Report From A Workshop on Chemical Hazards to Fish and Fisheries

Burlington, Ontario
September 10 - 12, 1985

M. Adam, W. D. McKone, and H. Shear

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Report From A Workshop on Chemical Hazards to Fish and Fisheries

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ABSTRACT

Adam, M., W.D. McKone, and H. Shear. 1987. Report from a workshop on chemical hazards to fish and fisheries. Can. Tech. Rep. Fish. Aquat. Sci. 1525: 105 p.

This Workshop on Chemical Hazards to Fish and Fisheries was held with the objective of describing:

1) The hazards posed by chemicals to Canadian fish and fisheries;

2) The hazards likely to become priorities during the next decades;

3) The likely state of Canadian fisheries in ten years, if no action is taken.

Recommendations are provided for the Department to consider in reviewing the existing program and leading to future directions that DFO toxic chemical program might take.

RÉSUMÉ

Adam, M., W.D. McKone, and H. Shear. 1987. Report from a workshop on chemical hazards to fish and fisheries. Can. Tech. Rep. Fish. Aquat. Sci. 1525: 105 p.

Ce Colloque concernant les effets des produits chimiques dangereux sur la pêche et les poissons visait les objectifs suivants :

1) les effets des produits chimiques dangereux sur la pêche et les poissons au Canada;

2) les effets des produits chimique dangereux susceptibles de devenir prioritaires au cours des prochaines décennies; et

3) la situation probable des pêches canadiennes dans dix ans si aucune mesure n'est prise.

On formule des recommandations à l'intention du Ministère qui serviront dans le processus de révision du programme actuel et permettront d'orienter le programme du MPO concernant les produits chimiques toxiques.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

In 1987, Canadian exports of fish and fish products to foreign markets are expected to earn $2.2 billion in foreign exchange. Domestic commercial and recreational fisheries will provide, directly or indirectly, employment for tens of thousands of Canadians. Canadian fisheries have suffered from the increasing impact of widespread contamination from increased industrialization in recent years. Chemical contamination has affected the Great Lakes, other freshwater lakes and rivers, estuaries and marine inshore fisheries. Chemical contaminants have been detected in some offshore species, and in the Arctic, far from sources of industrialization.

About 6 million chemicals have been synthesized or prepared from natural products, and about 60,000 are in common commercial use. About 1,000 new chemicals are created annually. Chemicals may enter fisheries waters as residues in wastes, through spraying or accidental spills, or by leakage from old disposal sites. Many chemicals are toxic at levels found at these sites, some deleterious, to fish. Many are of concern in human consumption of fish at tissue levels that may not be harmful to fish.

On September 10-12, 1985, DFO sponsored a Workshop on Chemical Hazards at Burlington, Ontario, convened by the Assistant Deputy Minister, Pacific and Freshwater Fisheries, DFO, Mrs. A. Lefebvre-Anglin, and chaired by Dr. B.S. Muir. The objectives of the Workshop were to describe:

1) The hazards posed by chemicals to Canadian fish and fisheries;

2) The hazards likely to become priorities during the next decade;

3) The likely state of Canadian fisheries in ten years, if no action is taken.

The Workshop produced a summary report in the spring of 1986 (included as Sections A and B) describing the major aspects of the chemical contamination of Canadian fisheries, and zonal reports detailing the specifics of chemical problems in different regions of Canada.

Major Hazards and Priority Issues

a) Historical stockpiles and disposal sites, which are difficult to control or eliminate, are important sources of contaminants to the freshwater and coastal marine environments;

b) Diffuse sources of contaminants constitute a second source that can have more widespread effects. Reducing the effects of releases from such sources requires harmonization of national and international efforts. Long-range atmospheric transport and deposition of contaminants, of which acid rain is an example, is also included in this class of diffuse sources;

c) Pesticide spraying consitutes a third category of releases but one that is amenable to greater control and regulation than the previous categories;

d) Recycling of chemicals already present in the environment occurs when natural, or human, activities disturb soils or sediment, or alter hydrologic regimes. Such events are rarely amenable to control;

e) Acute episodes of contamination and fish kills from accidental spills of chemicals in commercial and agricultural use are another souce of chemicals;

f) Deficiencies in both scientific understanding of chemical contamination effects on fish and available technology to resolve contamination problems, continue to perplex agencies to whom the responsibility for maintaining a clean environment, healthy fish stocks, and quality fish stocks, has been entrusted.

g) Regulatory deficiencies, either reflecting jurisdictional problems, ineffective enforcement, or administrative deficiencies continue to contribute to contamination and pollution incidents;

h) Difficulties concerning coordination and cooperation between regulatory agencies and between them and the industrial sector continue to reduce the effectiveness of measures to reduce or eliminate contamination of fisheries;

i) Public perceptions that fish are contaminated with toxic chemicals will continue to undermine the marketing of fish within Canada. The imposition of limits for the incidence of contaminants in foodstuffs in foreign markets more stringent than those in Canada, are also likely to undermine public confidence in instances where Canadian products do not meet, or are perceived not to meet, these criteria.

Barriers to Effective Clean-up and Prevention of Contamination

a) **Legislative Jurisdiction:**

Federal and provincial jurisdictional difficulties concerning the control of water and the regulation of industrial and municipal pollution are central to the contamination problem. Mixed jurisdiction, limited legislation and ineffective enforcement have prevented a straightforward and comprehensive attack on the variety of chemical contamination incidents which have affected Canadian fisheries.

b) **Biochemical Characteristics:**

Once released into the atmosphere or into fisheries waters, hazardous chemicals may resist chemical breakdown, concentrate in living organisms and recycle through the environment by biogeochemical processes. Moreover, chemicals may act synergistically in the environment, creating effects different from those of the separate components. Such chemical and biological factors add complexity to jurisdictional and regulatory difficulties, and add a new dimension to the problems faced by regulatory agencies in dealing with the control or clean-up of toxic chemicals in fisheries waters.

The Next Ten Years

Fish health and the marketability of fish products will continue to be at risk as long as the atmosphere and water are used as sinks for wastes. Despite some industrial regulation, diffuse and multiple sources of chemicals, particularly in heavily industrialized and high population locales, will continue to affect Canadian fisheries.

Future marketability of fish may be adversely affected when food tolerances are exceeded, or when new Canadian food tolerancss are set for chemicals not presently subject to regulation. Exports could be affected if importing countries set food tolerances lower than present levels of contamination. This may result in loss of confidence by both domestic and foreign buyers.

The productivity of fish stocks may be at serious risk over the next decade. Chronic exposure to toxic chemicals can impair reproduction, enhance mortality rates, reduce growth and change migratory behaviour. The result is reduced biomass and species diversity and reduced population size. Alterations to the natural habitat of fish resulting from chemical impacts will generate additional pressure on fish stocks.

Considering the jurisdictional, chemical and scientific difficulties, we can project that present regulatory measures will not adequately protect fish stocks and ensure their continued productivity.

A: PROBLEM IDENTIFICATION

1. RESOURCES AT RISK

Canada is the world's largest fish exporter with total exports in 1984 valued at over $1.6 billion, accounting for over 75% of Canadian fish production. By 1987, exports of fish and fishery products are expected to reach $2.2 billion. In the context of our large resource base in both traditional and underutilized species, Canada's dependence on export markets is expected to increase in the near future. Export markets are characterized by volatile exchange rates, unstable prices, growing competition from other fish producing countries and fish substitutes. Changes in the quality and acceptability of fish products, caused by chemical contamination, will add to the already complex marketing situation. The possibility of effects on the viability of stocks adds a further complication.

As reported in the newspapers, the Great Lakes system is potentially the most contaminated body of freshwater in North America. It covers 44,000 square miles, part of which lies in the industrial heartland of Canada and all of which is shared with the U.S.A. Toxic chemicals are found in all resident fish species. The Canadian and American commercial and recreational freshwater fisheries combined are the largest and most valuable in the world. The Ontario commercial fishery employs about 2,700 persons in the primary sector and 1,500 persons in the secondary processing sector. The recreational fishery is the largest and most valuable in Canada. Attracting over 600,000 non-resident anglers annually, it sustains an important component of Ontario's multi-billion dollar tourism industry, providing regional income and employment to some 10,000-15,000 people.

Other freshwater fisheries in Canada have not been so dramatically and extensively affected. However, with increased industrialization, these fisheries may suffer more seriously the widespread effect, with consequent loss of access to commercial, recreational and native users. Contamination is associated primarily with single sources such as mines, pulp and paper processing plants, and refineries. Freshwater resources are also at risk from the effects of long-range transport of atmospheric contaminants, and these risks are increasing.

To date, valuable marine inshore fisheries have suffered localized contamination affecting limited areas or specific species. In the offshore fisheries, contaminants such as

PCBs, have been found in cod in the Gulf of St. Lawrence and in various Arctic species. Many contaminants affecting Gulf waters derive from the heavily contaminated lower Great Lakes system while those found in the Arctic are most likely from southern regions and carried northward on airborne currents. Increased industrialization in the absence of proper regulation of effluents could result in further losses of fisheries resources.

2 FEDERAL AND PROVINCIAL JURISDICTIONAL DIFFICULTIES

2.1 JURISDICTIONAL RESPONSIBILITIES.

a) Constitutional Problems

The respective responsibilities of the Federal and Provincial Governments concerning the regulation of water resources and its users are difficult to define precisely. The constitutional responsibilities for water have not been clearly defined, except in a few instances (e.g., the Fisheries Act), and judicial decisions have not clarified the situation. Provinces retain jurisdiction over water resources by virtue of their responsibility for "property and civil rights". The Provinces also control local works and undertakings, and "all matters of a merely local or private nature" within their borders.

Additionally, a 1982 amendment to the Constitution Act specifies that the provinces have jurisdiction over electricity-generating works.

b) Federal Prerogatives

The Federal Government retains exclusive jurisdiction over some matters concerned with water management including fisheries, navigation, native peoples, relations with other governments, federal lands, works of common benefit to Canadians and "peace, order and good government". The federal prerogative on these matters limits the authority of the Provinces over waters. For example, the Federal Government can pass regulations to protect and manage fisheries and fish habitat under the authority of the Fisheries Act, and can prevent dangerous substances from being released into the environment under the authority of the Environmental Contaminants Act. Under the latter Act the Ministers of the Environment and Health and Welfare are jointly responsible for the compilation of a list of substances that pose a threat to the environment or to human health. Release of the listed substances is prohibited except under strict regulations. PCBs, PBBs, PCTs, MIREX and chlorofluorocarbons, have been listed as dangerous to human health. In other areas such as agriculture there is joint provincial-federal legislation but in cases of conflict, such as in the application of the Pest Control Products Act, federal legislation prevails.

The Provinces have exclusive jurisdiction over health-related matters, but the Federal Government through the Food and Drug Act, can use other legislative powers,relating to interprovincial and international trade, to regulate the permissible level of chemical contaminants found in fish used as food.

c) **Interprovincial jurisdiction**

The control of movement of water between provinces and territories remains a jurisdictional uncertainty. The federal authority to intervene where waters cross from one province or territory to another, or where they run along common boundaries, remains unclear. In a landmark case, judges at the Interprovincial Cooperatives trial left a void in the authority over interprovincial rivers. [Interprovincial Co-operatives Ltd. vs. The Queen in the Right of Manitoba 1975, 53 D.L.R. (3d) 321 (S.C.C.)].

d) **International Jurisidiction**

Many major rivers and lakes cross, or define, our border with the United States. The Federal Government, because of its authority for international affairs, becomes involved in managing these waterways. Two international agreements are of importance in the management of fish habitat, The Boundary Waters Treaty of 1909 and The Great Lakes Water Quality Agreement (1972, 1978). The Boundary Waters Treaty established the International Joint Commission and laid down the basic principles for the common use of water shared between the two countries. The Commission has been unable to address fully issues relating to deleterious substances in the aquatic ecosystem, because the issue of acid rain and toxic chemical dumps at Niagara have never been referred to the Commission for resolution.

The Great Lakes Fishery Convention (1956) provided a medium for fisheries management in the Great Lakes. The Great Lakes Fishery Commission, established under the Convention, is the overall fisheries management coordinating body in the Great Lakes. A Habitat Advisory Board, established by the Commission, is starting to liaise with IJC Committees.

e) **Implications for Resource Management**

The complexity of jurisdictional responsibility has contributed to reduced water in quality and missed opportunities for the enhancement of fisheries in highly populated areas of Canada. Unchecked industrial development and urban population growth have degraded local water supplies and fish habitat. In some cases, this has led to interruptions in fish marketing. Examples include the Great Lakes fisheries, closed because the levels of toxic chemicals in edible fish flesh have been found to exceed those considered potentially dangerous to human health. The result is a net loss of income and loss of recreational opportunities.

Activities in one jurisdiction can impair the quality of water available in another, creating disputes among conflicting public and private interests. Jurisdictional complexities confuse the public, industry and other water users.

