Coastal and Marine Areas 4

Coastal and Marine Areas

The continental shelf, a region of shallow water extending beyond the coastline and giving way to deep ocean, is the dominant physical feature of North America's marine zone. The shelf is typically high in nutrients, giving rise to a large production of algae and, in turn, a highly productive fish habitat (Botkin and Keller 1995). The width of the continental shelf varies considerably. Much of the Pacific coast has a narrow shelf, whereas in sections of the east it is extensive, providing for much of the commercial harvest of groundfish in North America. Canada's shelf region, one of the world's largest, covers 3.7 million km^2, mostly under a 200 m depth (EC 1996).

Canada's coastline is the longest in the world. Twenty-three percent of the population lives near the coast while about 55 percent of the US population lives in coastal areas that cover less than 17 percent of the total land mass (DFO 2001a; EPA 2001). The US coastal population is growing at four times the national average with some of the highest levels of urban growth taking place in small coastal cities, a trend that is expected to continue (CEC 2000). By the year 2010, coastal population in the United States will increase by almost 60 percent (Culliton, Blackwell and others n.d.).

Coastal ecosystems are the richest storehouses of marine biodiversity, and the physical conversion of these fragile areas to urban uses; their pollution from air, water, and land-based activities; and the exploitation of marine resources have degraded them and threaten the services they provide. Especially endangered are North America's most productive coastal ecosystems such as tidal flats, saltwater marshes, seagrass beds, mangrove swamps, estuaries, and other wetlands (see the biodiversity section) (CEC 2000).

One issue of high priority for North America's coastal and marine ecosystems is the precipitous decline in its fisheries since the mid-1980s (see Figure 21). Twenty-one of the 43 groundfish stocks in Canada's North Atlantic are in decline and nearly one-third of US federally managed fishery species are over-fished (CEC 2000). The collapse of the North Atlantic cod fishery inspired a Canadian moratorium on Northern Cod in 1992, which has caused considerable hardship for local and commercial fisheries in the region. In addition, significant salmon stock declines have become apparent on the Pacific and Atlantic coasts. For example, about 1.5 million small and large wild Atlantic salmon returned to spawn each year in North America's eastern rivers thirty years ago compared to fewer than 350,000 in 2000 (ASF 2000). Highlighted below is the decline in this region's Pacific Northwest salmon fishery. The situation is a complex one that involves migratory fish that cross national boundaries and a debate about the various roles of human impact and natural disturbance in the fish declines.

Initially used to enhance natural stocks, aquaculture has become a large-scale industry in North America, with commercial production expanding and new species being developed for fish farming. Since 1980, there has been a fourfold increase in US aquaculture, for example (see Figure 22) (Hanfman 1993). Harvests of farmed fish in North America grew from 375,000 tons to 548,000 tons between 1985 and 1995. Large-scale fish farming, however, can be unsustainable due to nutrients from wastes entering local waters and disease spreading, among other environmental impacts (CEC 2000).

An issue of increasing gravity to coastal and marine ecosystems is the overabundance of nitrogen from land-based activities. This priority issue is explored in greater depth in the following pages, showing the severity of the problem, especially in US coastal waters, where 60 percent of coastal rivers and bays are moderately to severely degraded by nutrient pollution. A related concern is that of harmful algal blooms,

Annual Fish Catch, 1972-1998

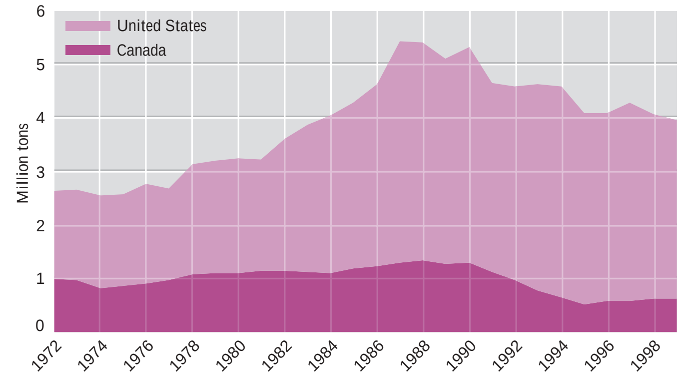


Figure 21
Annual fish catch, 1972-1998.

Source: Fishstat 2001

Aquaculture Production in North America, 1984-1998

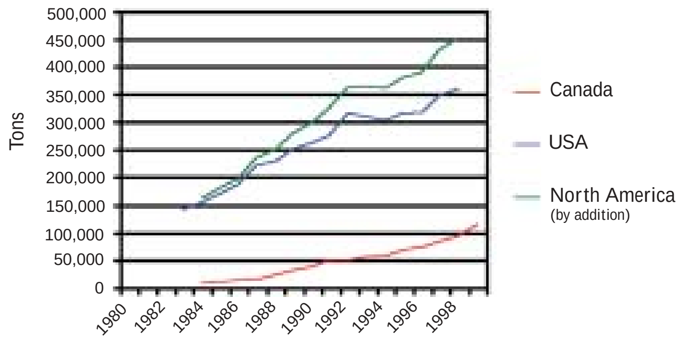


Figure 22
Aquaculture production in North America, 1984-1998.

Source: Hanfman 1993; Kope 1999; DFO 2000a

Box 18: Pacific Northwest Salmon

The Pacific Northwest is home to five species of salmon: Chinook, coho, sockeye, pink, and chum (or six when Steelhead is classified as a Pacific salmon), most of which hatch in rivers along the west coast then migrate to the sea, making their way northward to mature in colder waters. Several years later, they retrace their ocean journey south to spawn in the freshwater streams of their origin. Each group or stock has unique biological traits, uses its marine habitat (stream, estuary, coast, and ocean) to different extents, and is genetically adapted to its environment (Myers, Kope, and others 1998). British Columbia's approximately 1,000 spawning streams may support as many as 3,000 genetically and ecologically distinct salmon populations (Walters 1995). Salmon, therefore, are significant components of the region's ecosystems. The fish are particularly important to the history, culture, and social fabric of smaller coastal communities and indigenous peoples, whose way of life has been shaped by fishing. Salmon are also extremely significant for the economic role they play along North America's Pacific Northwest, both commercially and for recreational anglers (PSC 2000). In 1989, salmon accounted for 56 percent of the landed value of the fishery industry on Canada's West Coast (Statistics Canada 2000).

which have been spreading over the past 20 years, causing harm to humans, fish, marine birds, and mammals and to sectors of the economy that depend on healthy marine ecosystems.

