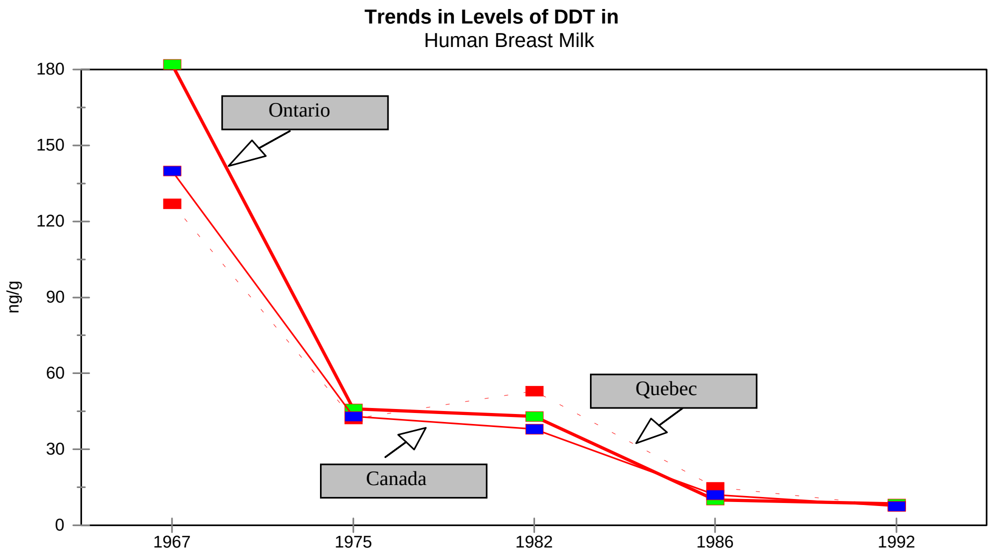
Source: Conserving Canada's Natural Legacy (CD Rom), Environment Canada (Table 107)

Graph 14



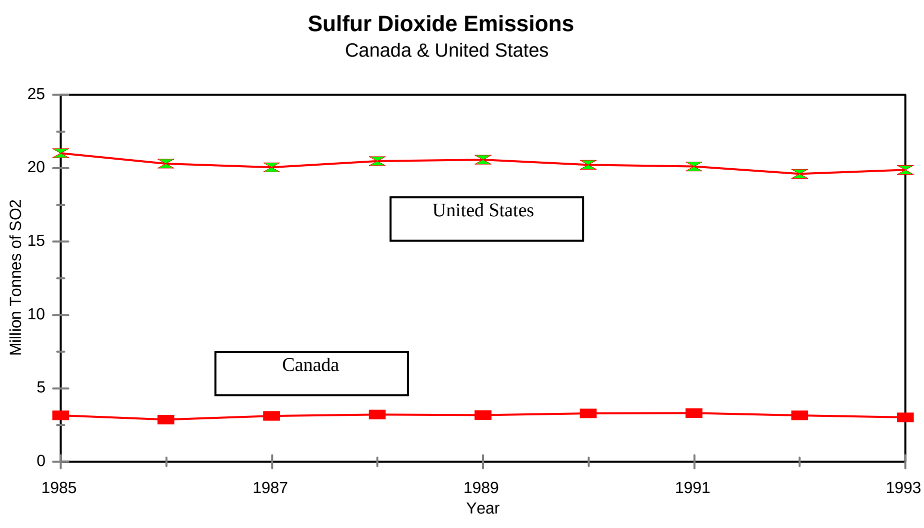
Source: Conserving Canada's Natural Legacy (CD Rom), Environment Canada (Table 624)

Graph 15



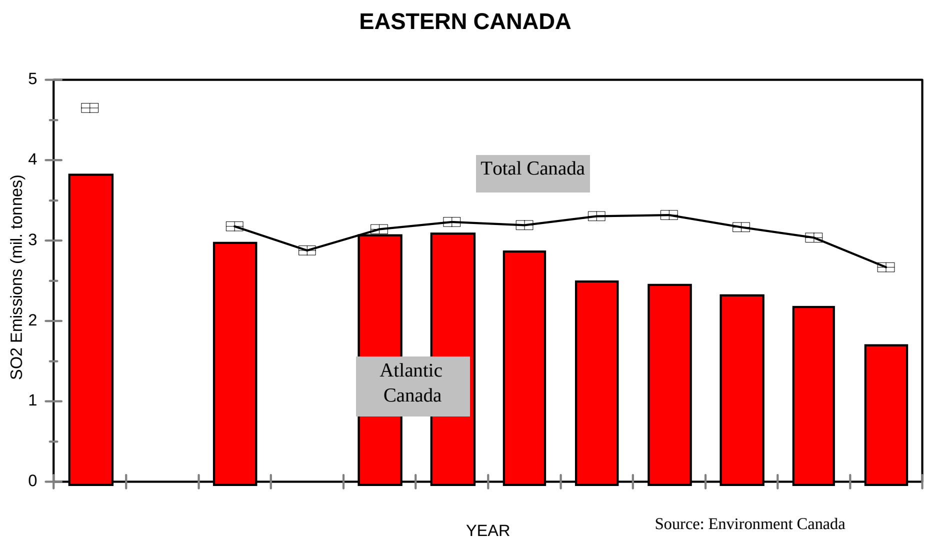
Source: Conserving Canada's Natural Legacy (CD Rom), Environment Canada (Table 623)