2.2 THE INTRODUCTION AND RECYCLING OF CHEMICALS IN FISHERIES WATERS

Toxic chemicals, discharged into the atmosphere, circulate and eventually settle on land or water, either as dust or rain and snow. Toxic chemicals which settle on the land may be bound up or dissolved in water. In the case of acids they leach naturally occurring metals from soil. Melting snow downwind from sulphur-emitting industries for example, can leach heavy metals in concentrations detrimental to fish health.

Toxic chemicals may be released directly into the water as a result of hydroelectric development, industry, aquaculture, forestry spraying, leakage from chemical dumps, and from municipal sewage treatment plants. For example, naturally occurring mercury and aluminum tend to dissolve in reservoir water at levels which affect both fish health and the marketability of fish products.

Chemical and physical exchange of toxic chemicals occurs at serve as another path to rivers and lakes. Some toxic chemicals entering sewage treatment facilities may be either removed with the sludge or pass completely through the system into the aquatic environment because the technology of the system is unable to remove them. Treatment technology may alter the structures of chemical constituents and thereby increasing the toxicity of treated effluent. Chemicals from contaminated sewage sludge can then be reintroduced into the air and water to be further recycled. Chemicals in the aquatic system may be bound to the sediment, only to be released at a future date if the equilibrium shifts as a result of environmental change.

In recent years, research has shown that natural cleansing processes may not be effective in eliminating toxic chemicals from water systems. Certain chemicals resist chemical degradation, and may instead move through biological cycles. Some chemicals accumulate in biological tissues. This process does occur in fish for certain chemicals, such as PCBs, PAHs, and heavy metals.

Toxic chemicals, once present in the environment, can be recycled and distributed geographically through a number of pathways, resulting in degradation in the health of fish and of fish habitat. Persistent chemicals may continue to be spread and recycled throughout the host ecosystem and other ecosystems for years before being degraded or more permanently removed. Additionally, the cycling of toxic chemicals can be modified by changes in the ecosystem (e.g. cultural impact or climate variation) which in turn may lead to changes in the degree of biological impact, depending on the forms of input loadings of contaminants.

Globally, about one thousand new chemicals are synthesized annually and many of these find their way into Canadian waters through different pathways. This large number of new chemicals makes it difficult to identify and analyze their effects on aquatic ecosystems. Certain chemicals have effects at concentrations lower than levels detectable by current technology. Recent advances in instrumentation, and reductions in sample contamination, have resulted in the detection of chemicals which were previously not thought to be present in aquatic ecosystems at significant levels. Further technological advances are necessary to define minimum levels of chemicals that are harmful to fish.

Demographic effects as human population expands will require further reductions in the release of toxic chemicals to maintain existing water quality in areas such as the Great Lakes.

Additionally, the interaction between existing chemicals in the environment and those newly synthesized and released into fisheries waters can have unsuspected and serious consequences for the health of fish. Current understanding of synergistic effects is limited.

Such chemical and biological factors add additional complexities to jurisdictional and regulatory difficulties and add a new dimension to the problems faced by the Federal Government and the Provinces when trying to control or clean up toxic chemicals. Preventing the release of a persistent chemical into the environment may have little noticeable immediate effect. Rather, it may take several years before an ecosystem has cleansed itself.

As long as toxic chemicals are released into the environment either directly or through recycling, fish health and the marketability of fish products will continue to be at risk.

3. THE NEXT TEN YEARS

3.1 MARKETABILITY OF FISH

Canada has regulated the maximum permissible concentration of mercury, PCB's, MIREX, DDT, and a number of organochlorines, and other compounds in fish flesh offered for sale domestically. Prior to 1979, the Food and Drugs Act and Regulations listed tolerances for arsenic, lead, copper, zinc and fluorine in marine and freshwater animal products but these tolerances were withdrawn in 1979. Presently, when elevated levels of contaminants are encountered for which a tolerance does not exist, and the Department of Health and Welfare has recommended to DFO that commercial fishing be prohibited, DFO has cooperated to avoid the necessity of action being taken under the Food and Drugs Act with resulting adverse publicity. Most foreign nations to which Canada exports fish have set standards for some of these chemicals. In some instances these foreign standards are more stringent than Canadian regulations. Such standards, both domestic and foreign, are normally set on the basis of maximum tolerances for human health, taking into account average consumption of fish.

Over the next decade, we can project that there will be instances when food standards will be exceeded, with some consequent adverse effect on marketability of the catch. This may occur as a result of continuing, and possibly increasing, airborne pollution from both domestic and foreign sources, or as a result of unregulated effluents from industrial, municipal, and non-point sources. Chemical leaching from old disposal sites may also form a significant source of contamination from highly toxic persistent compounds. Although emissions from some industries are regulated by law, diffuse and multiple sources from large industrial cities will degrade water quality and lead to instances where commercial catches exceed the permissible body burden limits.

No minimum concentration standards in fish flesh exist for certain chemicals that are presently detectable in fish, or for certain existing chemicals in the environment or in commercial use, but which are not detectable in fish. Dibenzofurans levels in fish are not regulated. A tolerance of 20 parts per trillion has been set for 2,3,7,8 TCDD (a dioxin isomer) in all fish, but tolerances have not been established for other dioxin isomers. Regulations limiting the concentration of pyrethroid insecticide exist for salt cod, but not for fresh fish. Since neither water quality standards nor effluent control standards exist for such chemicals, they may find their way into fisheries waters through normal use and manufacture. This situation is further complicated by toxic chemicals that occur as contaminants or byproducts in other chemical formulations. Where catches are rejected by foreign nations, the confidence of our trading partners in the quality of Canadian fish will be undermined.

Fisheries far from chemical sources may also be contaminated which in turn will affect their marketability. For example, the Great Lakes are a source of chemical contamination to the St. Lawrence River and the Gulf of St. Lawrence.

Marketability is radically affected by public perceptions of the quality of fish, whether or not the fish in fact carry chemical body burdens. Any incident that calls into question the quality of fish produced in Canada presents a risk of market losses in foreign nations. In most cases, markets lost due to lack of confidence in a product are difficult to re-establish.

3.2 MAINTAINING THE PRODUCTIVITY OF FISH STOCKS

A second major concern is the potential reduction of the productivity of fish stocks over the next decade. Chronic exposure of fish to toxic chemicals can impair their reproduction and growth, enhance mortality rates, change migratory behaviour and reduce biomass and productivity. There may also be changes to species diversity of aquatic invertebrates and vegetation which fish use as food.

The processes operating within aquatic communities are neither well known nor is their outcome predictable. A particular problem in this respect is our present inability to identify accurately, or measure, levels of community response resulting from contaminant pressure.

The pace of scientific advancement, firstly concerning the effects of chemicals on fish and fish habitat, and secondly in the development of appropriate techniques is inadequate to keep up with the rate of introduction of new chemicals, and the increasing contamination from industrial, municipal and atmospheric sources. Since the establishment of control regulations is predicated on the demonstration through scientific evidence of hazards of chemicals to fish health (or to human health for that matter) we can project that regulatory measures will not provide the level of protection for fish stocks that will ensure their continued productivity.

B. WORKSHOP REPORT

1. FRAMEWORK FOR THE WORKSHOP

On September 10-12, 1985, under the auspices of Mrs. A. Lefebvre-Anglin, the Assistant Deputy Minister, Pacific and Freshwater Fisheries, DFO sponsored a workshop on Chemical Hazards at Burlington, Ontario. Dr. B.S. Muir, Director-General of Fisheries and Biological Sciences chaired the Workshop, the objectives of which were to describe:

1) The hazards posed by chemicals to Canadian fish and fisheries.

2) The hazards likely to become priorities during the next decade.

3) The likely state of Canadian fisheries in ten years if no action is taken.

Seventy-eight people participated, including departmental managers and scientists whose special interest is toxic chemicals research, and representatives from other Government Departments, Canadian and American universities, and from the private sector.

The hazards posed by chemicals and those likely to become priorities over the next ten years were identified during the workshop and are described in this report under six major topics:

2.1) ORGANIC CHEMICALS
2.2) INORGANIC CHEMICALS
2.3) PESTICIDES
2.4) LONG RANGE TRANSPORT OF ATMOSPHERIC POLLUTANTS
2.5) ENERGY
2.6) SEWAGE AND OXYGEN CONSUMING WASTES

In addition, the scientific research, administrative and legislative aspects of dealing with toxic chemicals in the environment were addressed under four major categories:

2.7) SCIENTIFIC KNOWLEDGE BASE
2.8) LEGISLATION/REGULATION
2.9) COORDINATION AND COOPERATION
2.10) PUBLIC PERCEPTION AND SOCIO-ECONOMIC PROBLEMS

1.1 THE SYNTHESIS OF CHEMICALS

About six million chemicals have been synthesized or isolated from natural products and some sixty thousand chemicals are commonly used. Globally, approximately one thousand new chemicals are produced annually, and most of these eventually find their way into the environment. Many are toxic to some extent, some very seriously, to fish. Many are accumulated in fish and potentially pose a threat to humans.

Toxic chemicals may enter waters of significance to fish as pesticide residues, through accidental spills during manufacture, use, storage or transport, and by disposal of waste products into the atmosphere, into surface and groundwaters and onto land.

2. SUMMARY OF WORKSHOP DELIBERATIONS

2.1 ORGANIC CHEMICALS

2.1.1 Current Problems

a) **Unknown Effects** -- Many known organic toxicants are detectable in fisheries waters but the scope and severity of their impact has not been determined, for example:

- the biological effect of dioxins and dibenzofurans that have been detected in crabs in British Columbia and in Great Lakes fish species is unknown;

- high levels of contaminants are suspected as a cause of the low reproduction rate of stocked lake trout in the Great Lakes, but the relationship is not confirmed;

- although no causal relationship has been established between the high incidence of fish tumours in Great Lakes populations and organic chemicals, some of the chemicals present in the Lakes are known carcinogens;

- chlorophenols from wood preservation facilities have been detected in fish, sediment and water in the lower Fraser River in British Columbia, but the effect of this contamination has not been established.

b) **Acute Episodes** -- Many current chemical problems are characterized by acute responses as exemplified by fish kills, fishery closures, or market losses. For example:

- in 1982 West Germany prohibited the import of Lake Ontario eels with Mirex residues in the flesh;

- PCB's and organochlorine pesticide levels in some Great Lakes fish are severely limiting commercial marketing;

- polynuclear aromatic hydrocarbons have contaminated the lobster fishery in some locations in Nova Scotia, resulting in lost harvesting opportunites;

- whitefish in the Athabasca River have been tainted by oil and its byproducts;

- fish kills have occurred as a result of spills of chlorophenols in the Brunette and Serpentine Rivers in British Columbia.

2.1.2 Emerging Problems

The workshop classified three major sources of toxic organic chemicals which will continue to affect the fisheries in both fresh and salt water over the coming decade. These are:

a) **Historic stockpiles and disposal sites** -- Old sites are now sources of chemicals. For example, chemicals toxic to fish are leaching from landfill sites in the Niagara River area and entering ground and surface waters. Such contamination will affect future fisheries if leaching is not stopped before levels affect the health of fish (loss of food sources, reproductive failures, etc.) and markets by exceeding levels safe for human consumption.

b) **Diffuse and unknown sources of persistent chemicals** -- Chemicals such as Mirex, PCB's, DDT, and toxaphene are present in sediments and will continue to contaminate fish and fish habitat as they are released by natural or man-made perturbations, and recycled through aquatic systems. Other chemicals, including dioxins, furans, chlorinated styrenes, polychlorinated terphenyls, flame retardants, organophosphorus compounds, surfactants, plasticizers and additives to plastic, halogenated aromatic compounds, chlorinated paraffins and polychloroquaterphenyls, are now present in aquatic ecosystems and have unknown effects.

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c) **Acid rain** -- Acidic precipitation has accelerated the release of aluminum and other metals from soils. Once washed into water, aluminium has been toxic to larval fish productivity.

d) **Unknown and diffuse sources** -- Elevated levels of mercury in Atlantic swordfish precipitated the closure of that fishery in 1970. It should be noted that the dominant cause of these high levels is from natural processes. In February 1978, the US Food and Drug Administration changed their mercury tolerance from 0.5 ppm to 1.0 ppm and Health and Welfare Canada ruled in July 1979 that, due to the very limited consumption of swordfish in Canada, the previously (1970) announced tolerance of 0.5 ppm would no longer be applied to swordfish sold in Canada. This allowed the fishery to re-open in 1979.

2.2.2 Emerging Problems

Toxic inorganic chemical effects, from three major sources, are expected to increase over the next decade:

a) **Historic contamination from effluents or disposal sites** -- For example, methylation of mercury from historic discharge through biological activation in sediments creates a more readily available and more toxic form of the metal.

b) **Industrial expansion** -- Industrial expansion may generate effluents and emissions or accelerate natural processes. For example, impounding water to create hydro reservoirs may leach natural sources of mercury into fisheries waters. Coal mining and extraction of oil from tar sands and heavy oils may increase over the next decade as a result of new markets, this may increase acid mine drainage, heavy metal and nutrient contamination, and oil pollution.

c) **Use and practice** -- Modifications to the use of chemicals and the unabated release of waste products into the atmosphere, water or onto land will be a continuing source of contamination. For example, much of Canada's acid rain problem is produced by emissions from non-ferrous metal smelters. Moreover, mercury, aluminum, vanadium and manganese contamination leached from soil will increase if Canadian lakes and rivers continue to be acidified. Without adequate controls on metal emissions, contamination by zinc, copper, cadmium and nickel will continue to affect fisheries waters. The expected increased use of ammonia-based fertilizers in the forest industry will likely increase eutrophication of adjacent streams and rivers. From past experience this has reduced species diversity and productivity.