Pacific Northwest Salmon Fishery

The Pacific Northwest of North America is a region of extensive temperate forests drained by large rivers linking the land and sea. In the mid-1990s, a population of 6.5 million was concentrated in coastal cities and towns and it is still growing. The forests along the marine west coast are among the most productive in North America and forestry is the major resource activity there (see the forest section). The streams, estuaries, and ocean waters support rich fishery resources and the commercial fishery offshore is another key industry, with salmon being of primary importance (see Box 18) (CEC 1997).

Historically abundant in many Pacific coastal and interior waters, salmon runs and species diversity have been shrinking since the late 19th century (Walters 1995). In the beginning, dam construction (particularly in the United States), rockslides, poor management, and over-fishing were blamed (DFO 1999a). Over the years, fish ladders were built to permit migration, and enhancement activities, including hatcheries, spawning channels, and fish rearing were set up to allow for the survival to adulthood of more young fish (PSC 2000). Still, declines in Pacific salmon harvests accelerated after the 1970s. Newer dams and turbines that had been added along some major US rivers in the late 1970s were now blamed. In response, turbines were modified and additional structural and transport-oriented measures were taken to enable salmon migration (Mann and Plummer 2000).

By the late 1980s, both countries had imposed severe restrictions on harvests of some salmon species. Despite these and other measures, by the early 1990s, salmon values showed significant declines (see Figure 23). By the mid-1990s, the salmon population of the Columbia River had dropped by at least 70 percent, and Washington state severely restricted coho and Chinook. By 1996, there had been a 62 percent decline in total BC landings from 1989 (Statistics Canada 2000) (see Figure 24). A number of salmon species were threatened and in 1992 were added to the US ESA, which prohibits taking endangered salmonids (see Box 10 in the biodiversity section) (Carlisle 1999; TU/TUC 1999). The blame for salmon declines was increasingly debated among all those involved within and between the two countries sharing the fish, including federal fisheries managers, sports fishers, commercial fleets, and indigenous fishers (Glavin 1996).

In 1999, nine populations of salmon and steelhead on the Pacific Northwest coast were added to the ESA, bringing the number of listed subspecies of west coast salmon to 24. The US government stated that the listings were the result of habitat degradation from land and water development projects, over-harvesting, dam construction and operation, and some hatchery practices (Rabalais 1999). In 1998, Canada closed coho fishing to protect stock in the Tompson River and upper Skeena, instituting a coho recovery plan that restructured Canadian fisheries (Carlisle 1999; TU/TUC 1999). At the end of the decade, of the five species of Pacific salmon, two were considered overexploited and the others deemed to be fully

Commercial Pacific Northwest Salmon Values, 1972-Latest Year

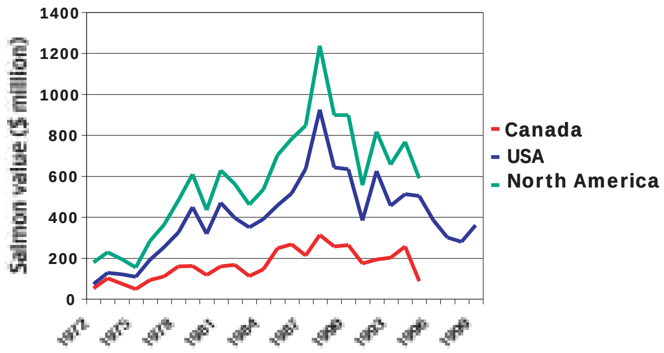


Figure 23
Commercial Pacific Northwest salmon values, 1972-latest year.

Source: DFO 2000b; NMFS 2000

Commercial Pacific Northwest Salmon Catch, 1972-Latest Year

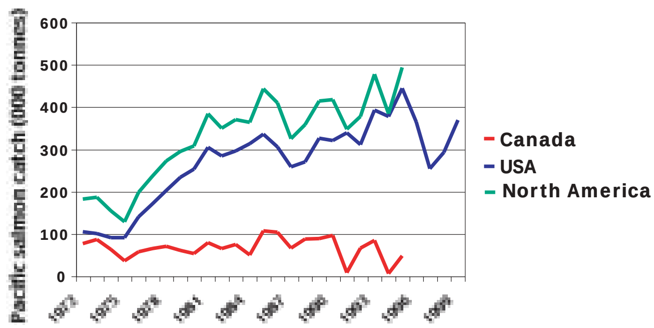


Figure 24
Commercial Pacific Northwest salmon catch, 1972-latest year.

Source: DFO 2000b; NMFS 2000

exploited when compared with levels necessary to achieve maximum sustained yield (Kope 1999).

Over-harvesting combined with habitat destruction or degradation

Box 19: Impacts of Logging on the West Coast Salmon

Salmon depend on freshwater habitat to spawn and so are particularly vulnerable to its degradation. Forest clearing and road building expose stream habitats to more sunlight and heat than is required for salmon health and can lead to erosion and flash flooding that disrupts sediment levels. Naturally fallen trees create spawning ponds and contribute necessary nutrients to the streams, while logging debris can clog them, inhibiting fish migration and reducing dissolved oxygen levels. A 1992 survey of salmon streams on Vancouver Island revealed that logging had partially or permanently damaged over 60 percent of them (YCELP 1995).

from dams, hatcheries, logging (see Box 19), mining, overgrazing, urbanization, agricultural runoff, industrial pollution and water development projects were considered by most to be the key causes, and there is little doubt that the cumulative effects of these activities contributed to declines in harvests of some salmon populations (Walters 1995).

By the end of the 1990s, some scientists considered the role of natural cycles, such as the occurrence of several El Niño events over the last few decades, as increasingly important in the dramatic decline in marine survival of some stocks (NMFS 1998; Statistics Canada 2000). El Niño events trigger the flow of unusually warm seawater along the west coast, affecting species productivity and prey and predator distribution (NMFS 1998). During the last century, the 1997 El Niño was the strongest, and that of 1983 the second hottest (Welch 1999).

In addition, in the early 1990s, scientific data began to indicate the existence of 20- to 30-year cycles of plentiful and then scarce salmon related to a regime shift called the Pacific Decadal Oscillation (PDO) (Carlisle 1999; Brown 2000). Warm phases in this pattern of Pacific climate variability correlate with enhanced biological productivity in Alaska's coastal ocean and inhibited productivity off the coast of the Pacific Northwest. Cold phases have the opposite characteristics (JISAO 2000). This could explain that while Chinook and coho salmon declined, those species that migrate further offshore have been relatively stable. It is now widely accepted that the regime shifted in the winter of 1976–77 (Kope 1999; Hare and Mantua 2000). Historically, the salmon have withstood such natural regime shifts, but now the combination of habitat loss and the particularly low levels in some salmon populations may have made these fish more vulnerable to extinction from their effects (NMFS 1998).