Graph 16

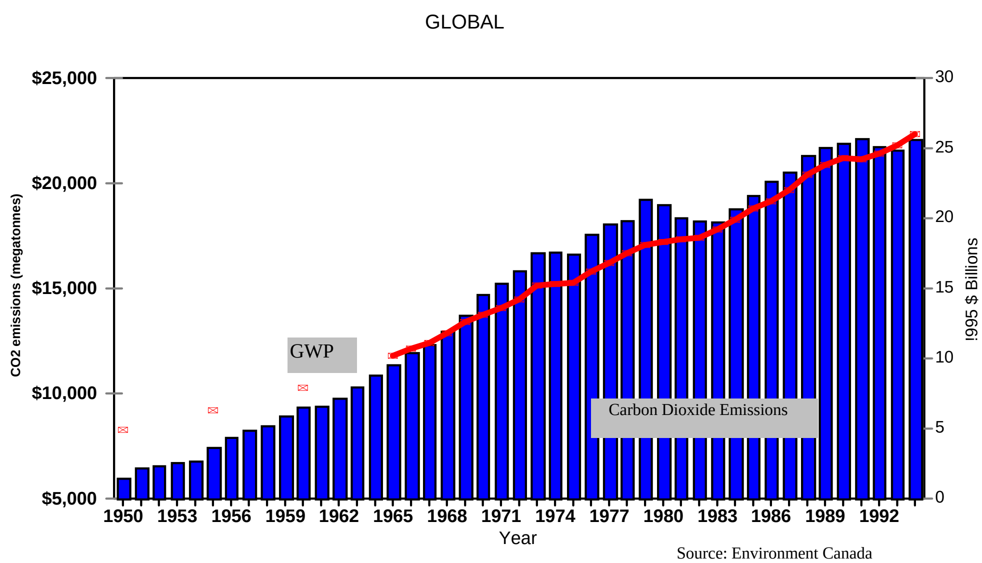


Source: Conserving Canada's Natural Legacy (CD Rom), Environment Canada (Table 105)

Graph17


EASTERN CANADA
5
4
3
2
1
0
SO2 Emissions (mil. tonnes)
Total Canada
Atlantic Canada
YEAR
Source: Environment Canada

Graph 18



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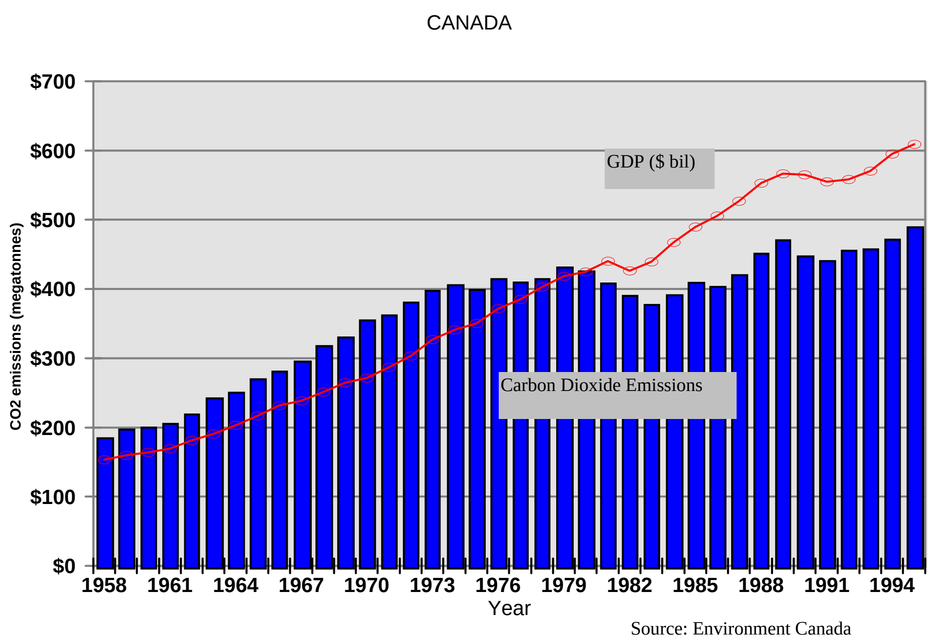