2.3 LONG RANGE TRANSPORT OF ATMOSPHERIC POLLUTANTS (LRTAP)

2.3.1 Current Problems

Both organic and inorganic chemicals may be carried over long distances via atmospheric circulation; the contaminants may have different residence times in the atmosphere, and the tracking of sources and sinks can be very difficult. Two types of problems are evident as a result of the long range transport of pollutants:

a) **Transport of persistent toxic chemicals** -- Metals and organic compounds that are resistant to natural degradation in the environment may be transported and circulated through the atmosphere and deposited in areas far from the original source. For example, the suspected source of toxaphene in Lake Superior fish is from the central and southern U.S. where it has been used extensively. Despite limited use in Canada, toxaphene contamination may soon affect the marketability of Lake Superior fish.

b) **Acid rain** -- The impact of acidic precipitation on fish and fish habitat is well documented, including loss of habitat and food organisms, metal contamination of both water and sediments, reproductive failure, reduced fish production, episodic fish kills, and secondary effects such as toxicity of aluminum and heavy metals and their bioaccumulation.

2.3.2 Emerging Problems

The long range transport of air pollutants as a process for distribution and redistribution of a variety of chemical contaminants should not be underestimated. No part of Canada, or the world, may be immune from distant activities. Two major sources of future contamination associated with the long range transport of chemicals are anticipated:

a) **Recycling of chemicals already present in the environment** -- Persistent organic compounds such as PCBs from the Great Lakes may recycle through volatilization, air borne transport downwind and redissolution. The St. Lawrence River and the Gulf of

St. Lawrence may also contain these chemicals transported from the Great Lakes via suspended particulates. The apparent enhancement of mercury bioaccumulation in acidified waters may result in major contamination of fisheries. Continuing loss of recreational and native fisheries can be expected. Recreational fisheries alone are estimated to have lost over $90 million per year in eastern Canada.

b) **Industrial expansion** -- Expansion of oil refining activities and other industrial development in the Northwest and Yukon Territories, and especially in the northern regions of British Columbia and Alberta, could generate further acid rain and other problems related to the long range transport of atmospheric contaminants.

2.4 PESTICIDES

2.4.1 Current Problems

Pesticides have been particularly disruptive to fisheries because of their high toxicity to fish, their persistence in the environment, their propensity for recycling once present in the environment, and their widespread use. Three major categories of effects are apparent as a result of pesticide contamination:

a) **Market disruptions** -- Products have been rejected on an incident-by-incident basis resulting in losses to the industry because of contamination by persistent pesticides. For example, fisheries, for eels and salmonids in the Great Lakes, eels in the St. Lawrence River, and geoduck clams off the British Columbia coast have been closed. The sport fishery in Ontario has also been particularly affected by pesticides. Numerous lakes and rivers in the province have fish contaminated with pesticides to a level requiring consumption advice, in the provincial "Guide to Eating of Sport Fish in Ontario".

b) **Acute effects** -- Misuse and accidental spills of pesticides have caused fish kills in various locations. While the long term effect of the episodic removal of fish from populations may not be critical, there may be more cases than have been reported which have gone unnoticed because of the lack of effective surveillance and monitoring programs.

c) **Unknown effects** -- A number of instances have been discovered where high levels of pesticides are present in the environment or as body burdens in fish and marine mammals, but the physiological and ecological effects have not been determined. For example, recent autopsies of beluga whales from the St. Lawrence River have shown very high levels of oganochlorine pesticides in the liver and blubber. Also, millions of hectares of forests are sprayed annually with insecticides and herbicides causing substantial reduction of fish food organisms. However, the actual impact of a reduced food supply on fish populations has not been investigated.

The contamination of marine organisms by organochlorines appears to be ubiquitous, presumably as a result of the aerial transport of these materials into the aquatic environment. Concerns about the buildup of such substances in fish and marine mammals are very widespread, emphasizing that these problems have to be considered in a global, rather than purely a national perspective.

Erosion of agriculture and forestry land which has been treated with pesticides constantly transports a variety of persistent pesticides into the aquatic environment, resulting in degradation of water quality for fish.

2.4.2. Emerging Problems

Three major factors associated with the production and use of presticides give cause for concern for the coming decade.

a) **Increased use** --Recent forecasts predict that pesticide use will more than double by the turn of the century. Clearcutting forestry techniques and increased monoculture could cause a four to ten-fold increase in the use of herbicides to remove unwanted species of trees. Of equal importance is the removal of riparian vegetation, creating a loss of fish and habitat production.

b) **New pesticide compositions** --Projections of the future use of pyrethroid insecticides suggest a shift to these new chemicals from the current organophosphate and carbamate insecticides; they may be 1000 to 10000 times more toxic to fish than most currently registered insecticides.

b) **Regulatory deficiencies** -- Non-active ingredients, such as surfactants and emulsifiers in pesticide formulations have received little attention under the federal pesticide registration process, but may, in fact, be toxic to fish. For example, nonylphenol, a diluent of Matacil insecticide is ten times more toxic to fish than the active ingredient.

Lack of provision of post-registration monitoring of pesticides under the Pest Control Products Act is also a serious concern.

2.5 ENERGY

2.5.1. Current Problems

Energy related industries are a major source of toxic chemicals. Accidental spills and releases through waste disposal from oil and gas exploration, production, refining and transport to markets, leaching and spills from uranium mining are some examples.

a) **Inadequate standards regulating the storage of products and release of wastes** -- Numerous incidents of chemical release have occurred due to inadequate regulatory action and inadequate care in the handling of products and wastes. For example, the chronic leakage of oil and its byproducts has tainted fish in the Athabasca system and in the Arctic. Petroleum products discharged into water have fouled fishing gear, with subsequent tainting of fish.

Where sewers discharge directly to a river or lake, the disposal of automobile waste oil into storm sewers releases trace metals and polynuclear aromatic hydrocarbons (PAH) (created during engine operations) which are toxic to fish. Leakage from underground gasoline storage tanks has contaminated ground water, and in areas with high water tables, surface water contamination can occur.

The incomplete combustion of fossil fuels results in the release of PAHs, some metabolites of which are known to be carcinogenic to fish.

b) **Shipwrecks and chronic spills** -- Tanker accidents and chronic spills occur in the handling, transport, or use of oil and oil products. For example, oil spilled from the vessel Arrow has caused long-term pollution of the Nova Scotia coastline as a result of resuspension of the original oil spilled.

2.5.2. Emerging Problems

Over the next decade, energy related industries may pose increasing chemical threats to fisheries from three types of sources:

a) **Increased industrialization** -- The expansion of coal mining may generate more toxic contaminants in sediments, through the release of heavy metals, acid mine drainage, coal-generated sulphur dioxide (a precursor of acid rain) and polynuclear aromatic hydrocarbons (PAHs). Increased or new drilling activity in coastal waters, production from synfuel plants, increases in the number of coal and oil storage facilities and the operation and eventual decommissioning of Canadian nuclear power reactors have the potential to generate large amounts of hazardous wastes from a variety of conventional industrial practices.

   Oil exploration in the marine environment will increase the associated danger of blowouts. For example, in September 1985, an artificial island in the Beaufort Sea was lost due to unexpectedly high waves. No oil or gas was released, but a future production island could be less fortunate. Finally, increased transportation of oil will increase the probability of a significant oil spill given the current level of transport technology.

b) **Resuspension of contaminants** -- Some harbour sediments have been contaminated over the years through minor spills and disposal of ship and shore wastes. Dredging of such harbours for a variety of reasons may lead to the resuspension of toxic chemicals from the dredged materials.

c) **Contamination associated with radioactive materials** -- The London Dumping Convention has recently passed a resolution suspending ocean dumping of low-level radioactive wastes; high-level radioactive wastes are already proscribed from ocean dumping under the Convention. Canada has not adopted a policy of sea disposal of radioactive wastes and, therefore, these international developments will have little national impact. The land-emplacement option for waste, presently preferred by Canada, will nevertheless require that leakages of radionuclides into the environment are minimal. However, routine releases of radionuclides do occur into the North Atlantic Oceans from nuclear fuel reprocessing operations in Europe. Continued surveillance of the dispersion of these radionuclides and their accumulation in marine organisms is essential for the purposes of human health protection in respect to seafood consumption and other pathways of human exposure.

Land-based disposal of low level radio-active wastes in the USA and from mining wastes in Canada remain a potential problem by leaching into the aquatic system to eventually have impact on fish health.

2.6 SEWAGE AND OXYGEN-CONSUMING WASTES

2.6.1. Current Problems

Municipal sewage, and wastes from agriculture, forestry and food processing may generate acute chemical toxicity, bacterial and viral contamination, and oxygen depletion in waters supporting commercial or recreational fisheries. Adequate effluent processing technology and disposal standards are needed to reduce adverse effects on fish. Examples of local problems are:

- a large area of the Fraser River estuary near the Iona Island Sewage Treatment Plant has suffered severe dissolved oxygen depletion and bottom sludge deposits, resulting in major kills of fish and invertebrates.
- in the past, before a treatment system was put in place, effluents from a food processing plant in New Brunswick caused fish kills.
- pulp mill effluents have destroyed habitat and impaired salmon migration by severe depletion of dissolved oxygen. Untreated wastes from pulp and paper mills are often highly toxic to fish and may deplete oxygen in waters supporting commercial and recreational fisheries.

2.6.2. Emerging Problems

Three types of problems associated with the disposal of sewage and oxygen-consuming wastes will affect fisheries in the coming decade:

a) **Re-suspension** -- Remobilization of wastes from sediments and toxicity of metabolites from industrial waste treatment sources will present an ongoing hazard.

b) **Problems associated with treatment technology** -- New processing technology for producing pulp by mechanical processes is creating new waste problems for which conventional treatment is inadequate or inappropriate. Post-chlorination of treated sewage and pulpmill wastes can form chlorinated compounds more toxic and persistent than the original compounds.

c) **Recognition of toxic substances** -- Polylignins from pulp mill wastes are suspected of being toxic to fish, and not inert as previously thought.

2.7 PROBLEMS ASSOCIATED WITH THE SCIENTIFIC KNOWLEDGE BASE AND CAPABILITIES.

2.7.1. Current Problems

DFO's role is to address scientific problems associated with fish health and with the maintenance of the productivity of fish stocks in areas affected by chemical contaminants. Technical and methodological advances would have to be developed to measure the effects of concentration of chemicals lower than those presently detectable by current technology and to identify new chemicals.

Since DFO scientists cannot carry out all necessary research on chemical effects in the environment, they must be able to interpret investigations carried out elsewhere and must be able to advise other regulatory departments on matters relating to the protection of fish and maintenance of fish quality.

a) **Hazard Assessment** --Aquatic toxicity hazard assessment currently considers only acute toxicity and the environmental fate of specific chemical or chemical mixtures. Hazard assessment generally ignores chronic toxicity, possible synergism, and the impact of an array of chemicals which may be present in the environment simultaneously stressing organisms. The confidence with which the hazard of chemicals to fish and fisheries can be assessed is low because these interactions are poorly understood. Moreover, the effects of chemical burdens on the stability of ecosystems and their ability to support health fish stocks is most difficult to assess.

b) **Chemical and Biological Cycling** --Chemical and biological processes determining the fate and the rapid distribution of many chemicals are not well understood.

The scientific understanding of processes leading to the in situ transformation of chemicals in sediments and their recycling in aquatic ecosystems is important. It permits the assessment of current and future potential hazard of chemicals in the Great Lakes, in fisheries waters near pulp and paper mills, other effluent discharges, contaminated harbours, and embayments.

c) **Tests and Techniques** --Lack of diagnostic or forsenic early warning tests that identify chemical exposure and effects on aquatic biota impedes the assessment process and impairs the ability to prove cause and effect. Such tests are vital to relate the presence of a chemical in fish habitat to its effect on fish. The development and validation of a battery of sublethal tests, such as enzyme and hormonal assays, may yield information on chemical impacts before lethal effects occur and fish populations decline. Diagnostic tests would provide convincing evidence demonstrating causal relationships in prosecutions for Fisheries Act violations.

--There is a lack of monitoring programs for assessing the impact of control programs for pesticide uses under the Pest Control Products Act so that DFO is unable to assess the possible impacts of pesticide residues on fish populations.

--An ecosystem approach to measure subtle community responses and changes in ecosystem structure and function could permit the development of predictive models. They could be applied to different areas of the country affected by acid rain or to the effects of chemicals on biological communities. Baseline data on representative ecosystems would be a prerequisite for this approach.