Complicating the issue are the two international borders that separate British Columbia's waters from Alaska's and those of the Northwest US states (DFO 1999a; TU/TUC 1999). During their life cycle, salmon of US origin travel through Canada's waters and Canadian fish pass through US zones with a resulting history of intercepting fishery practices. Expansion of high-intercepting fisheries during the 1950s and '60s by the two countries discouraged conservation and enhancement and encouraged over-harvesting (DFO 1999a). Negotiations between Canada and the United States to resolve the issue began in the 1960s and culminated with the 1985 Pacific Salmon Treaty (see Box 20). Initially unsuccessful, the treaty was renegotiated and new, fairer, and more protective measures were added in 1999.

Although there is a natural variability of abundance levels for Pacific salmon, uncertainty remains about recent salmon declines. The relative importance of fishing, climatic change, and habitat conditions has been changing over recent decades and varies with each location and population (Walters 1995). The dilemma has prompted a number of

status reviews, renewed fishing agreements, and new management approaches (Alden 1999).

For example, in 1998, Canada initiated the Pacific Fisheries Adjustment and Rebuilding Program to conserve and rebuild Pacific salmon stocks and to revitalize Pacific

Box 20: Bilateral Agreement, The Pacific Salmon Treaty

The 1985 Pacific Salmon Treaty was based on the principles of conservation to prevent over-fishing and allow for optimum production and equity so that each party receives benefits equal to those from salmon production originating in its waters (PSC 2000). However, harvest rates and ceilings were set too high for stocks to rebuild and the United States considered Canada's approach to the equity issue unacceptable, which led to a stalemate. The original fishing arrangements ended in 1992 because of disagreements (TU/TUC 1999).

Between 1992 and 1999, a series of initiatives were taken to reach a new bilateral fishing arrangement. As of 1994, the Treaty lacked effective implementation, which culminated in a total breakdown of negotiations in 1997. One of the initiatives was the appointment of special representatives from the two countries, whose 1998 report refers to the unresolved dispute between them as a case of unregulated self-interest risking the unsustainable harvest of the commons (Strangway and Ruckelhaus 1998).

In 1999, the Pacific Salmon Treaty was renegotiated. A new, comprehensive accord signed on 3 June 1999 finally resolves the long-standing differences over Pacific salmon conservation (NOAA 1999). It is based on sustaining wild stocks, preventing over-fishing by matching harvest levels to actual abundance, sharing the burdens of conservation and the benefits of stock recovery, and establishing a common basis to assess stocks, monitor fish, and evaluate performance. The agreement signals a cooperative, conservation-based approach to the management of Pacific salmon fisheries, and a more equitable sharing of salmon catches between Canada and the United States. It should help to protect weak stocks and stabilize harvest arrangements for 10 to 12 years (DFO 2001b; DFAIT 2002).

salmon fisheries. It also implemented a precautionary approach to salmon management, resulting in significant harvest reductions to protect stocks at risk (DFO 1999b).

Pending decisions on ESA listing of Pacific salmon and steelhead trout were completed in 1999 and 2000. A total of 26 distinct groups are now listed as either threatened or endangered. Stakeholders, including government officials, state, local, and tribal officials, and the public, are working together to address habitat restoration and other concerns to aid salmon recovery (Buck, Corn, and Baldwin 2001). In December 2000, the United States released a comprehensive long-term federal strategy to help restore the 14 salmon subspecies in the Columbia River Basin listed on the ESA. It states that actions are necessary to restore health to the tributaries and estuaries where these species spawn in order for them to recover. It provided for four dams on the lower Snake River to be breached if a number of salmon survival standards, reviewed at five-, eight-and 10-year points, are not met. The standards include habitat restoration, harvesting curtailment, limits to harmful hatchery operations, measures to conserve wild salmon, ways to improve survival through hydropower systems, and better conditions in streams and reservoirs (Federal Caucus 2000).

Natural climatic regime shifts, climate change (see Box 21), and habitat loss and destruction are conspiring to threaten the continued viability of North America's Pacific salmon populations. As those dependent on them as a source of income also struggle to survive, both countries are taking additional measures, outlined in their national sustainable fisheries strategies, to help to restore these and other wild fish stocks to North America's coastal and marine waters and to enhance and maintain global biological diversity. Fisheries and Oceans Canada instituted a new Sustainable Development Strategy for 2001–03, which is built on the key economic,

Box 21: Impacts of Climate Change on Pacific Salmon and Other Wild Fish Stock

Both countries are concerned about the potential for climate change to affect salmon populations and other wild fish stocks in North America's coastal and ocean waters. Studies by Canadian government scientists that simulated expected changes from a doubling of CO_2 in the atmosphere indicate that the resulting change in climate could virtually eliminate salmon habitat from the Pacific Ocean (NRCan 1998). A 1994 Environment Canada study of the impact of climate change on Fraser River salmon reported that altered flow regimes, aquatic temperatures, river hydrology, and seasonal runoff will intensify competition among water users in the watershed (Glavin 1996). And a recent US report on climate change impacts notes that a projected narrowing in the annual water temperature range in many estuaries may cause species' ranges to shift and increase the vulnerability of some estuaries to introduced species (USGCRP 2000).

environmental, and social principles of sustainable development, including public participation, the precautionary approach, and expanded scientific knowledge about aquatic ecosystems (DFO 2001a).

The US Sustainable Fisheries Act of 1996 amended the Magnuson Fishery Conservation and Management Act to incorporate numerous provisions requiring science, management, and conservation action by the National Marine Fisheries Service (NMFS). The aims of the NMFS Strategic Plan are to maintain healthy stocks, eliminate over-fishing and rebuild over-fished stocks, increase long-term economic and social benefits from living marine resources, and promote the development of robust and economically sound aquaculture (OSF 2000). Recent restrictions, bilateral cooperation, and new ecosystem approaches have contributed to improving the ocean survival of some important salmon stocks, but it remains to be seen if all Pacific salmon species rebound and how other North American fish stocks fare (DFO 2000c; DFO 2001a).

Nutrient Loading

Over the past 20 years, the introduction of excess nutrients has increasingly been recognized as causing a number of environmental problems in coastal ecosystems (NRCan 2000). Eutrophication, or the increased supply of organic matter to an aquatic system (see Box 22), is one of the most common effects and is now the most widespread problem affecting estuaries and coastal zones (Howarth, Anderson, and others 2000; NRCan 2000). Although an overabundance of nutrients in the environment due to human activities was recognized as a problem in North America's freshwaters as early as the 1970s (EC 2000), until the late 1990s, the severity and extent of the problem in coastal waters had not been adequately appraised due to the complexity of the phenomena and the lack of consistent national data sets (Bricker, Clement, and others 1999).