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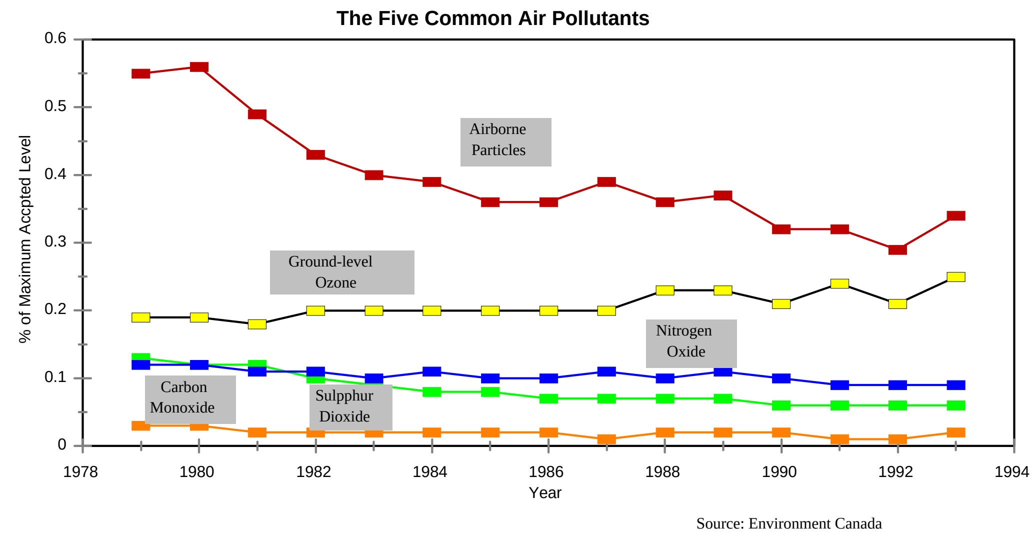
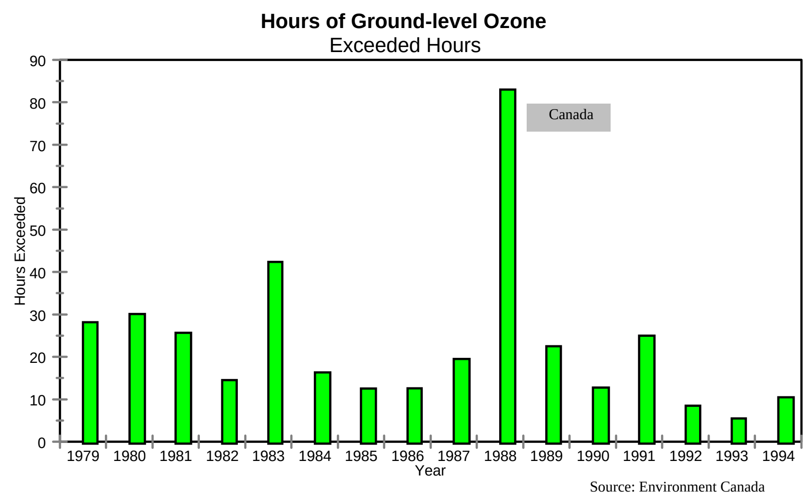
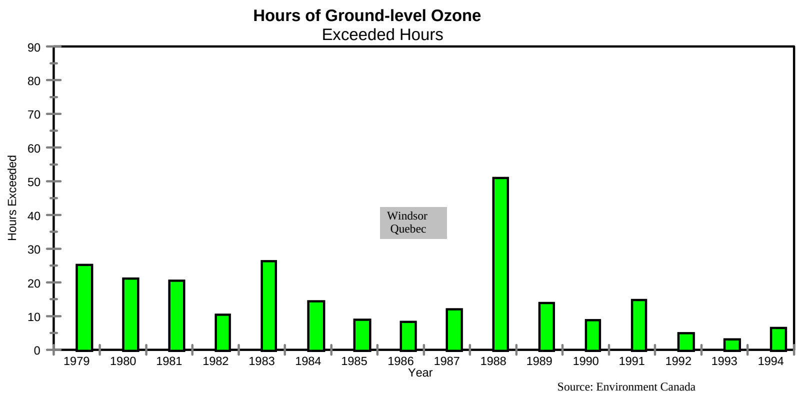


Graph 21



Graph 22



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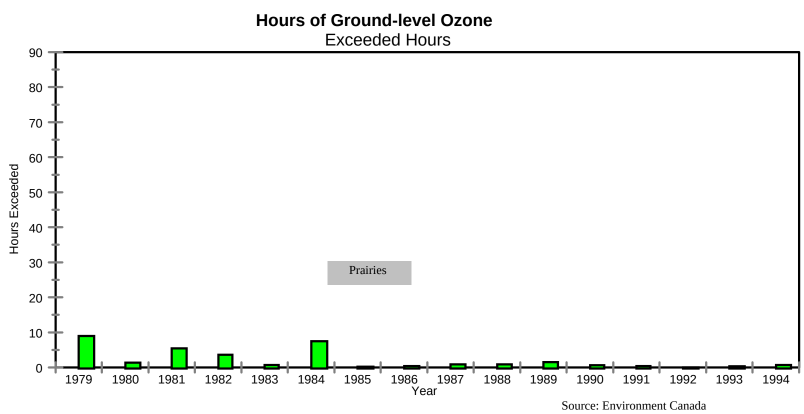

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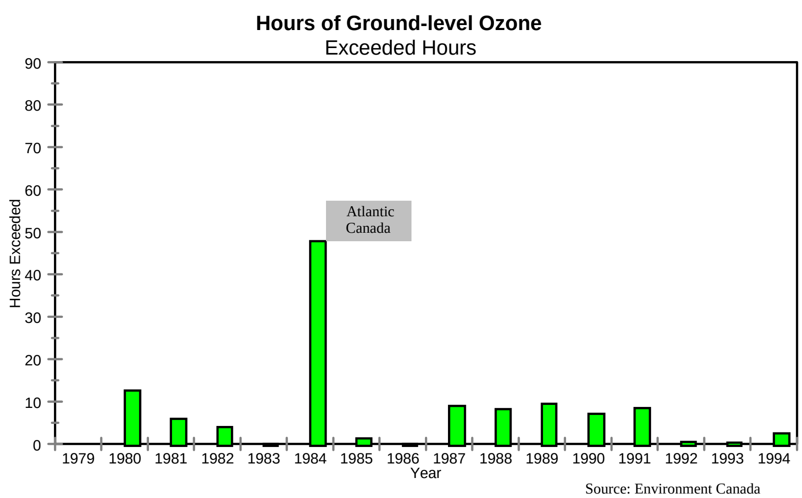