--Good data quality assurance programs specifically aimed at validation of effects have not been put in place.

d) **Equipment and Technology** --Sophisticated chemical analytical facilities and trained laboratory technical staff in the Department are needed to meet the research and regulatory requirements related to the control of toxic chemicals in fish. The capital replacement budget and field support should be reviewed regularly to permit an effective departmental response to emergencies.

2.8. PROBLEMS ASSOCIATED WITH LEGISLATION AND REGULATIONS

2.8.1 Current Problems

a) **Inadequacies in Control Legislation** --The Department of the Environment administers Section 33 of the Fisheries Act. This section permits the establishment of federal effluent regulations. DFO has the responsibility for research in support of Section 33 and can also provide support through Operations Branches in protection. Historically, existing cooperative mechanisms between the two Departments have not worked well in establishing research priorities, and compliance and enforcement support. In May, 1985, however, a Memorandum of Understanding was signed between DFO and DOE establishing a mechanism to ensure cooperation in the administration of Section 33.

--The existing DFO/DOE/Provincial/Industrial mechanisms for reviewing regulations are very slow.

--Fines provided under the Fisheries Act and through Provincial regulations are an inadequate deterrent for violation of regulations by companies releasing effluents. In addition, regulations do not include habitat rehabilitation as part of any legal judgement.

--The Pest Control Products Act has a number of inadequacies relative to the protection of fish from the effects of pesticide use. These include no federal or provincial regulatory control over the domestic and agricultural uses of pesticides; no provision for compliance and effects monitoring of pesticide application after registration; no formal mechanisms to resolve the frequent fisheries concerns, and no adequate data requirements on the supposedly inert ingredients of pesticide formulations during the registration process. In addition, DFO has limited staff available to provide timely advice to Agriculture Canada on pesticide registrations.

--Ocean Dumping Control Act cannot list all potentially hazardous substances. Nevertheless, there is a need for increased flexibility in the revision of the schedules to this Act to: 1) enable rapid imposition of regulatory controls on substances identified as hazardous; 2) to facilitate revisions to limiting concentrations of hazardous substances; and 3) to enable the Act to be brought rapidly into line with revisions to the London Dumping Convention. Future use of incineration of wastes at sea under the terms of the London Convention presents an additional potential source of marine contamination.

--Inadequate attention has been given to the impact of toxic chemicals on fish habitat under the Great Lakes Fisheries Convention Act.

--More recently Canada signed the Montreal Guidelines, a UNEP International Agreement for the prevention of marine pollution from land-based discharges. This agreement will require a great deal of effort by all levels of government to integrate the guidelines with existing national and international legislation.

--The responsibilities for enforcement and compliance legislation for different water uses between federal and provincial regulatory bodies are not well coordinated and results in inconsistent application.

--Mechanisms, such as performance bonds, are not in place under federal legislation to aid habitat rehabilitation and cover possible liabilities arising from abandoned industrial sites, such as open pit coal mines.

b) **Permissible Limits** --The target of 20 kg/ha/year wet sulphate deposition for Eastern Canada to control the effects of acidic precipitation is too high to protect many sensitive lakes, and the habitat for fish will remain unproductive for many species.

c) **Difficulties with the Management of Departmental Programs** --DFO has difficulty in responding adequately to the number of requests to review pesticide registrations. The Minister of Agriculture has recognized DFO as a weak partner in the regulatory process for pesticides.

--DFO has difficulty meeting the requirements of the Federal Environment Assessment and Review Process.

2.9 COORDINATION AND COOPERATION PROBLEMS

2.9.1. Current Problems

The workshop identified four major areas where cooperation and coordination are presently inadequate.

a) **Cooperation on Research** --Interregional multidisciplinary scientific cooperation between the federal government, provinces, and university researchers is presently inadequate.

b) **Government to Government Agreements** --Joint federal/provincial agreements to address the need for upgrading municipal sewage treatment plans, and to resolve overlapping jurisdictional disputes have not been developed.

--DFO's role in international negotiations on transboundary Great Lakes toxic chemical contamination is inadequate to enable us to provide advice on areas of concern in relation to fish and fish habitat.

--Lack of senior level DFO representation at interagency meetings and at bilateral negotiations with the US concerning the long-range transport of air pollutants does not allow us to adequately advise on the effects of remedial action in relation to providing a healthy environment for fish.

c) **Government-Industry Strategies** --Joint federal-provincial-industry processes to deal with the complex problems of industrial effluents are currently weak.

--The potential for increased fish and shellfish production through aquaculture investment is very substantial and offers opportunities for major commercial development. However, the success of aquaculture rests on the maintenance of acceptable habitat for fish-farming and ensuring that the effects of aquaculture operations on adjacent wildlife populations and other aquatic amenities are also acceptable.

--No government-industry strategy is available to deal with either the impact of environmental chemical on the growing aquaculture industry, or the impact of this industry on aquatic systems.

d) **Information Exchange** --Information exchange mechanisms with public health agencies concerning chemical contamination of fisheries products are inadequate to provide a better climate of understanding.

2.10 PUBLIC PERCEPTION AND SOCIO-ECONOMIC PROBLEMS

The workshop participants identified the fact that knowledge of the existence of toxic chemicals in fish would have detrimental repercussions on public perception and confidence in fish quality, and this, in turn would have social and economic consequences on the commercial and recreational fish industries.

A perception also exists in some areas of Canada, that the Minister of Fisheries and Oceans and DOE should ensure that the Fisheries Act is enforced to protect important fisheries resources. The problems of social and economic losses caused by fisheries closures, lost employment, dislocation of communities, and costs for government in compensation payments, we also identified. However, there was insufficient time and expertise available to address these topics thoroughly.

C. REGIONAL ZONAL OVERVIEWS

3.1 ATLANTIC FISHERIES RESOURCES ZONAL OVERVIEW

by D.J. Scarratt

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The following was taken from the Halifax Chronicle Herald on August 28, 1985.

"Canada Still Top Fish Exporter

> Canada has maintained its position as the world's largest exporter of fish in 1984, shipping out $1.59 billion worth of product. The Department's annual statistical review showed a 2% increase in exports over 1983, holding Canada's position as the largest exporter in terms of value for the seventh consecutive year...."

This simply gives some idea of the overall export value of fish. It does not include purely domestic product, nor value to support industries, nor does it include any estimate of values of fish caught by foreign flag vessels within the Canadian Economic Zone.

Canadians caught about 1.25 million tonnes of fish in 1984 and of this some 85% were taken in the Atlantic Zone. Nationally, Canada's fisheries contribute about 1% (or about $1 billion) to the Gross Domestic Product. This percentage is considerably magnified in the Atlantic regional economy where approximately 15% of the G.D.P. is accounted for by fisheries. In coastal areas some communities are virtually dependent upon fisheries and allied trades. In Atlantic Canada there are over 50,000 fishermen, 30,000 fishing vessels, and 22,000 plant workers, employed by some 300 fish processing plants.

With few exceptions the majority of Atlantic Canadian fishermen exploit Canadian waters and do not normally range beyond the coast or the adjacent Continental Shelf (the single exception, perhaps is tuna). The normal range is Georges Bank to Labrador. The fisheries are controlled to avoid over-exploitation and to accelerate restoration of stocks following heavy depletion, mostly by foreign vessels in the 1960's and early 1970's. Canada's share of the Atlantic groundfish catch has risen from a low of 33% in 1974 to a current level of 84% (1984). (Table 1) Total groundfish landings (1.12 million tonnes) are now almost restored to 1974 levels (1.16 million tonnes) up from the 1977 low of 721 thousand tonnes.

Thus, from a purely selfish point of view, it makes extremely good sense for Canadians to ensure that the fish we catch are clean and wholesome, physiologically unaffected by chemical contaminants and that there are enough fish to catch.

Marine Finfish

The management régime for the finfish fisheries is based on estimates of total allowable catches (TACs) for each of the managed species in various NAFO areas and sub-areas of the Atlantic economic zone. For the most part, the estimates relate to discrete populations of each species, which is why a quota may cover fish in a number of adjacent areas. Wherever possible the areas are small enough to distinguish and separate discrete spawning units, although, with some species, e.g., herring, a number of separate spawning populations may be lumped together in one quota. In some instances, e.g., haddock, pollock, herring, Gulf of St. Lawrence cod, the fish are highly migratory. Individual areas will have widely different TACs (Table 2), and, depending on the species, historic fishing patterns and economic value, quotas may be allocated to different sectors of the industry, (e.g., inshore or offshore, gillnet or purse seine fisheries) or, in some cases, to individual boats or enterprises. The allocations apply to both offshore and inshore finfish operations with the exception of the weir fishery for "sardines" in New Brunswick, which is not subject to quota and which historically has yields of about 25 thousand tonnes per annum.

Invertebrates

Values of invertebrate fisheries totalled $273.5 million (Table 3) in 1984, of which the lobster fishery contributed 54%. Next highest values were scallops at $55.6 million and queen crabs at $47.1 million. Lobster landings are currently quite stable. Scallop landings are dependent upon year-class strength and have been declining on Georges Bank but increasing elsewhere. Queen crab landings are reasonably stable. The shrimp fishery is possibly fully exploited in the Gulf of St. Lawrence, but has expansion potential off Labrador and Greenland. Oyster landings have been fairly stable with productivity from New Brunswick and Prince Edward Island and increasing production from Bras d'Or, Nova Scotia. There are developing culture industries for mussels and European oysters in Nova Scotia and New Brunswick. Clam production is fairly stable at around 6000 tons; however, there are moves to exploit areas that are closed because of fecal coliform contamination, and this may increase pressures to open areas which may also have high inorganic and organic contaminant loads.

Diadromous and estuarine species

Included within this general group are species such as trout, smelt, striped bass, shad, gaspereau, sturgeon, tomcod, eels and, of course, Atlantic salmon (Table 4). For the most part they do not yield particularly large landings on a national scale, but they can be extremely important locally. Salmon also have a very high recreational profile. Because significant parts of their life cycle are spent in estuaries which traditionally are close to sources of industrial pollution most of these species are exposed far more than offshore species to industrial discharges.

Shad are particularly interesting as it has recently been shown by tagging studies that most of the shad fished in the Bay of Fundy fishery are from stocks spawned in U.S. rivers. Dadswell has suggested that visible differences in the condition of fish taken at different times of the fishery may reflect conditions in their 'home river'. This would be an interesting point to explore through the analysis of contaminant burdens.

A significant proportion of eels landed are exported to the European market. Unlike gaspereau which spawn in fresh water and live most of their post-larval lives in the ocean, eels spawn in the ocean and ascend rivers as elvers to grow and develop in fresh water. Eels are known to accumulate hazardous chemical and serious levels of mirex have been observed in eels from the St. Lawrence river and of mercury in many Nova Scotia streams.

The commercial landings of salmon only give a partial picture of the total value of this species. Total reported landings in 1984 were 748 tons worth $2.8 million. Commercial fisheries were closed in much of Nova Scotia, New Brunswick and Québec and controls imposed on recreational angling. Nevertheless, estimates have also been made of the value of the recreational fishery (Atlantic Salmon Journal, June 1985) which, in the Atlantic Provinces, bring $42.6 million to government and private enterprises; considerably more than the revenue generated by the traditional commercial fishery, while taking only about 20% of the total number harvested.

Aquaculture

The last few years have seen the emergence of culture industries for salmon, (principally in S.W. New Brunswick, but also in S.W. Nova Scotia, Cape Breton and South Newfoundland), and rainbow trout from a variety of freshwater and coastal sites. American and European oysters, mussels, and some scallops are also cultivated (Table 5).

The salmon aquaculture industry is projected to reach 2,000 tonnes by the year 2,000 in the Bay of Fundy alone. Cultivated finfish may be particularly vulnerable to contamination due to the use of scrap fish or shellfish offal in feeding formulations and the location of cage sites in or near harbours and estuaries or in close proximity to local sources of municipal or industrial pollution. There is already evidence of contamination from exposure to man-made materials, e.g. plasticisers, used in the manufacture of aquaculture equipment. There will be a particular dependence on sources of clean fresh water for hatcheries and for growth to planting out stages. Shellfish tend to be particularly vulnerable to true metal contamination.

Specific Atlantic Contaminant Problems

With the major exception of the ubiquitous contamination by halogenated hydrocarbons, and aerially transported contaminant (e.g., acid rain) most serious, anthropogenically-caused Atlantic problems appear to be local. However, Atlantic Canada is "downwind" and "downstream" of the major industrial areas of eastern North America and the relatively "pristine" quality of the environment should not be regarded with any degree of complacency.

a) Organic Chemicals

The extent of damage caused to fisheries by organic contaminants, including pesticides, is not known due to lack of field evidence; however, "sick" or dead animals (e.g., tuna - beluga) have been discovered with high loadings of PCBs, etc. It is not known the extent to which processes, at the individual or population level, have been impaired. There is, nevertheless, serious cause for concern. There is speculation that in the Gulf of St. Lawrence, material transported by river is sedimented out in the estuary, which is acting as a sink, and that contaminants further seaward are transported aerially. Current contaminant trends in the Gulf of St. Lawrence are steady or continue upward. Organochlorine levels in herring are at a level where physiological effects may be anticipated. "Top predator" fish, such as sharks and tuna, may already be affected. Examples of "sick", heavily contaminanted fish have been documented.