Box 22: Eutrophication and Hypoxia

Eutrophication refers to the gradual increase in nutrients such as nitrogen and phosphorus in a body of water due to natural processes, which can be accelerated by human activities. The process and symptoms vary from one region to another due to differences in underlying geology and soil types (EPA 1998).

Excessive nutrients encourage an abundant plant life that can lead to chronic over-enrichment with symptoms that include low dissolved oxygen, fish kills, murky water, and depletion of desirable flora and fauna. Lakes, estuaries, and bays subject to eutrophication can eventually become bogs and marshes (EPA 1998; EPA 2001). Elevated levels of chlorophyll indicate the onset of eutrophication while depleted dissolved oxygen indicates more serious or highly developed eutrophication (Clement, Bricker, and Pirhalla 2001). When the concentration of dissolved oxygen in water bodies falls below 2 ppm, the level generally accepted as the minimum required for most marine life to survive and reproduce, the condition is termed a state of hypoxia or hypoxic waters (EPA 1998).

Nutrient additions to marine and coastal ecosystems increased dramatically over the past several decades due to large increases in population density, fossil fuel use, sewage inputs, animal production, and fertilizer use (EC 2001). These activities release nitrogen and phosphorus, which can enhance plant growth in aquatic systems causing oxygen depletion and multiple effects on the ecosystem: eutrophication can cause the alteration of food webs, decreased biological diversity, loss of seagrass, destroyed fish habitat, the closure of shellfish areas, degraded beaches, and site contamination (Carpenter, Caraco, and others 1998; EC 1999; EC 2001).

Over the past 30 years, North America has had notable success in stemming nutrient emissions from point sources, or localized inputs. Since the early 1970s, anti-pollution legislation has greatly reduced point sources of nitrogen and phosphorous—principally from the discharge of municipal sewage and industrial wastes—and successfully controlled phosphates in laundry detergents (NOAA 1998). During the early 1970s, half of the phosphorous found in US domestic wastewater came from laundry detergents, which contained some 12 percent phosphorous by weight. By 1982, the phosphorous content of detergents had dropped to about 5 percent and accounted for 35 percent of amounts in wastewater (Miller Jr.1985).

Today, non-point sources, or dispersed activities, are the major concern. In many parts of North America non-point nutrient inputs to fresh and coastal waters come mainly from fertilizer and manure runoff. Over the past three decades, fertilizer use in the region rose by almost 30 percent (see Figure 27 in the land section).

A trend toward rearing livestock (cattle, hogs, chickens and other animals) in intensive feedlots has also resulted in the release of huge amounts of manure to surface and coastal waters (Mathews and Hammond 1999). In the United States, intensive feedlots are the third leading agricultural source of water pollution, and the issue of excess livestock manure has gained increased public attention, underscoring the need for better protection against non-point sources of water pollution. With ever more animals confined on fewer and larger feedlots, there is frequently not enough accessible cropland on which to use all the manure efficiently. Inadequate manure management has led to coastal water pollution in many regions and serious policy difficulties in addressing the growing problem (Harkin 1997) (see Box 23). Significant amounts of nitrogen are also deposited in aquatic ecosystems from airborne sources derived from manure, as well as from vehicles and electric utility power plants (NOAA 1998).

Sources of nutrients vary greatly from place to place. Along the north Atlantic coast, non-point sources of nitrogen are some ninefold greater than inputs from wastewater treatment plants (EC 2001). But in some coastal areas, wastewater treatment plants remain the primary sources of nutrient inputs. For example, much municipal wastewater discharged into Canada's coastal waters is still subject only to primary treatment (EC 2000).

Rather than in coastal or marine environments, however, Canada's most serious over-enrichment

Box 23: Intensive Hog Farming

Nutrients from hog production, which has increased in scale, intensification, and geographical concentration over the past 25 years, strongly affect the health of North America's marine and coastal areas (Welsh, Hubbell, and Carpentier 2000). In 1992, there were about 60 million swine in the United States, which represents an 18 percent increase from the previous decade. During the same period, the number of hog farms dropped by 72 percent (Copeland and Zinn 1998). Canada's hog population grew from about 6 million in 1976 to 11 million in 1996 while the number of hog farms decreased from 65,000 to 20,000 during the same 20-year period (EC 2000). This trend toward industrialization of hog farming was influenced by cost and production advantages such as economies of scale, new technologies, advances in animal genetics, and new and more efficient management practices (Furuseth 1997).

Operations also have become more regionally concentrated since the 1980s. The most notable concentration has occurred in North Carolina's low coastal flood plain. The number of hogs in the state increased threefold between 1987 and 1998. North Carolina was 14th in hog production in 1970, but by the end of the 1990s it ranked second (NPPC 1999). Most of Canada's hog farms are found in southern Ontario and Quebec and the Prairie provinces (EC 2000). Geographic concentration was influenced by a number of factors, including incentives such as tax breaks and subsidies offered by local governments in both countries to attract hog producers in order to create local financial and employment gains. In some cases, US states such as North Carolina offered inexpensive land to attract the industry to economically declining rural areas (CIBE 1999). Finally, states with no anti-corporate farming laws also influenced geographic concentration (Welsh, Hubbell, and Carpentier 2000).

The intensification and concentration of hog production has exacerbated the challenge of manure and other hog waste disposal. Almost all hog manure (like manure from other livestock) is applied to agricultural land. Rich in nitrates and phosphates, hog manure is a valuable fertilizer, but if applied to the land in amounts that exceed plant needs, excess nutrients leach through the soils to contaminate ground or surface waters. There is increasingly too little land for the amounts of hog manure produced in these regions of concentrated hog farming (Furuseth 1997).