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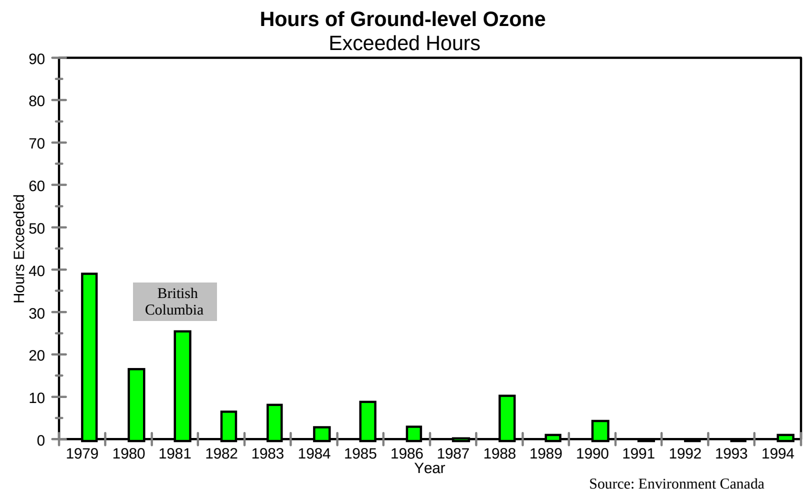
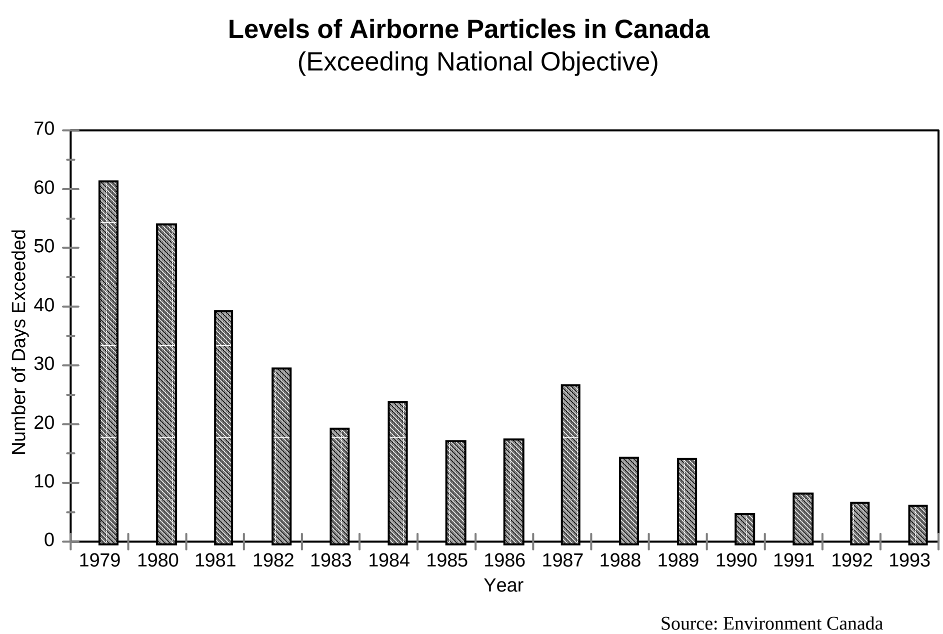
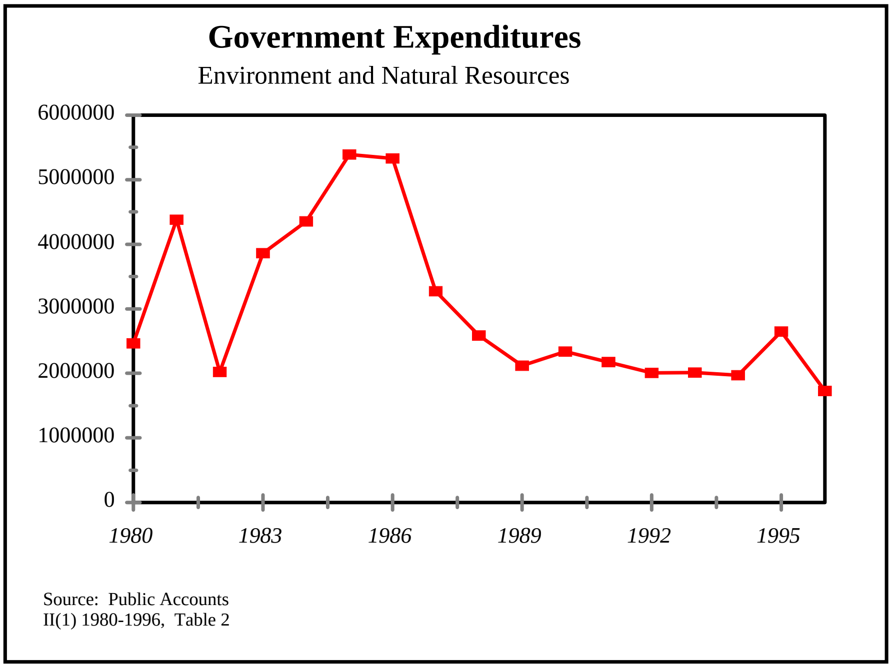