There have been serious local problems, such as the PAH contamination of lobster in Sydney Harbour, N.S., due to discharges from a coking plant and contamination from other industrial discharges and accidental releases, e.g. oil spills.

b) Pesticides

The perpetual "battle" with forestry reached a stand-off with the adoption of the "fenitrothion equivalent rate" as a working principle whereby the threat to aquatic systems posed by 2 X 210 g/ha fenitrothion was considered the standard against which new pesticide formulations were judged. There is concern about the increasing demand for the use of synthetic pyrethroids and the use of "inert ingredients" in formulations. There is no understanding of the impact of agricultural pesticide applications, and no field capability to speak of, for assessing forestry, agricultural, or industrial pesticide use. The use of herbicides is increasing but remains uninvestigated. There is particular concern in Prince Edward Island where estuarine and coastal fisheries are vulnerable.

c) Energy Applications

Oil spills appear to be less of an issue now than formerly, as problems are largely understood, and contingency response mechanisms are well in place (e.g., MOT Joint Resource Teams, REET, etc.). Offshore exploration and production of hydrocarbon products pose the questions of tainting or contamination of localized stocks from the use of oil-based muds, and mud constituents and blow-outs. The recent detection of catonic surfactants of unknown origin in marine fish caught near a gas well blow-out has added a new problem to the growing list. The coal industry poses questions of disposal of waste rock, the control of leachates, and discharges from coal washing plants. The process of removing sulphur, etc. to reduce stack emissions, may create local waste disposal problems. With the exception of the need for long-term storage/disposal of radionuclides, the routine operation of nuclear generating stations does not appear to pose any particular hazards.

d) L.R.T.A.P.

In Nova Scotia, some fourteen streams are now devoid of salmon populations as a result of acidification; and an equal number of streams are vulnerable. The suggestion that much of the organic contamination in Atlantic Canada may be distributed aerially is alluded to above. Many metals are also transported in this way.

e) Inorganic Contaminants

There still remain problems of mine waste disposal and ore treatment which have given rise to site-specific problems. The mining region of northeastern New Brunswick is of particular concern. Cadmium has been an issue at a lead smelter in Belledune, New Brunswick where the Department of Fisheries and Oceans was obliged to intervene in the lobster fishery as a result of dangerously high cadmium loadings. High Cd levels in some visceral tissues of scallops have been detected in areas distant from anthropogenic sources.

f) Sewage

Sewage and oxygen consuming wastes, pose problems in the vicinity of a number of pulp mills and downstream from a number of large cities (Montreal, Halifax, Saint John for example) which are still discharging raw sewage to receiving waters. Pulp-mill effluents in at least one area may be reducing the potential for aquaculture developments.

General Issues

There are a number of localized dredging problems which are paradoxical in that fishing fleets require the dredging, yet the Department of Fisheries and Oceans imposes constraints on the process. At Canso and Petit de Grat in Nova Scotia, PCB's in sediments have been conjecturally identified as derived from the trace amounts found in fish, which are subsequently deposited and accumulated in sediments in the vicinity of process water discharges.

The question of the levels of contaminants allowable in fish products is contentious. Theoretically the limit, unless specified, is zero, yet this standard cannot be enforced. Recent approaches have tended to set limits based on "background" levels in areas where no known sources of contamination have been identified. Some nations have standards for certain contaminants, and some export shipments (e.g., eels with high mirex loadings) have been denied entry. Accurate measurements of contaminants, and confidence in the analysis is a prerequisite for establishing any enforceable tolerance levels.

The treatment posed by ocean incineration of hazardous wastes does not appear to have been satisfactorily addressed. This is seen by some to pose a severe and unnecesary hazard to the marine environment under the guise of expediency.

Regional Problems

a) Québec

- Of significant concern is the transport of contaminants from the Great Lakes and from Quebec industries, their possible deposition in the St. Lawrence River and estuary, and the source of contaminants to the Gulf fisheries. It is suspected that aerial transport may be the major significant mechanism of dispersion of contaminants into the Gulf but clearly the role of water transport cannot be ignored.

- It is not anticipated that levels of contaminants will diminish, even of substances which are now controlled. Some species (e.g. beluga) have recently received high public profile.

- There are problems with disposal of contaminated dredge spoils (Baie Comeau, Gaspé, Chandler, Cap-aux-Meules).

- There are problems of acid rain in sensitive lake and stream areas.

- There are area-specific problems such as mercury in the Saguenay. and general problems such as Mirex in eels.

b) Newfoundland

- Use of biocides in forestry.

- Fish tainting from hydrocarbon exploration and development.

- Pulp mill discharges, e.g., Exploits River.

- Raw sewage disposal in Conception Bay South and Greater St. John's.

- Hydrocarbon exploration and development, Grand Banks.

c) Gulf Region

- Miramichi dredging, both main channel dredging, and approaches to wharves, due to high organic contaminant and hydrocarbon loadings.

- Belledune: cadmium and other heavy metal problems from base metal mining and smelting, resulting in restrictions on the fishery.

- Mining discharges including mine abandonment and acid mine water seepage.

- Opening of fecal-contaminated shellfish beds to harvesting for depuration and the incidental problems of metal and organic contaminants.

- Localized contamination from pulp mills.

- Pesticide spraying on forests in N.B., and agricultural use in and P.E.I., particularly synthetic purethroids.

d) Scotia-Fundy

- PAH contamination at Sydney, N.S., due to steel mill and coking plant discharges.

- Coal wash plant discharges, Cape Breton Island.

- Acid shale disturbances during construction programs, e.g. Halifax airport extension.

- Mining discharges, tailing ponds, and hazardous waste sites (e.g., Truro, Yarmouth County, Cape Breton Island, Nova Scotia, and Charlotte County, St. John, New Brunswick).

- Pulp mill discharges.

- Contaminated dredge spoil disposal, e.g. Petit de Grat, Barrington area.

- Potash mining discharges and emergencies (N.B.)

- Acid rain, Southwest Nova Scotia is particularly vulnerable being "first-in-line" to receive aerially transported polltants including PCBs and toxaphere.

- Pesticide use in agriculture and forestry.

- Hazardous waste sites.

- Feed lot sewage systems in Annapolis Valley.

- Hydrocarbon exploration - Scotian Shelf and Georges Bank.

- Aquaculture developments.

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Table 1

Selected Groundfish TACs (thousand tonnes) 1985

Species	Total	Canada	Canadian Percent
Cod	635	548	86
Redfish	199	140	70
Haddock	30	23.9	80
Flatfish	199.5	176.5	88
Pollock	53	42	79

Table 2

1985 TACs in NAFO Fishing Areas 2,3,4
(Selected species)
(thousand tonnes)

Species	NAFO Fishing Areas	Geographical Area	Total	Canada	Percent
Cod	2+3	G-B, Lab	373	307	82
	4Vs,4Vn,4W,4X	Scotian Shelf	101	98	98
	4R,4S,4T	Gulf of St. Lawrence	167	146.5	88
Herring	2+3		-	-	-
	4Vs,4Vn4W,4X		94.5	94.5*	100
	4R,4S,4T		31	31	100
Silver Hake	2-4		100	1	1
Total Finfish	2-4		1520	1151	75

*New Brunswick Weir fishery not subject to quota (catches about 25,000 t/annum) not included in TAC.

Table 3

Selected Invertebrate Landings 1984
(tonnes)

Species	N.S.	N.B.	P.E.I.	PQ	NF	Total	($'000)
Clams	1,791	2,829	1,121	623	-	6,364	5,565
Oyster	58	288	60	-	-	406	475
Scallop	28,489	3,734	840	1,102	470	34,635	55,679
Lobster	12,105	5,962	5,966	1,804	2,118	27,955	147,947
Shrimp	1,878	1,072	-	5,277	2,696	10,923	14,948
Q. Crab	1,750	16,021	277	12,746	10,240	41,034	47,118

Table 4

Freshwater, Estuarine, Diadromous Species
Selected Landings 1984

Species	tonnes	($'000)
Trout	78	338
Smelt	951	451
Bass	20	42
Shad	11	63
Gaspereau	3,874	915
Sturgeon	21	33
Tomcod	27	3
Eels	376	676
Salmon	748	2,789

Table 5

Value of Species cultivated in Atlantic Canada 1984

Species	tonnes	($'000)
European Oyster	3.3	27
Mussels	876	1,070
Scallops (spat, by count)	20 thousand	
Trout	109	409
Salmon	103	1,880

3.2 GREAT LAKES FISHERIES RESOURCES ZONAL OVERVIEW

by
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Each of the speakers during yesterday's Plenary Session presented detailed overviews on the types of chemical hazards that may impact on an aquatic ecosystem (Table 1). The Great Lakes basin, which is home to some 37 million people, has several examples of each type of these chemical hazard problems. Within the basin there are more than 825 major municipal and industrial discharges and more than 4000 solid and liquid waste disposal sites. The province of Ontario alone discharges in excess of 330 million gallons of liquid industrial waste annually.

Each year the International Joint Commission, the bi-national agency charged with overseeing the Canada/U.S. Great Lakes Water Quality Agreement, prepares a list of the Areas of Concern within the basin. Since 1973, this list has described sites where one or more specific water quality objectives of the Agreement were exceeded (Table 2). Basically it describes areas where the beneficial uses of water and biota have been degraded.

Based on annual surveys there were 69 Areas of Concern identified in 1974 with two thirds of the sites located in the lower Great Lakes, that is Lake Erie and Lake Ontario. Most areas were identified because specific water quality objectives, primarily related to eutrophication parameters, were not being met. The reports in 1976 and 1977 began to identify the emergence of toxic chemicals as the criteria for designation of a problem area. The recognition of massive sediment contamination with PCB's, up to 50,000 ppm in Waukegan Harbour on Lake Michigan, signaled the beginning of reports outlining the significance and impact of in-place pollutants. Remedial programs and limitations on identified discharges did not improve the status of some problem areas due to historical discharges which resulted in continuing contamination of water and fish inhabiting that location.

In 1978 the Water Quality Agreement was revised to include additional specific objectives for toxic substances. Areas of non compliance were rated utilizing both these additional agreement objectives and the status and effectiveness of remedial action programs. Reports in 1980 first identified the significance of contaminated groundwater as a source of toxic organic compounds entering the Lake Michigan ecosystem. There was an increased frequency of criteria being exceeded due to the presence of elevated levels of PCB, DDT and dieldrin in both top predator and forage fish.

A further redefinition of the criteria for identifying Areas of Concern took into account the identification of causative factors, the existence and progress of a remedial action plan and finally deletion of a problem area designation when the full complement of uses for the site was restored.

The 1985 report on Great Lakes Water Quality lists 42 areas of concern with sites equally divided between the upper and lower Great Lakes (Figure 1). In 38 of the 42 areas of concern concentrations of toxic substances, both organics and heavy metals, exceed the IJC objectives proposed for the protection of both aquatic and human health. Fish consumption advisories are in effect for 31 of the 42 areas of concern and are issued primarily because of PCB or Hg contamination. In some cases the presence of compounds such as PAH's, dibenzofurans or chlorophenol compounds, for which there are no human health guidelines may not be reflected in the consumption advisories listed. At 25 of the 42 problem areas, it has been determined that the biological community has been adversely impacted. At all of these 25 sites there has been a coincidental identification of contamination by heavy metals or toxic organic substances.

Based on the evidence that toxic chemicals are recognized as an increasing problem within the Great Lakes, what is the potential for loss to the fishery and what signs do we have that further deterioration is already underway? One significant impact of contaminants on the Great Lakes fishery is the reduction in the marketability of commercial products. Early in 1970 monitoring studies demonstrated that mercury concentrations exceeded regulatory levels in several fish species in Ontario. Commercial fishing activities were closed in the St. Lawrence River, Ottawa River, English and Winnipeg River systems, Lake St. Clair, Lake Ontario and parts of Lake Huron. These closures affected 258 commercial fishermen and 4 Indian bands. In 1982, the German government, concerned with the import of contaminated fish, restricted the sale of Canadian eels by imposing a limit of 0.1 ppm of mirex and controlled eight other organic compounds at levels considerably less than the Canadian action levels.

Recently identified chemicals such as dioxin, specifically 2,3,7,8-TCDD, are now being detected in commercial fish and pose a threat to international markets. Canada established a guideline of twenty parts per trillion for 2,3,7,8-TCDD and it is possible that some species of commercial fish may exceed this level. However, even fish below the guideline have been rejected by export markets. Japan refused to purchase Lake Erie fish products in 1983, for fear that these fish might be contaminated with dioxins. Analyses resolved the situation, but is was clearly demonstrated that importing countries do not have confidence in the quality of Canada's freshwater commercial fish products. This is extremely important since Canada exports more than 95 percent of the freshwater commercial catch.