Hog manure is mostly stored in open-air lagoons with relatively little treatment before being sprayed on land to irrigate forage crops. Both lined and unlined lagoons can leak contaminants into groundwater. In the United States, intensive feedlots are the third leading agricultural source of water pollution and in North Carolina, they are the biggest source of nutrient pollution (Environmental Defense 1998). In 1997, Hurricane Floyd flooded many of the large hog facilities that had been built on North Carolina's low coastal flood plain. Hog wastes from at least 46 waste lagoons flowed into the surrounding floodwaters, contaminating local drinking water and threatening human health (Taylor 2001). A two-year moratorium on new hog factories was instituted in 1997 to allow new and lasting solutions to the problems associated with the state's hog industry to be developed (Environmental Defense 1998).

problems are found in the rivers of the southern Prairie Provinces, where agricultural activity is intensive, and in southern Ontario and Quebec, where inputs from manure and fertilizer as well as from municipal sewage and industrial wastewater are heavy (EC 2000). Canadian estuaries in the North Atlantic are less severely affected by nutrient loading than more southerly ones

Area of Gulf of Mexico Low-Oxygen Zone, 1985-1998

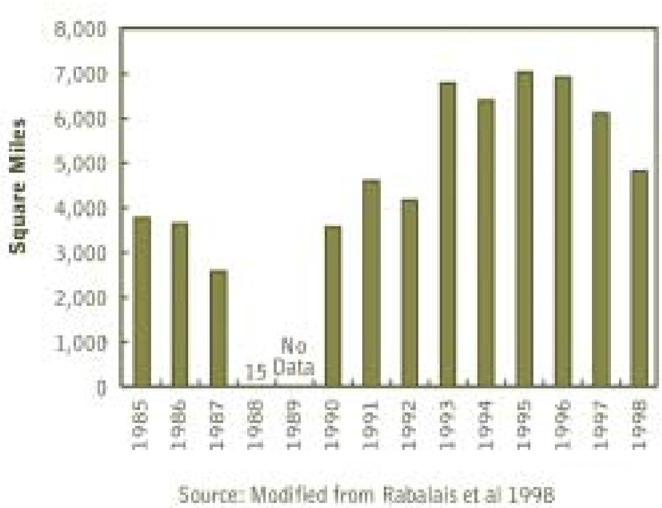


Figure 25
Area of Gulf of Mexico low-oxygen zone, 1985-1998.

Source: H. John Heinz III Center 1999.

thanks in part to a cooler climate and significant flushing of coastal waters (NOAA 1998).

Nutrient additions to the US coast have been increasing over the past two decades. In the mid-1990s, greater nutrient loading from municipal discharges and agricultural runoff contributed to the classification of some US estuarine and coastal waters as not 'fishable or swimmable' (CEQ 1996). In 1998, more than 60 percent of US coastal rivers and bays were moderately to severely degraded by nutrient contamination, and nitrogen was found to be the single greatest environmental threat in some 'trouble' spots on the Atlantic coast (Howarth, Anderson, and others 2000). More recently, a 2001 report states that approximately 65 percent of the nation's estuarine surface area has moderate to high eutrophic conditions. A high level of human influence is associated with 36 of the 44 estuaries with high eutrophication (Clement, Bricker, and Pirhalla 2001). In the last 40 years, human activity has increased the flux of nitrogen in the Mississippi River some fourfold and in rivers in the northeastern US some eightfold (NRCan 2000).

The Mississippi River, which drains 40 percent of the continental United States, carries excess nutrients to the Gulf of Mexico where they contribute to an area of hypoxia (see Box 22) called the 'dead zone'. Nearly 12,950 km^2 in the Gulf of Mexico were affected with low oxygen conditions in 1998 (H. John Heinz III Center 1999) (see Figure 25). The region is now subject to intensive research. An EPA task force formed in 1997 examined the causes and consequences of Gulf hypoxia as part of the basis of an Action Plan to reduce, mitigate and control hypoxia in the northern Gulf of Mexico. In October 2000, a US $1 billion-per-year plan was agreed upon to revive some 30 percent of the dead zone by 2015 (NOS 2000).

The US Clean Water Act, last reauthorized in 1987, and the 1972 and 1980 Coastal Zone Management Act directed states to develop management plans for non-point contamination sources and provided funding and incentives to implement them. In addition, the US National Estuary Program (NEP) was established in 1987 to identify key problems in specific estuaries and to develop and implement management plans to address them (NOAA 1998). The 1987 Chesapeake Bay Program, for example, was set up under the NEP. It is a federal-state-local partnership working to reduce nitrogen and phosphorous loading to the Bay by 40 percent. The Chesapeake Bay is the largest estuary in the United States and one of the most productive in the world. The region has a population of over 15 million and important commercial fish and shellfish harvests, and is a major stopover for migratory birds. By the late 1990s, only the phosphorous reduction goal had been met. Progress in reducing nutrients in the region is being hampered because of population growth and development (OECD 1996; EPA 1997).

Nutrient enrichment is a likely contributing factor in the recent dramatic increase in the number, intensity, frequency, and expanse of algal blooms or red tides (CEC 2000). Harmful algal blooms (HABs) (see Box 24) are found in the waters of almost every US coastal state and most have experienced their environmental, human health, and economic impacts (NSTC 2000). The number of coastal and estuarine waters in the United States that host major recurring incidents of HABs doubled between 1972 and 1995 (Harkin 1997) (see Figure 26). Along with nutrient enrichment, the recorded increase in several algal groups is likely to be due to improved methods of detection and greater monitoring efforts, introduction of exotic species, failure of grazers to control the algal species' growth, climate changes, natural events, and habitat degradation (Bushaw-Newton and Sellner 1999; NSTC 2000).

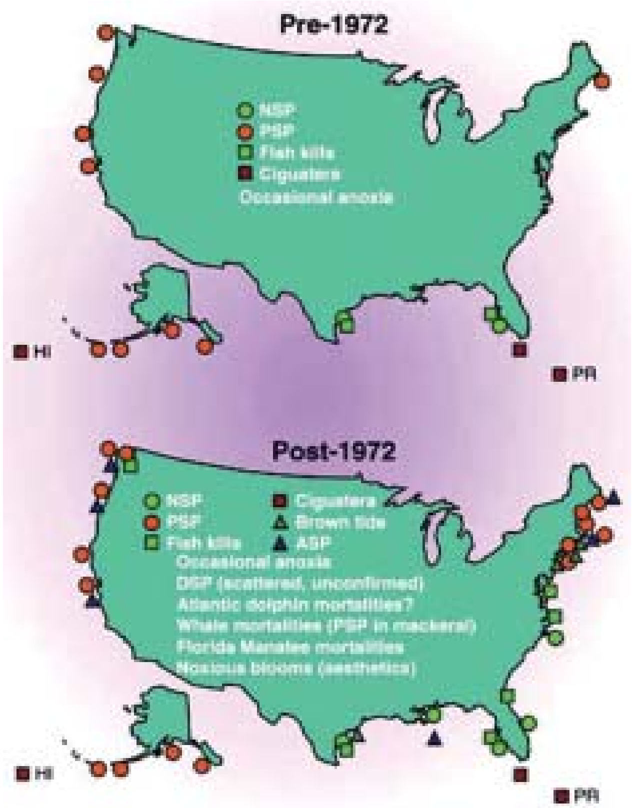
The impacts of HAB events can include human illness and death from eating contaminated fish or shellfish, mass mortalities of wild and farmed fish, restricted local harvests of fish and shellfish, and changes in marine food chains due to the negative effects on eggs,