Graph 26



Graph 27



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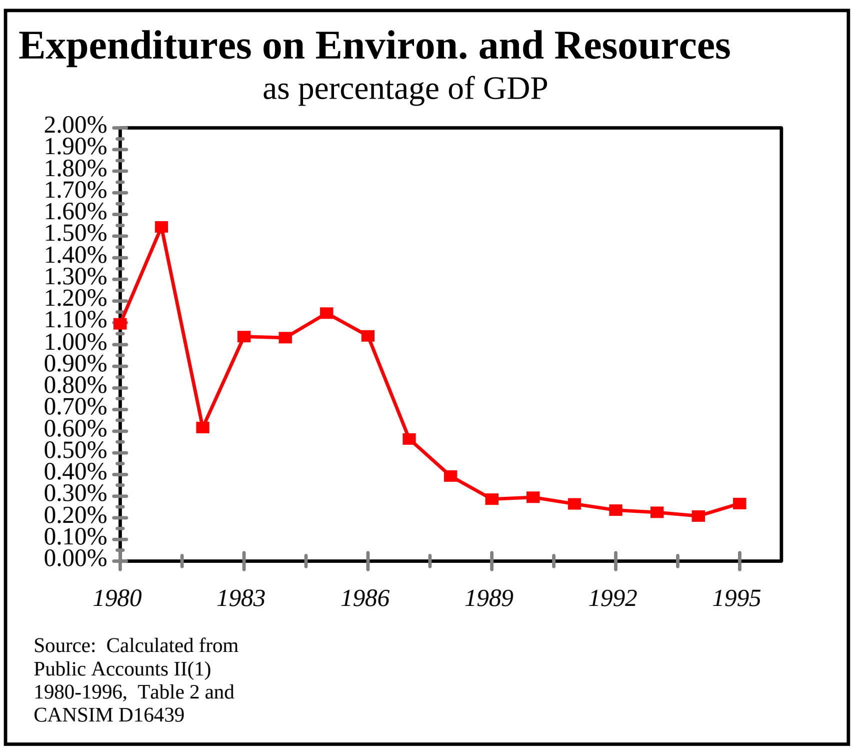

Table 1

Some descriptive biophysical characteristics of Canada's marine and terrestrial ecozones