There is a considerable investment in the Great Lakes commercial fishery. The total value of boats, associated fishing gear, shore installations and continuing new capital investment exceeds 500 million dollars (Table 3). The fishery currently offers employment for over 1500 people. Over the last two and a half decades total landings of fish and their landed value in the Canadian portion of the Great Lakes commercial fishery increased through 1980 (Figure 2). The 1984 data identify a significant decline in landings but a 50% increase in the value of the fishery to more than 35 million dollars. This suggests that if a saleable product could be harvested then an incredibly lucrative market is available to the commercial industry.

The recreational fishery is also an area where the impact of toxic chemicals has the potential to inflict severe economic losses. Data through 1980 indicate that the recreational fishery represents a large investment by the public with over one million anglers involved (Table 4). More recent estimates have increased that figure to one and three quarter million anglers. The investment in the recreational fishery including long term outlays such as boats, and accessories, vehicles, camping equipment is 124 million dollars. Indirect costs associated with travel, food and lodging increase the value to in excess of 330 million dollars. These figures take into account only revenue generated in Canada. Estimates of the total value of expenditures for Great Lakes angling which include spending by U.S. residents exceed $2 billion.

The down side of this success story is the frequency of sportsfish consumption advisories issued by various state and provincial fisheries agencies around the Great Lakes. Table 5 presents a summary from the 1985 "Province of Ontario Guide to Eating Sport Fish" booklet. Consumption advisories were issued for more than 70% of the 47 sites tested in Lake Ontario and downstream on the St. Lawrence River. The restrictions are primarily associated with levels of PCB or mercury which exceed Health & Welfare Canada guidelines in place for the protection of human health. In many cases if the levels of either PCB or Hg declined below the action level, consumption restrictions would still be in force due to the presence of contaminants such as dioxin, lead, Mirex or possibly toxaphene.

We have also been asked to comment on what hazards may become priorities in the next decade. Rather than identifying specific compounds as priority issues, it may be preferable to focus on potential sources of chemicals which pose a threat to the fishery in the future. These sources of chemical hazards for the Great Lakes include atmospheric deposition, contaminanted sediments and waste dumps. These sources may be termed second generation problems within the Great Lakes basin. In many cases industries with point source discharges, the initial source of chemical contamination, are either implementing remedial action programs or are in compliance with permitted discharge levels. The regulatory actions seen as reactions to first generation toxic chemical problems were imposed throughout the Great

Lakes basin in the 1970's and resulted in substantial declines in contaminant burdens of fish. But recently the rate of this decline has begun to slow down in some cases, especially in Lake Ontario, increasing concentrations have been documented for some compounds. Total body burdens of both PCB and Mirex in a single age class of Lake Ontario lake trout are increasing after a period of consistent decline from 1977 through 1980/81 (Figures 3 and 4) Additional data implicates the large toxic chemical waste dumps along the Niagara River as potential sources for these materials found in increasing concentrations in Lake Ontario fish. Movement of contaminated groundwater away from the disposal sites has been documented and is an increasing source of contaminant loading to the Great Lakes. The recent NRTC report has identified 214 hazardous waste sites along the Niagara River with 164 of them within 3 km of the river. Sixty-six sites were identified as having the potential to contaminate the river based on the presence of a permeable substrate, sufficient groundwater gradient and analytical evidence of chemical migration. More than 75% of 1.2 million tons of contaminated materials stored at these 66 sites has the potential to be leached into the Niagara River and distributed downstream into Lake Ontario.

The production of chlorophenols at chemical manufacturing complexes along the Niagara River and Saginaw Bay on Lake Huron gave rise to the waste by-products, dibenzodioxins and dibenzofurans. The release of these extremely toxic compounds into the environment from waste disposal sites is evident by the accumulation pattern seen in biota collected from across the Great Lakes (Figure 5). There is concern for the continuing and perhaps accelerating off-site migration of the entire complex of toxic materials dumped in these chemical landfill areas. This issue is one that requires continuing strong international negotiation. To date no program has been implemented for the on-site destruction of buried or stored toxic materials although the fundamental technology does exist.

The long range transport and deposition of toxic materials is another emerging issue for the Great Lakes. The presence of the compound toxaphene in the Great Lakes ecosystem is indicative of the potential impact the mechanisms of long range transport and atmospheric deposition may have. We are vulnerable to activities which occur well outside the Great Lakes basin.

Toxaphene, a chlorinated insecticide, has been reported in lake trout from Lake Superior at concentrations that exceed the level of PCB, normally the most prevalent compound in Great Lakes fish. Total use of toxaphene in Canada dropped from 12.5 tons in 1978, including 1.5 tons used in Ontario, to approximately 1.0 ton for Canadian farmers in 1981. Conversely up to 50,000 tons of toxaphene have been used annually in the United States with more than 90% of the compound used in states which lie outside the Great Lakes drainage basin. Thus, a lake ecosystem has been severely affected by compound that was not extensively used within its drainage basin. Although the manufacture of toxaphene in the U.S. was banned in 1982 and all usage must cease by 1986, its use is still permitted in Central and South America. Exotic materials like toxaphene are not the only problem of this type. Atmospheric inputs of

PCB's represent greater than 80% of the total input from all sources for Lakes Superior, Michigan and Huron. The basic conclusion is that deep lakes with large surface areas and low turnover rates are at risk to the accumulation of toxic materials made available as a result of long range transport and atmospheric deposition.

The final emerging issue to be discussed concerns the input of toxic materials from sediments which has been termed an in-place pollutants problem. Even if we eliminate the discharge of all toxic materials immediately, contaminated sediments will remain a source of chemical contamination in the Great Lakes for a considerable length of time. This problem is obviously more acute in heavily industrialized areas with a long history of effluent discharge. Contaminants first adsorb to the organic sediment fractions and then through the processes of alkylation or transformation they become available for rapid bioaccumulation by benthic invertebrates at the base of the food web. Concentrations are biomagnified as the chemicals are transferred from forage fish up the food chain to top predator species. When the highly contaminated top predators die and decompose the contaminant burdens are returned to the lower trophic levels. As a result of the cyclic nature of these processes sediment related contaminant problems tend to affect fisheries long after chemical inputs have been discontinued and frequently in areas far removed from the chemical source.

Mercury contaminated effluents from chlor-alkali plants associated with pulp and paper mills concentrated along the north shore of Lake Superior, are still influencing body burdens in local fish stocks although the actual discharges were drastically curtailed more than 10 years ago. Similarly Mirex contaminated sediments from a single major source on Lake Ontario have spread the problem throughout the lake's entire ecosystem. This material is now being transported further downstream and is at detectable concentrations in biota from the St. Lawrence River.

The problems with continuing inputs of contaminants from historical activities as evidenced by the impact of chemical waste dumps and in-place pollutants are likely to be with us perhaps in increasing magnitude for some considerable time.

What potential do we have to react to contaminant problems before we are at the stage of issuing consumption advisories to anglers and closing commercial fishing operations? The development and use of fish health diagnostic tools is a means of providing an early warning mechanism to detect a range of contaminant related problems in the fish stocks of the Great Lakes. These diagnostic tools may be as simple as the notation of the incidence of irregularities in anatomical features. The presence of external tumours, liver tumours or skeletal anomalies is an indication of stress often related to elevated levels of contaminants. More sensitive tests such as the estimation of enzyme suppression often indicate contaminant related stress before contaminant burdens are measurable in the population. Figure 6 compares the incidence of lip papillomas in white suckers from the more heavily contaminated Lake Ontario versus the prevalence in populations from the relatively less polluted Lake Huron. These are simple observations of gross external features but the data correlates well with the general contaminant burdens in fish from these sites. Figure 7 demonstrates the same comparison utilizing the levels of mixed function oxidase, a more sensitive indicator of contaminant exposure. Other techniques such as Quantitative Structure Activity Relationships need to be refined in order to give us increased anticipatory capabilities.

Many of these analytical procedures may be drawn from the mammalian toxicological literature. Still a great deal of developmental work is required before these techniques can be directly related to specific contaminant exposure and the responses quantified. Nevertheless the technology must be developed or we may simply continue to write a series of obituaries for some of the Great Lakes fish stocks. The recent advances in analytical chemistry sensitivity must be accompanied by similar progress to detect subtle sublethal responses of contaminant levels.

The last point we were asked to speculate on was the state of the Great Lakes fishery a decade from now if no action is taken. The regulatory actions which were implemented as a result of the Great Lakes Water Quality Agreement were a good first step but recent data indicates that many new problems are now occurring. Both the leaching of materials from chemical waste dumps and the release of toxic compounds from contaminated sediments are a continuing threat to a viable recreation and commercial fishery. There has been considerable investment in sportsfish stocking programs and the sea lamprey control program continues to enhance lake trout stocks for the commercial industry. But this investment may be for naught if the resource is not usable. Linked to this local problem is the threat of increased rejection of Canadian fish products and a general concern in international markets that the Great Lakes fishery will close due to chemical contamination of fish stocks. To put the Great Lakes toxic chemical problems into a national perspective it is important to consider that just as each of the Great Lakes flows into the next, the entire basin empties into the St. Lawrence River, which itself ultimately affects events further downstream. Thus the problems experienced in the Great Lakes may serve as the bellwether for situations which may arise well outside its basin.

ACKNOWLEDGEMENTS

Vic Cairns and Lynne Luxon of the Great Lakes Fisheries Research Branch provided data on lip papillomas and MFO levels.