Box 24: Harmful Algal Blooms (HABs) and Red Tides

The algae that form Harmful Algal Blooms or HABs are a very diverse group of organisms that range from single-celled microalgae or phytoplankton to large seaweed-like macroalgae. The most well known is the dinoflagellate *Pfiesteria piscicida.* Some species produce toxins and appear in great abundance in massive 'blooms'. Some contain pigments that tint the water red to produce what is commonly known as 'red tides', while others turn the water green or brown or have no color or massive concentration during the toxic phase. HABs are harmful because they produce highly potent toxins that can kill marine organisms directly or travel through the food chain as the algae are consumed by shellfish and other marine life, causing harm at multiple levels. Although the toxins may only slightly affect shellfish, the amount in one clam can kill a human (NSTC 2000; EC 2001).

young, and adult marine invertebrates, seabirds, sea turtles, and mammals (NSTC 2000). The expansion of HABs in the United States over the past 20 years has caused losses of about US $100 million per year in medical-related expenses and impacts on the fishing and tourism industries, among others (Bushaw-Newton and Sellner 1999).

Location of HAB-related Events in US Coastal Waters Before and After 1972



Abbreviations: NSP, neurotoxic shellfish poisoning; PSP, paralytic shellfish poisoning; ASP, amnesic shellfish poisoning; DSP, diarrheic shellfish poisoning.

Figure 26
Location of HAB-related events in US coastal waters before and after 1972.

Source: Bushaw-Newton and Sellner 1999.

In response to incidents of human illness from contaminated shellfish, both Canada and the United States have developed testing and water quality programs to identify phytoplankton toxins and to provide information about them to the public. Recently, public concern and research into marine toxins and HABs has intensified due to increased incidences of fish kills and fish with lesions in 1997 in Chesapeake Bay tributaries and in North Carolina (NOAA 1998). The Ecology and Oceanography of Harmful Algal Blooms (ECOHAB), an interagency program established in 1996, provides information on environmental conditions that favor optimal growth and toxicity of several noxious species and supports numerous research projects on HABs (CEQ 1996). The US Harmful Algal Bloom and Hypoxia Research and Control Act requires an examination of the means to reduce, mitigate, and control HABs, and of their social and economic costs and benefits. Controlling the human inputs that stimulate nutrient enrichment is one approach that may reduce the incidence of HABs (NSTC 2000).

Canadian and US Ocean Acts (1997 and 2000, respectively) establish frameworks for improving the stewardship of North America's coastal and ocean waters (EC 1999; The White House 2000). As yet, there is no binational strategy to address nutrient loading in North America's coastal waters, and coordination among the various agencies responsible for their management is still inadequate (NRCan 2000). Evidence suggests that the situation can be reversed, but the need remains for increased political action and cultural and behavioral changes to reduce human activities that emit nutrients to the water- and airsheds that feed coastal streams and rivers.

References

Alden, Robin (1999). A Troubled Transition for Fisheries: Sustaining Marine Fisheries. *Environment* 41 (4):25-8

ASF (2000). *The Wild Atlantic Salmon: State of the Populations in North America 2000*. The Atlantic Salmon Federation http://www.asf.ca/stateofsalmon/SOP2000E.pdf. Accessed 29 May 2002

Botkin, Daniel, and Edward A. Keller (1995). *Environmental Science: Earth As a Living Planet*. New York, John Wiley & Sons, Inc.

Bricker, S., C. Clement, D. Pirhalla, S.P. Orlando, and D.R.G. Farrow (1999). *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*, National Ocean Service, NOAA

Brown, Kathryn (2000). Pacific Salmon Run Hot and Cold. *Science* 290 (5492):685-6

Buck, Eugene H., M. Lynne Corn, and Pamela Baldwin (2001). *IB10072: Endangered Species: Difficult Choices*, CRS Issue Brief for Congress, National Council for Science and the Environment http://cnie.org/NLE/CRSreports/Biodiversity/biodv-1.cfm#_1_1. Accessed 23 January 2002

Bushaw-Newton, K.L., and K.G. Sellner (1999). Harmful Algal Blooms. In *NOAA's State of the Coast Report*. US National Oceanic and Atmospheric Administration, Silver Spring, Maryland http://state-of-coast.noaa.gov/bulletins/html/hab_14/hab.html. Accessed 12 February 2002

Carlisle, John (1999). *Nature, Not Man, is Responsible for West Coast Salmon Decline*. National Policy Analysis http://www.nationalcenter.org/NPA254.html. Accessed 12 February 2002

Carpenter, Stephen, Nina F. Caraco, David L. Correll, Robert W. Howarth, Andrew N. Sharpley, and Val H. Smith (1998). Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. *Issues in Ecology* (3)

CEC (1997). *Ecological Regions of North America: Toward a Common Perspective*. Montreal, Commission for Environmental Cooperation of North America http://www.cec.org/files/pdf/BIODIVERSITY/eco-eng_EN.pdf. Accessed 11 February 2002

CEC (2000). *Booming Economies, Silencing Environments, and the Paths to Our Future: Background Note by the Commission for Environmental Cooperation on Critical and Emerging Environmental Trends*. Montreal, Commission for Environmental Cooperation of North America http://www.cec.org/pubs_docs/documents/index.cfm?varlan=english&ID=66. Accessed 26 February 2002

CEQ (1996). *Environmental Quality: The Twenty-fifth Anniversary Report of the Council on Environmental Quality*. Washington DC, US Council on Environmental Quality

CIBE (1999). Industrial Hog Farming in Canada Becoming a Major Environmental Problem. *The Gallon Environment Letter Special (Canadian Institute for Business and the Environment)* 3 (30)

Clement, Chris, S.B. Bricker, and D.E. Pirhalla (2001). Eutrophic Conditions in Estuarine Waters. In *NOAA's State of the Coast Report*. Silver Spring MD, National Oceanic and Atmospheric Administration http://state-of-coast.noaa.gov/bulletins/html/eut_18/eut.html. Accessed 12 February 2002

Copeland, Claudia, and Jeffrey Zinn (1998). *Animal Waste Management and the Environment: Background for Current Issues*. The National Council for Science and the Environment http://cnie.org/NLE/CRS/abstract.cfm?NLEid=16293.Accessed 12 February 2002