Ecozone	Landforms	Surface materials/ soils	Climate/oceanographic characteristics	Vegetation/ productivity	Wildlife (mammals/ birds)	Human activities	Main communities
Marine ecozones							
Pacific	Pacific Ocean basin and narrow continental shelf; numerous fjords	Generally ice-free except for local pockets of landfast ice (seasonal)	General eastward-setting oceanic current (Subarctic Current) with divergence point off the shelf; pronounced seasonal upwelling in the south; El Niño influences	One of Canada's most productive oceanic areas	Important seasonal migrations of animals between neritic and oceanic areas; important commercial species include oyster, shrimp, five species of salmon, herring, Pacific Hake, Sablefish, Pacific Halibut, clams, Dungeness Crab, rockfish, and flatfish species	Fishing, tourism	
Arctic Archipelago	Limited to "shelf-type" depths; high Arctic islands, Arctic and Hudson Bay coasts; much is rocky coastline, numerous channels and straits; high coastal relief in east, low in south and west	Seasonal ice; open water 2–3 months in summer	Relatively high freshwater input along northern continental boundary	Higher productivity and abundance of life than permanent ice area	Intense summer migration into region, generally following the ice edge retreat; locally high concentrations of marine birds and mammals, including Beluga, Walrus, seals; Polar Bear	Oil and gas, limited fishing and hunting	
Arctic Basin	Limited to the most northern polar cap areas	Mainly permanent pack ice	Affected by easterly winds driving a clockwise circumpolar gyre in basin; no land components	Low biological productivity and diversity	Polar Bear and seals dominate mammals	Few, if any, activities	
Northwest Atlantic	Primarily continental shelf; generally low coastal relief	Seasonal ice area	Labrador Current exerts strong influence both on shelf and offshore (lower-salinity cold water)	Strongly influenced by the Labrador Current and Arctic waters	Subarctic species in north to boreal species in south; important commercial species include oyster, shrimp, Snow Crab, haddock, hake, Pollock, American Plaice, codfish, halibut, flounder, herring, mackerel, Capelin, and Atlantic Salmon	Fishing, tourism	
Atlantic	Large southern shelf areas (Grand Banks, Scotian Shelf) as well as the Northwest Atlantic Ocean basin	Generally ice-free except for local pockets of landfast ice and some years of seasonal ice	Includes mostly temperate water masses originating from the south; Gulf Stream offshore and Slope Water Current at the shelf break; mixing zone between cold, lower-salinity water from the north and warmer water from the south	A very productive area for many species	Includes both neritic and oceanic species; important commercial ground fisheries occur on shelves; important commercial species include lobster, scallop, codfish, haddock, hake, Pollock, redfish, halibut, mackerel, and Atlantic Salmon	Fishing, tourism	
Terrestrial ecozones							
Arctic Cordillera	Mountains	Ice, snow, colluvium, rock/ Cryosols	Extremely cold, dry; continuous permafrost	Mainly unvegetated; some shrub–herb tundra	Polar Bear (along coast), Arctic Hare; Northern Fulmar, Common Ringed Plover, Snow Bunting	Hunting, tourism	Pond Inlet, Clyde River, Broughton Island
Northern Arctic	Plains, hills	Moraine, rock, marine/ Cryosols	Very cold, dry; continuous permafrost	Herb–lichen tundra	Peary Caribou, Muskox, Wolf, Arctic Hare; Red-throated Loon, Brant, ptarmigan, Greater Snow Goose	Hunting, tourism/ recreation, some mining	Iqaluit, Cambridge Bay, Holman, Arctic Bay, Taloyoak, Pangnirtung, Sachs Harbour, Cape Dorset, Resolute, Igloolik
Southern Arctic	Plains, hills	Moraine, rock, marine/ Cryosols	Cold, dry; continuous permafrost	Shrub–herb tundra	Barren-ground Caribou, Wolf, Grizzly Bear, Arctic Fox, Arctic Ground Squirrel, lemming; Arctic Loon, ptarmigan, Snowy Owl	Hunting, trapping, tourism/ recreation, mineral development	Tuktoyaktuk, Rankin Inlet, Arviat, Paulatuk, Povungnituk
Taiga Plains	Plains, some foothills	Organic, moraine, lacustrine/ Cryosols, Brunisols	Cold, semiarid to moist; discontinuous permafrost	Open to closed mixed evergreen–deciduous forest	Moose, Woodland Caribou, Wood Bison, Wolf, Black Bear, Red Squirrel; Northern Shrike, Spruce Grouse	Hunting, trapping, tourism/ recreation, oil and gas development, marginal agriculture in south	Inuvik, Fort Simpson, Wrigley, Norman Wells, Aklavik, Hay River, Fort McPherson
Taiga Shield	Plains, some hills	Canadian Shield rock, moraine/ Cryosols, Brunisols	Cold, moist to semiarid; discontinuous permafrost	Open evergreen–deciduous trees; some lichen–shrub tundra	Moose, Barren-ground Caribou, Wolf, Snowshoe Hare, Red Squirrel; Red-necked Phalarope, Northern Shrike	Tourism/ recreation, some mining, some hunting and trapping	Yellowknife, Goose Bay, Uranium City, Churchill Falls, Happy Valley, Kuujjuarapik