FIGURE 1

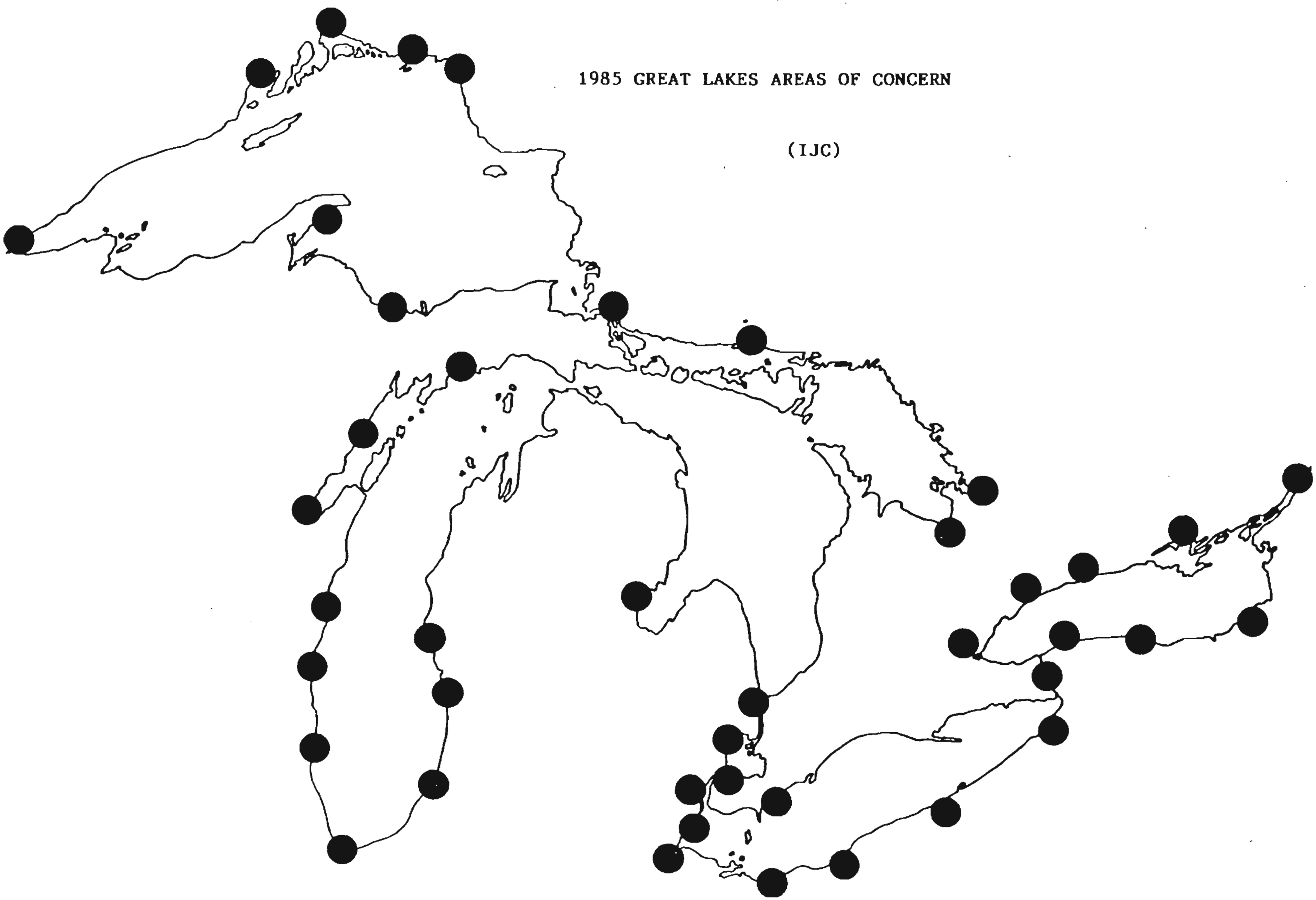


FIGURE 2

GREAT LAKES COMMERCIAL FISHERY

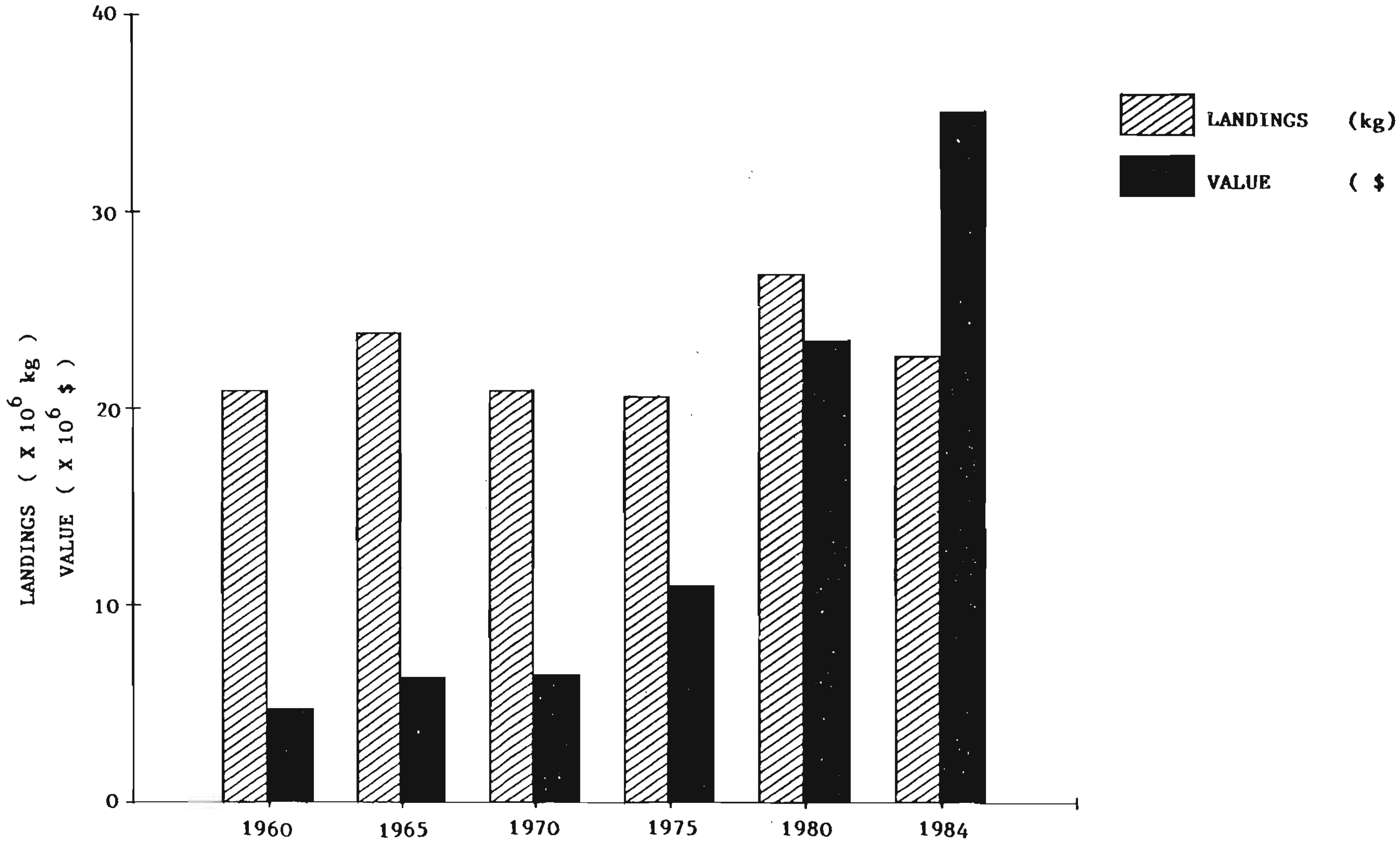


FIGURE 3

LAKE ONTARIO LAKE TROUT (AGED 4 +)

WHOLE FISH PCB LEVELS

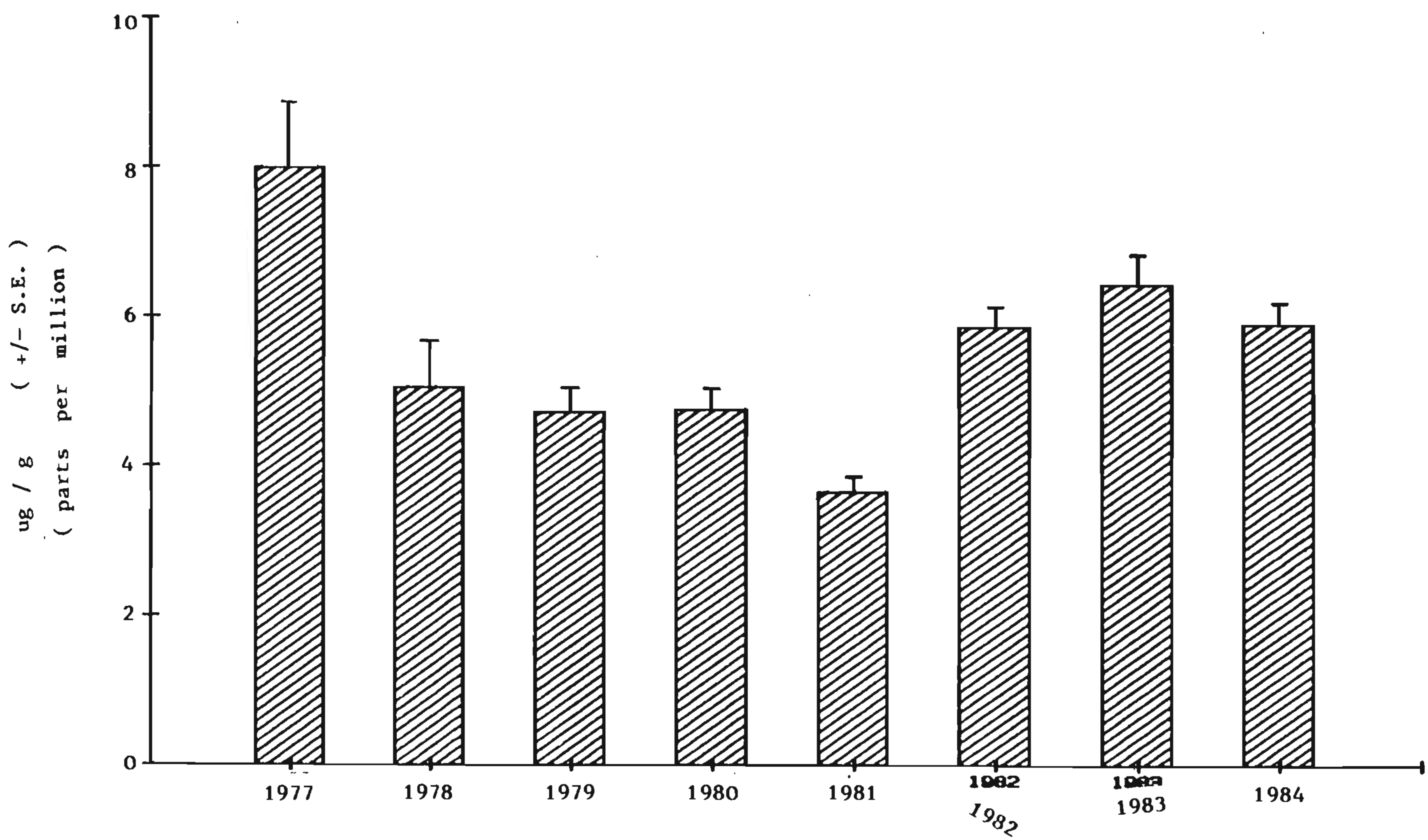
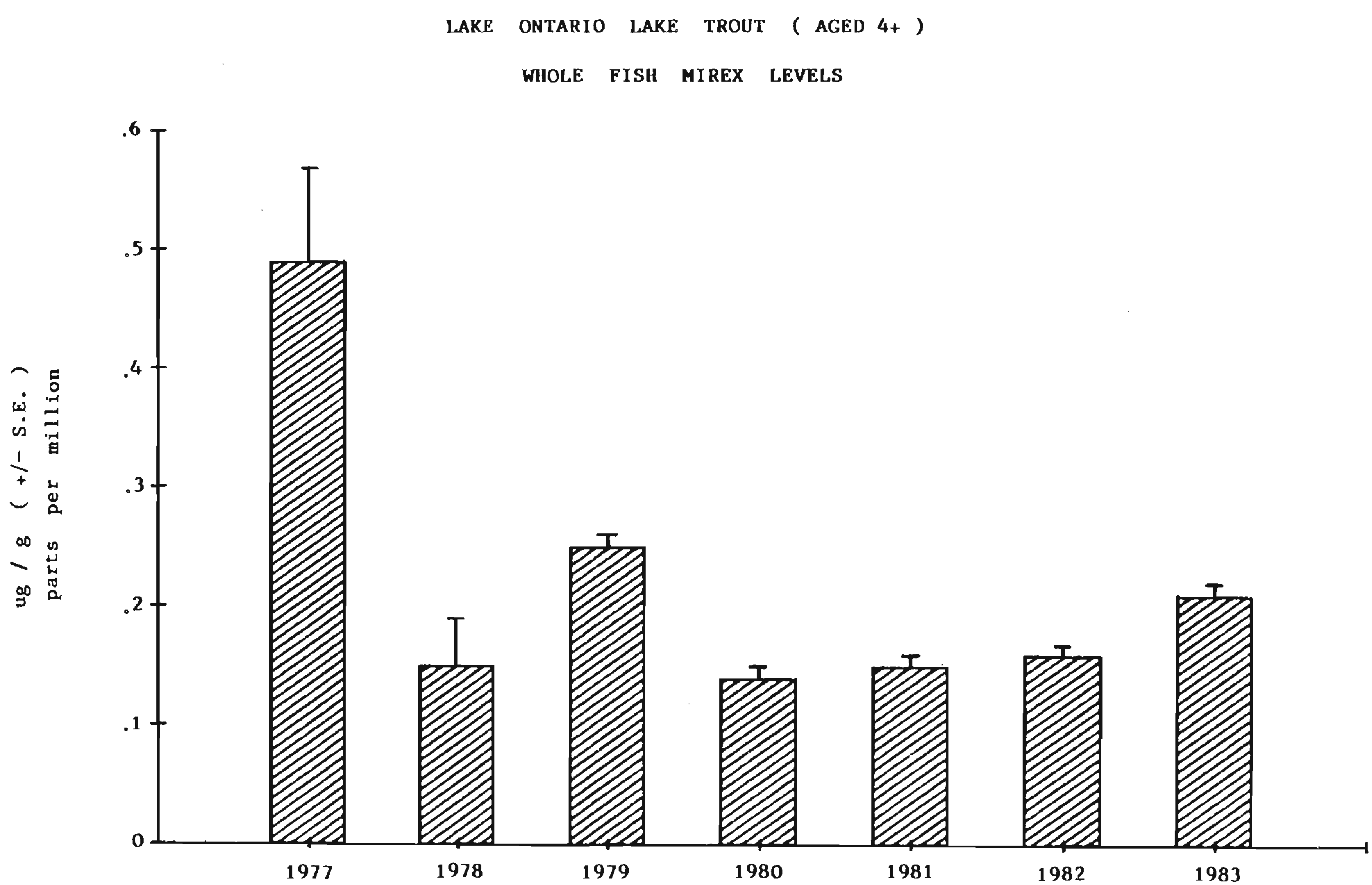


FIGURE 4



LAKE ONTARIO LAKE TROUT (AGED 4+)
WHOLE FISH MIREX LEVELS
ug / g (+/- S.E.)
parts per million
.6
.5
.4
.3
.2
.1
0
1977
1978
1979
1980
1981
1982
1983