Culliton, T.J., C.M. Blackwell, D.G. Remer, T.R. Goodspeed, M.A. Warren, and J.J. McDonough III (n.d.). *Fifty Years of Population Change Along the Nation's Coasts, 1960-2010. Coastal Trends Series, Report #2*. Rockville MD, Strategic Assessment Branch, Ocean Assessment Division, Office of Oceanography and Marine Assessment, National Ocean Survey, NOAA

DFAIT (2002). *Current Issues in Canada–US Relations*. Washington DC, Department of Foreign Affairs and International Trade, Embassy of Canada http://www.canadianembassy.org/foreignpolicy/report.asp. Accessed 11 February 2002

DFO (1999a). *1999 Agreement Between Canada and the US Under the Pacific Salmon Treaty*. Fisheries and Oceans Canada http://www.ncr.dfo.ca/pst-tsp/agree/toc_e.htm. Accessed 12 February 2002

DFO (1999b). *Backgrounder: Pacific Fisheries Adjustment and Restructuring Program*. Fisheries and Oceans Canada http://www.ncr.dfo.ca/COMMUNIC/BACKGROU/1999/hq29%28115%29_e.htm. Accessed 12 February 2002

DFO (2000a). *Canadian Aquaculture Production Statistics*. Fisheries and Oceans Canada http://www.dfo-mpo.gc.ca/communic/statistics/aquacult/aqua_e.htm. Accessed 12 February 2002

DFO (2000b). *Annual Summary Commercial Statistics, Salmon Landings in BC (1951-95)*. Fisheries and Oceans Canada – Pacific Region http://www-sci.pac.dfo-mpo.gc.ca/sa/. Accessed 12 February 2002

DFO (2000c). Fisheries and Oceans Announces Rebuilding Efforts Result in Astounding Recovery of Upper Adams and Nadina Sockeye Runs. *News Release*. Fisheries and Oceans Canada http://www-comm.pac.dfo-mpo.gc.ca/english/release/p-releas/2000/nr00138e.htm. Accessed 12 February 2002

DFO (2001a). *Building Awareness and Capacity: An Action Plan for Continued Sustainable Development 2001-2003*. Fisheries and Oceans Canada http://www.dfo-mpo.gc.ca/sds-sdd/SDS01-03_e.pdf/susdev-e2.pdf. Accessed 11 February 2002

DFO (2001b). *Pacific Salmon Treaty: Canada and US Reach a Comprehensive Agreement under the Pacific Salmon Treaty*. Fisheries and Oceans Canada http://www.dfo-mpo.gc.ca/pst-tsp/main_e.htm. Accessed 11 February 2002

EC (1996). *The State of Canada's Environment – 1996*. Environment Canada http://www.ec.gc.ca/soer-ree/English/1996Report/Doc/1-1.cfm. Accessed 28 May 2002

EC (1999). *Canada's Oceans: Experience and Practices*. Canadian Contribution to the Oceans and Seas Dialogue, Paper for the Seventh Session of the United Nations Commission on Sustainable Development (UN CSD), 19-30 April

EC (2000). *Nutrient Additions and Their Impacts on the Canadian Environment: Reporting on the State of Canada's Environment*. Environment Canada http://www.durable.gc.ca/group/nutrients/report/index_e.phtml. Accessed 28 May 2002

EC (2001). *Nutrients in the Canadian Environment: Reporting on the State of Canada's Environment*. Environment Canada, Indicators and Assessment Office, Ecosystem Science Directorate, Environmental Conservation Service http://www.ec.gc.ca/soer-ree/english/national/nutrientseng.pdf. Accessed 31 January 2002

Environmental Defense (1998). *Environmental Defense Hog Watch* http://www.hogwatch.org/. Accessed 12 February 2002

EPA (1997). *Deposition of Air Pollutants to the Great Waters: Second Report to Congress*. Research Triangle Park NC, US Environmental Protection Agency, Office of Air Quality Planning and Standards

EPA (1998). *Terms of Environment, Revised Edition*. US Environmental Protection Agency http://www.epa.gov/OCEPAterms. Accessed 12 February 2002

EPA (2001). *Nutrient Criteria: Technical Guidance Manual,Estuarine and Coastal Marine Waters*. US Environmental Protection Agency, Office of Water http://www.epa.gov/ost/standards/nutrients/marine/. Accessed 11 February 2002

FAO (1990-1998). *Total Fish Catch (MT)*. FAOSTAT Fisheries Data http://apps.fao.org/page/collections?subset=fisheries. Accessed 13 February 2002

Federal Caucus (2000). *Basinwide Salmon Recovery Strategy*. SalmonRecovery.gov http://www.salmonrecovery.gov/strategy.shtml. Accessed 13 February 2002

Fishstat (2001). *FISHSTAT Plus, Universal Software for Fishery Statistical Time Series*. FAO Fisheries, Software version 2.3 http://www.fao.org/fistatist/fisoft/fishplus.asp. Accessed 31 May 2002

Furuseth, Owen J. (1997). Restructuring of Hog Farming in North Carolina: Explosion and Implosion. *Professional Geographer* 49 (4):392-303

Glavin, Terry (1996). *Dead Reckoning: Confronting the Crisis in Pacific Fisheries.* Vancouver, Greystone Books

H. John Heinz III Center (1999). *Designing a Report on the State of the Nation's Ecosystem: Selected Measurements for Croplands, Forests, and Coasts and Oceans.* The H. John Heinz III Center for Science, Economics and the Environment http://www.heinzcenter.org/publications/Coasts.pdf. Accessed 12 February 2002

Hanfman, Deborah T. (1993). *The Status and Potential of Aquaculture in the United States: An Overview and Bibliography.* National Agricultural Library Aquaculture Information Center, National Agricultural Library Beltsville, Maryland http://ag.ansc.purdue.edu/aquanic/publicat/govagen/nal/status.htm. Accessed 12 February 2002

Hare, S.R., and N.J. Mantua (2000). Empirical Evidence for North Pacific Regime Shifts in 1977 and 1989. *Progress in Oceanography* 47 (2-4):103-46

Harkin, Senator Tom (1997). *Animal Waste Pollution in America: An Emerging National Problem.* Report Compiled by the Minority Staff of the United States Senate Committee on Agriculture, Nutrition, & Forestry for Senator Tom Harkin http://www.senate.gov/~agriculture/Briefs/animalw.htm. Accessed 13 February 2002

Howarth, Robert , Donald Anderson, James Cloern, Chris Elfring, Charles Hopkinson, Brian Lapointe, Tom Malone, Nancy Marcus, Karen McGlathery, Andrew Sharpley, and Dan Walker (2000). Nutrient Pollution of Coastal Rivers, Bays, and Seas. *Issues in Ecology* (7) http://esa.sdsc.edu/issues.htm