Ecozone	Landforms	Surface materials/ soils	Climate/oceanographic characteristics	Vegetation/ productivity	Wildlife (mammals/ birds)	Human activities	Main communities
Taiga Cordillera	Mountains	Colluvium, moraine, rock/ Cryosols, Gleysols, Brunisols	Cold, semiarid; discontinuous permafrost	Shrub–herb–moss–lichen tundra	Dall's Sheep, Grant's Caribou, Black Bear, Grizzly Bear; Peregrine Falcon, Ptarmigan	Trapping, hunting, mining, tourism/ recreation, oil and gas	Old Crow
Hudson Plains	Plains	Organic, marine/ Cryosols	Cold to mild, semiarid; discontinuous permafrost	Wetland; some herb–moss–liche n tundra, evergreen forest	Woodland Caribou, Moose, Black Bear, marten, Arctic Fox; Canada Goose	Hunting, trapping, recreation	Churchill, Moosonee, Attawapiskat
Boreal Plains	Plains, some foothills	Moraine, lacustrine organic/ Luvisols, Brunisols	Cold, moist	Mixed evergreen–deciduous forest	Woodland Caribou, Mule Deer, Moose, Black Bear, beaver, Muskrat; Boreal Owl, Blue Jay	Forestry, agriculture, tourism/recreati on, oil and gas development	La Ronge, The Pas, Flin Flon, Peace River, Fort Smith, Fort Vermilion, Hinton
Boreal Shield	Plains, some hills	Canadian Shield rock, moraine, lacustrine/ Podzols, Brunisols	Cold, moist	Evergreen forest, mixed evergreen–deciduous forest	White-tailed Deer, Moose, Black Bear, Canada Lynx, marten, Red Squirrel; Boreal Owl, Blue Jay	Forestry, mining, tourism/ recreation, hunting, trapping	Thunder Bay, St. John's, Sudbury, Sault Ste. Marie, Chicoutimi, North Bay, Sept-Îles, Gander, Thompson
Boreal Cordillera	Mountains, some hills	Colluvium, moraine, rock/ Brunisols, Podzols, Cryosols	Moderately cold, moist	Largely evergreen forest; some tundra, open woodland	Moose, Dall's Sheep, Grizzly Bear, Black Bear; Ptarmigan, Spruce Grouse	Hunting, trapping, forestry, tourism/ recreation, mining	Whitehorse, Dawson, Faro, Teslin, Haines Junction, Mayo Landing
Pacific Maritime	Mountains, minor coastal plains	Colluvium, moraine, rock/Podzols, Brunisols	Mild, temperate, very wet to cold alpine	Coastal evergreen forest	Black Bear, Grizzly Bear, Mountain Lion; Black Oystercatcher, Tufted Puffin	Forestry, fish processing, urbanization, agriculture	Vancouver, Victoria, Prince Rupert, Nanaimo, Port Alberni, Chilliwack
Montane Cordillera	Mountains and interior plains	Moraine, colluvium, rock/Luvisols, Brunisols	Moderately cold, moist to arid	Evergreen forest, alpine tundra, interior grassland	Woodland Caribou, Mule Deer, Moose, North American Elk, Mountain Goat; Blue Grouse, Steller's Jay	Forestry, agriculture, tourism/ recreation	Prince George, Kelowna, Kamloops, Williams Lake, Vernon, Penticton, Nelson, Trail, Cranbrook, Quesnel
Prairies	Plains, some hills	Moraine, lacustrine/ Chernozems	Cold, semiarid	Grass; scattered deciduous forest ("aspen parkland")	Mule Deer, White-tailed Deer, Pronghorn, Coyote, Prairie Dog; Sage Grouse, Burrowing Owl	Agriculture, urbanization, recreation, oil and gas development	Calgary, Winnipeg, Edmonton, Regina, Saskatoon, Lethbridge, Red Deer, Prince Albert, Brandon
Atlantic Maritime	Hills and coastal plains	Moraine, colluvium, marine/ Brunisols, Podzols, Luvisols	Cool, wet	Mixed deciduous–evergreen forest	White-tailed Deer, Moose, Black Bear, Coyote, Raccoon; Blue Jay, Eastern Bluebird	Forestry, agriculture, fish processing, tourism/ recreation	Halifax, Saint John, Dartmouth, Charlottetown, Moncton, Sydney, Rimouski, Sherbrooke
Mixedwood Plains	Plains, some hills	Moraine, marine, rock/Luvisols, Brunisols	Cool to mild, moist	Mixed deciduous–evergreen forest	White-tailed Deer, Red Fox, Raccoon, Striped Skunk, beaver, Grey Squirrel; Great Blue Heron, Blue Jay	Agriculture, urban-ization, tourism/ recreation	Toronto, Montreal, Windsor, Hamilton, Quebec, Ottawa, London, Mississauga

Source: Wiken (1986); State of the Environment Directorate, Environment Canada; Marine Environment Quality Advisory Group, (1994); Ecological Stratification Working Group, (1996).

Table 2

Some quantitative environmental and socioeconomic characteristics of Canada's terrestrial ecozones

	Area						Population (1991)					
		Land		Fresh water			Canada			Urban areas		
Ecozone groupings[a]	Total area (% of Canada)	Area (km^2)	% of Canada's total area	Area (km^2)	% of Canada's total area	Dominant cover type	No. of people	% of total Canadian population	Density (no. of people/ 100 km^2)	No. of people	% of total ecozone population	GDP 1991 ($ millions)
Arctic												
Arctic Cordillera	2.5	230 873	2.3	19 717	0.2	Perennial snow/ice	1 047	<0.01	0.5	0	0.0	12
Northern Arctic	15.2	1 361 433	13.7	149 447	1.5	Barren lands	16 328	0.06	1.2	3 450	21.1	379
Southern Arctic	8.3	773 041	7.8	59 349	0.6	Arctic/alpine tundra	10 314	0.04	1.3	0	0.0	150
Taiga												
Taiga Plains	6.5	580 139	5.8	66 861	0.7	Coniferous forest	21 429	0.08	3.7	9 651	45.0	532
Taiga Shield	13.7	1 253 887	12.6	112 513	1.1	Transitional forest	33 589	0.12	2.7	11 860	35.3	1 145
Hudson Plains	3.6	353 364	3.5	8 996	0.1	Transitional forest	9 938	0.04	2.8	1 003	10.1	115
Boreal												
Boreal Shield	19.5	1 782 252	17.9	164 118	1.6	Coniferous forest	2 831 824	10.37	158.9	1 694 777	59.8	49 005
Atlantic												
Atlantic Maritime	2.0	183 978	1.8	19 772	0.2	Mixed forest	2 510 203	9.20	1 364.4	1 235 588	49.2	39 925
Great Lakes–St. Lawrence												
Mixedwood Plains	2.0	138 421	1.4	56 009	0.6	Agricultural cropland	########	51.35	10 125.7	#########	84.8	325 199
Central Plains												
Boreal Plains	7.4	679 969	6.8	57 831	0.6	Coniferous forest	707 695	2.59	104.1	299 019	42.3	13 744
Prairies	4.8	469 681	4.7	8 429	0.1	Agricultural cropland	3 851 089	14.11	819.9	3 120 032	81.0	90 756
Pacific and Western Mountains												
Taiga Cordillera	2.7	264 480	2.7	360	<0.1	Coniferous forest	309	<0.01	0.1	0	0.0	5
Boreal Cordillera	4.7	459 680	4.6	4 920	<0.1	Coniferous forest	30 839	0.11	6.7	16 335	53.0	946
Pacific Maritime	2.2	205 175	2.1	13 805	0.1	Coniferous forest	2 504 393	9.17	1 220.6	2 174 948	86.8	58 152
Montane Cordillera	4.9	479 057	4.8	13 053	0.1	Coniferous forest	751 761	2.75	156.9	452 418	60.2	14 035
Canadian total	100.0	9 215 430	92.4	755 180	7.5		########	100.00	296.2	#########	76.6	594 100

[a] Marine ecozones are not listed.

Note: Percentages may not add up owing to rounding.

Source: State of the Environment Directorate, Environment Canada.

Table 3

Breeding Bird Survey trends, 1966–1994

Terrestrial ecozone[a]	% annual change in population					
	Habitat type			Migration pattern		
	Forest	Scrubland	Grassland	Long-distance migrant	Short-distance migrant	Resident (nonmigrant)
Pacific Maritime	-0.9	-1.1	-2.8	-1.4 [n]	-1.3	+0.6
Montane Cordillera	+0.3	+1.7 [s]	+0.4	+0.3	+0.2	+0.1
Boreal Plains	+1.6	-0.3	-0.6	+0.3	-0.2	-0.2
Prairies	+1.9 [s]	+0.5 [n]	-0.6	0.0	-0.1	-0.7
Boreal Shield	+0.2	-0.7 [n]	-1.6 [s]	0.0	-0.7 [s]	+2.9 [s]
Mixedwood Plains	+1.4 [n]	+0.3	-2.3 [s]	-1.5	-0.4	+0.2
Atlantic Maritime	0.0	-1.3 [s]	-2.5 [s]	-0.5 [n]	-0.7 [s]	-0.3
Canada[b]	+0.2	-0.5 [s]	-1.2 [s]	-0.2	-0.4 [s]	0.0

[a] Insufficient data were available to calculate trends for the three Taiga ecozones and the Boreal Cordillera and Hudson Plains ecozones, and no data were available for the three Arctic ecozones.

[b] Average for the terrestrial ecozones where sufficient data existed.

[s] = trends statistically significant; [n] = trends nearly statistically significant; for others, trends not statistically significant.

Source: C. Downes, Canadian Wildlife Service, Environment Canada, personal communication.

Table 4

Pollutant	Averaging time	Maximum desirable concentration	Maximum acceptable concentration	Mazimum tolerable concentration
Sulfur Dioxide	**annual**	**11 ppb**	**23 ppb**	**-**
	24-hour	**57 ppb**	**115 ppb**	**306 ppb**
	1-hour	**172 ppb**	**344 ppb**	**-**
Airborne Particles (Total Suspended Particulates)	**annual**	**60 ug/m(cubed)**	**70 ug/m(cubed)**	**-**
	24-hour	**-**	**120 ug/m(cubed)**	**400 ug/m(cubed)**
Ozone	**1-hour**	**50 ppb**	**82 ppb**	**153 ppb**
Carbon Monoxide	**8-hour**	**5 ppb**	**13 ppb**	**17 ppb**
	1-hour	**13 ppb**	**31 ppb**	**-**
Nitrogen Dioxide	**annual**	**32 ppb**	**53 ppb**	**-**
	24-hour	**-**	**106 ppb**	**160 ppb**
	1-hour	**-**	**213 ppb**	**532 ppb**

Table 5

Dependent Variable: SO_2
1971-1994
Autocorrelation-Corrected OLS Estimates

VARIABLE	Estimated Coef.	T-ratio	Elasticity
SMELTER	2148.3	3.16	1.28
GROWTH	-96.605	-0.15	0.003
GROWTH2	1043.2	1.41	0.024
TIME	-96.587	-11.54	-
CONSTANT	$0.191*10^{06}$	11.62	-
R^2 - adjusted - 0.8664			

Table 6

	Business Environmental Protection Expenditures by Activity '1994 ('000 dollars)		
Expenditures	Operating expenditures	Capital expenditures	Total expenditures
Activity type			
Environmental monitoring	235902	145944	381846
Environmental assessments and audits	81291	55081	136372
Reclamation and decommissioning	217231	109935	327166
Wildlife and habitat protection	68401	54193	122594
Waste management and sewerage services	257725	-	257725
PAC end-of-pipe facilities	828138	999688	1827826
PAC integrated processes	186211	216197	402408
Fees,fines and licences	43560	-	43560
Other	141551	-	141551
Total	2060010	1581038	3641048

Table 7

Environmental Protection Expenditures by Industry ('000s of Dollars)			
Expenditures	Operating expenditures	Capital expenditures	Total expenditures
Industry			
Logging	67353	8565	75918
Mining, crude oil and natural gas	391841	287431	492394
Food	86124	34199	120323
Beverage	22815	21710	44525
Pulp and paper	273307	613323	886630
Primary metals	390560	87001	477561
Fabricated metal products	43550	8086	51636
Transportation equipment	107014	35035	142049
Non-metallic mineral products	31258	20337	51595
Refined petroleum and coal products	181367	118998	487243
Chemical products	200633	84205	284838
Other manufacturing industries	-	-	-
Energy utilities and pipeline transport	264188	262148	526336
Total	2060010	1581038	3641048