JISAO (2000). *The Pacific Decadal Oscillation (PDO).* Joint Institute for the Study of the Atmosphere and Ocean http://tao.atmos.washington.edu/pdo/. Accessed 12 February 2002

Kope, Robert G. (1999). Pacific Salmon. In *Our Living Oceans: Report on the Status of US Living Marine Resources, 1999.* US National Marine Fisheries Service, US Department of Commerce, NOAA Tech, Memo. NMFS-F/SPO-41, on-line version http://spo.nwr.noaa.gov/unit12.pdf. Accessed 13 February 2002

Mann, Charles, C., and Mark L. Plummer (2000). Can Science Rescue Salmon? *Science* 289 (5480):716-19

Mathews, Emily, and Allen Hammond (1999). *Critical Consumption Trends and Implications: Degrading Earth's Ecosystems.* Washington DC., World Resources Institute

Miller Jr., G. Tyler (1985). *Living in the Environment: An Introduction to Environmental Science.* Vol. 4. Belmont, CA, Wadsworth Publishing Company

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grand, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples (1998). *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.* US Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35

NMFS (1998). *Factors Contributing to the Decline of Chinook Salmon: An Addendum to the 1996 West Coast Steelhead Factors For Decline Report.* Protected Resources Division, National Marine Fisheries Service http://www.nwr.noaa.gov/1salmon/salmesa/pubs.htm#Factors for Decline. Accessed 13 February 2002

NMFS (2000). *Fisheries Statistics & Economics, Commercial Fisheries, Annual Landings.* Silver Spring MD, National Marine Fisheries Service, Fisheries Statistics and Economics Division, http://www.st.nmfs.gov/. Accessed 27 February 2002

NOAA (1998). *1998 Year of the Ocean: Perspectives on Marine Environmental Quality Today.* US National Oceanic and Atmospheric Administration http://www.yoto98.noaa.gov/yoto/meeting/mar_env_316.html. Accessed 13 February 2002

NOAA (1999). *United States Announces Agreement With Canada On Pacific Salmon.* US Department of State, US Department of Commerce http://www.nwr.noaa.gov/1press/060399_1.html. Accessed 13 February 2002

NOS (2000). *National Centers for Coastal Ocean Science, Gulf of Mexico Hypoxia Assessment.* National Ocean Service, National Oceanic and Atmospheric Administration, US Department of Commerce http://www.nos.noaa.gov/products/pubs_hypox.html. Accessed 13 February 2002.

NPPC (1999). *1999/2000 Pork Issues Handbook*. National Pork Producers Council http://www.nppc.org/IssueHandbook/99_2000_handbook.pdf. Accessed 13 February 2002

NRCan (1998). *Sensitivities to Climate Change*. Natural Resources Canada, Geological Survey of Canada http://sts.gsc.nrcan.gc.ca/adaptation/sensitivities/map5.htm. Accessed 13 February 2002

NRCan (2000). *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution*. Committee on the Causes and Management of Coastal Eutrophication, Ocean Studies Board and Water Sicence and Technology Board; Commission on Geosciences, Environment, and Resources; National Research Council. Washington DC, National Academy Press http://books.nap.edu/books/0309069483/html/R1.html. Accessed 13 February 2002

NSTC (2000). *National Assessment of Harmful Algal Blooms in US Waters*. National Science and Technology Council, Committee on Environment and Natural Resources http://www.habhrca.noaa.gov/FinalHABreport.pdf. Accessed 11 February 2002

OECD (1996). *Environmental Performance Reviews: United States*. Paris, Organization for Economic Co-operation and Development

OSF (2000). *Office of Sustainable Fisheries Home Page*. Office of Sustainable Fisheries, NOAA Fisheries, National Marine Fisheries Service http://www.nmfs.noaa.gov/sfa/sfweb/index.htm. Accessed 11 February 2002

PSC (2000). *Pacific Salmon Commission*. Pacific Salmon Commission http://www.psc.org/Index.htm. Accessed 13 February 2002

Rabalais, Nancy N. (1999). *Oxygen Depletion in Coastal Waters: NOAA's State of the Coast Report*. Silver Spring MD, US National Oceanic and Atmospheric Administration http://state-of-coast.noaa.gov/bulletins/html/hyp_09/hyp.html. Accessed 12 February 2002

Statistics Canada (2000). *Human Activity and the Environment*. Ottawa, Minister of Industry

Strangway, David W., and William D. Ruckelshaus (1998). *Pacific Salmon Report to the Prime Minister of Canada and to the President of the United States*. Fisheries and Oceans Canada http://www.ncr.dfo.ca/pst-tsp/reports/report.htm. Accessed 13 February 2002

Taylor, David A. (2001). From Pigsties to Hog Heaven. *Environmental Health Perspectives* 109 (7):A328-31

The White House (2000). *Statement by the President on Oceans Act 2000*. Martha's Vineyard MA, The White House, Office of the Press Secretary http://clinton6.nara.gov/2000/08/2000-08-07-statement-by-the-president-on-oceans-act-of.html. Accessed 13 February 2002

TU / TUC (1999). *Resolving the Pacific Salmon Treaty Stalemate*. Seattle, Trout Unlimited USA in partnership with Trout Unlimited Canada http://www.tu.org/newsstand/library_pdfs/pacificsalmon99.pdf. Accessed 13 February 2002

USGCRP (2000). *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*. Washington DC, National Assessment Synthesis Team, US Global Change Research Program http://sedac.ciesin.org/NationalAssessment/. Accessed 13 February 2002

Walters, Carl (1995). *Fish on the Line: The Future of Pacific Fisheries*. Vancouver, The David Suzuki Foundation

Welch, David (1999). What is the Most Alarming Potential Impact of Climate Change on Salmon Stocks? Panel at Climate Change and Salmon Stocks, 27 October, at Vancouver BC, Pacific Fisheries Resource Conservation Council

Welsh, R., B. Hubbell, and C.L. Carpentier (2000). Agro-Food System Restructuring and the Geographic Concentration of US Swine Production, 1975–1996. *Environment & Planning* unpublished manuscript currently under review

YCELP (1995). *A Request for a NACEC Secretariat Report on Opportunities for Forest Preservation and Sustainable Management*. Student Clinic, Yale Center for Environmental Law and Policy, Yale Environmental Policy Clinic for the Natural Resources Defense Council http://www.yale.edu/envirocenter/clinic/nacec.html. Accessed 27 February 2002