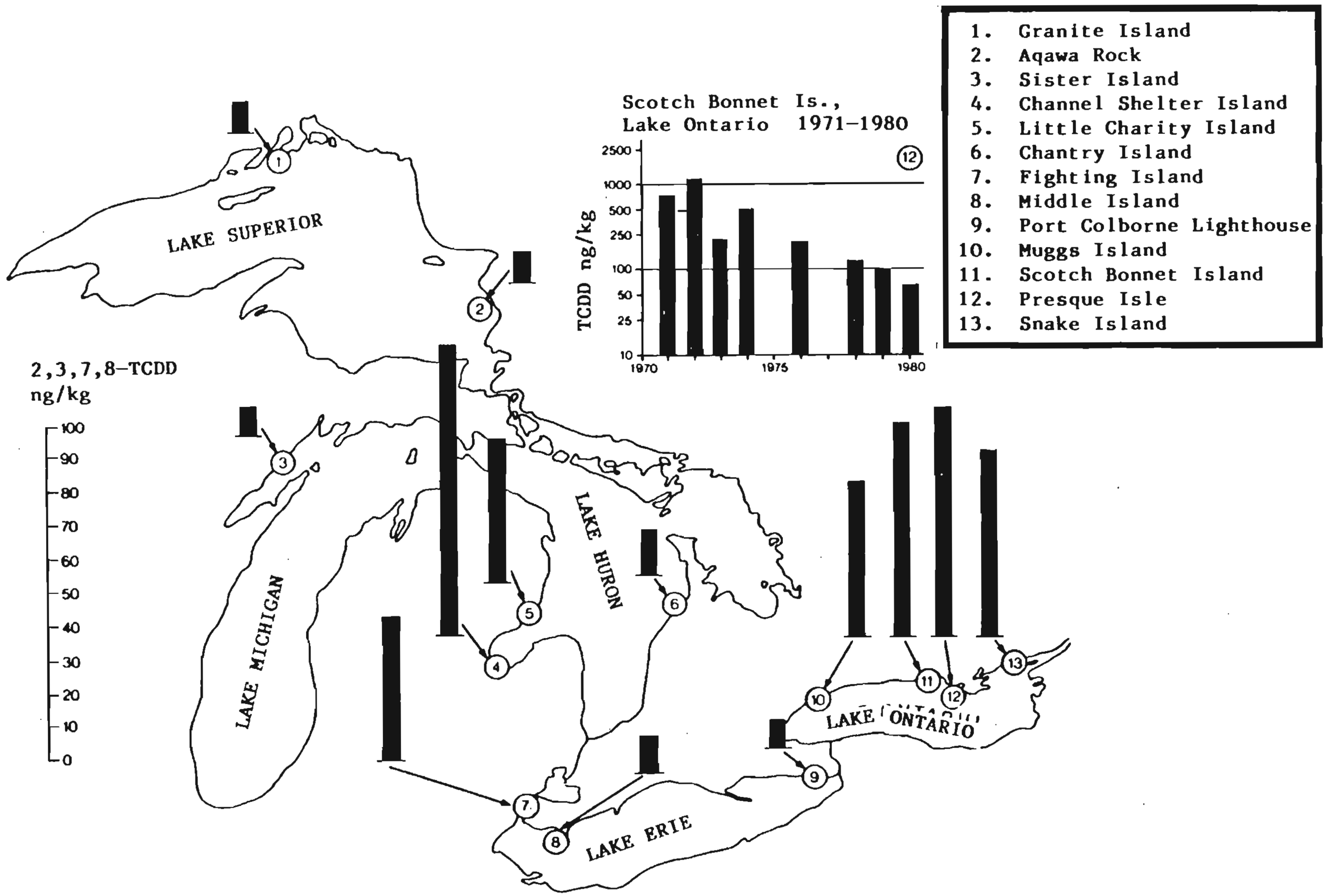
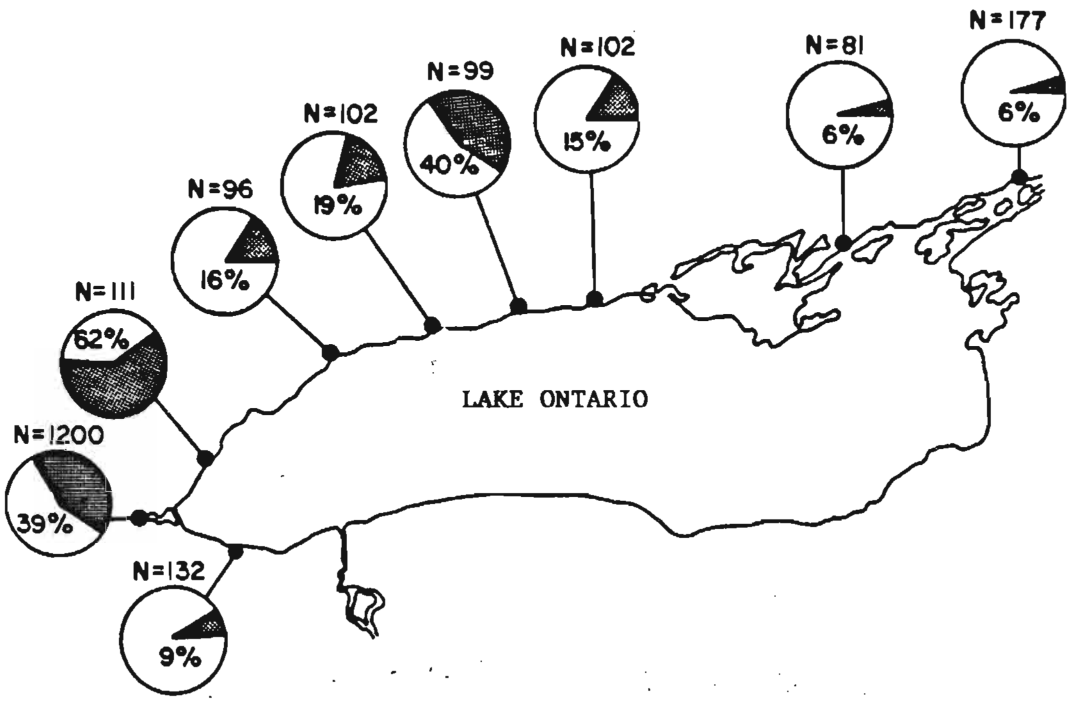


FIGURE 5, 2,3,7,8-TCDD concentration in herring gull eggs in 1980 from selected Great Lakes nesting colonies.
Data Source: Canada Wildlife Service, Burlington, Ontario



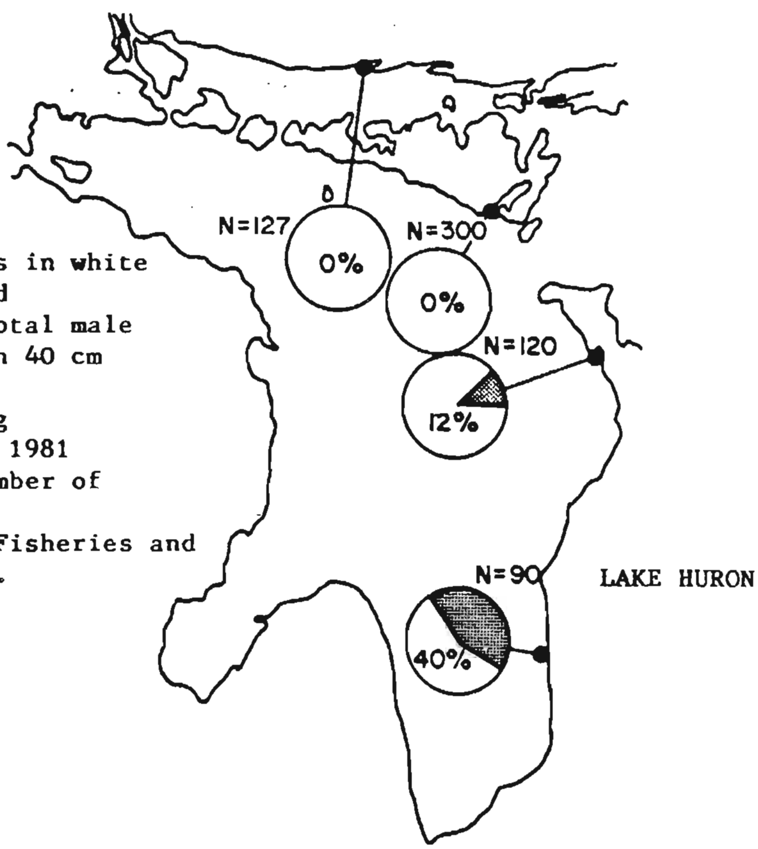
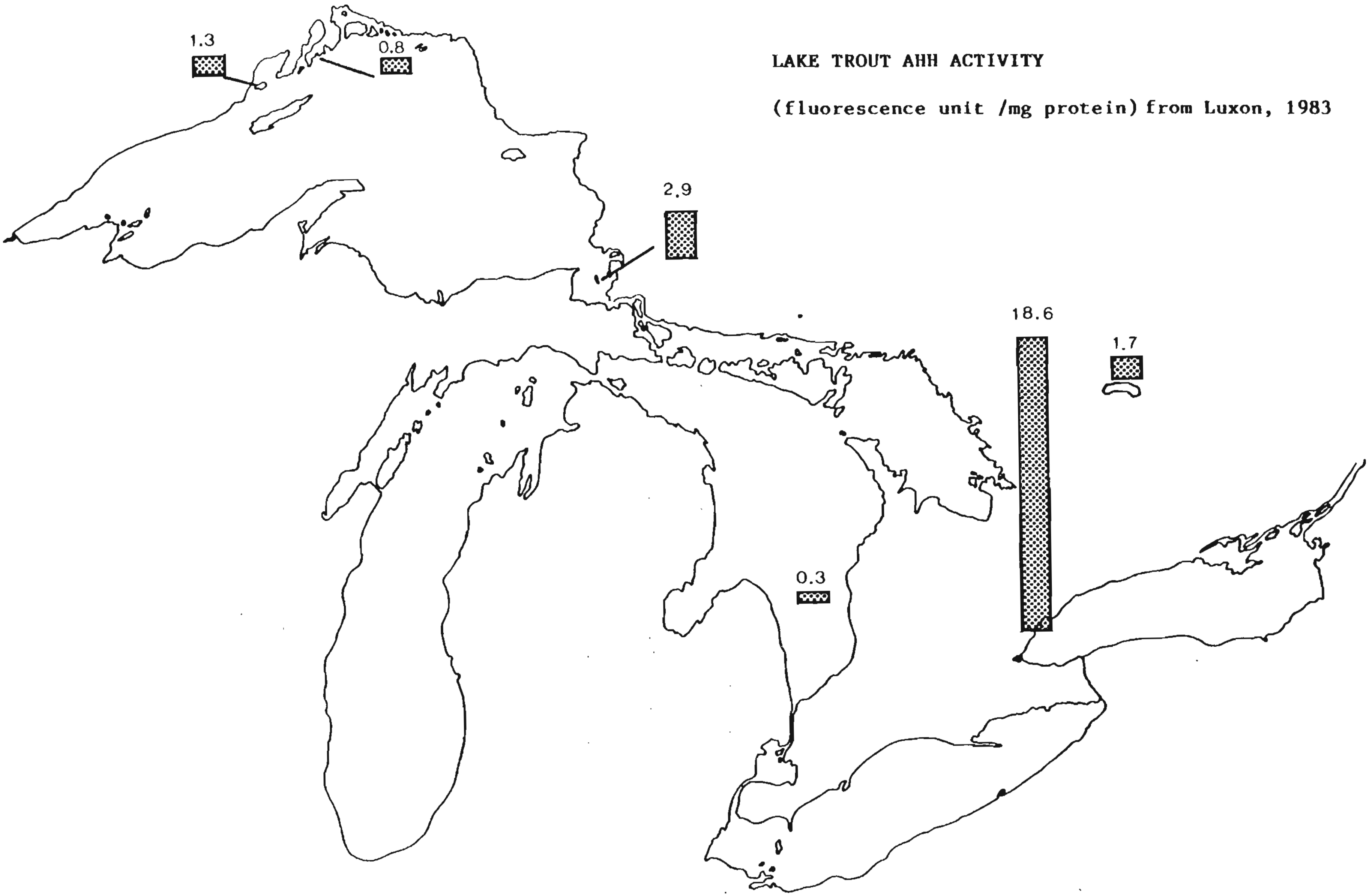


FIGURE 6.

Prevalence of lip papillomas in white suckers from Lakes Huron and Ontario as the percent of total male and female fish greater than 40 cm in fork length collected by electrofishing during spring spawning runs for the years 1981 through 1983. "N" equals number of fish collected.
Data Source: Department of Fisheries and Oceans, Burlington, Ontario.

FIGURE 7,



LAKE TROUT AHH ACTIVITY

(fluorescence unit /mg protein) from Luxon, 1983

Table 1

Organic Chemicals

Pesticides
Energy Wastes
LRTAP (Acid Rain)
Metals and Nutrients
Bod/Cod Wastes

Table 2

Areas of Concerns

Date	Number	Comment
1973	Annual Assessment of Water Pollution Sites	
1974	69	1972 GLWQA Objectives Exceeded
1975	63	
1976	47	PCD in Waukegan Harbour Sediment
1977	47	Identified Industrial/Municipal Sources
1978	48	Increased Toxic Substance Awareness
1980	51	Status of Remedial Programs
1983	39	
1985	42	Progress of Remedical Action Plan

Table 3

Commercial Fishery Employment and Investment

Men	1,588
Fishing Boats	$303.4 x 10^6$
Fishing Gear	$128.8 x 10^6$
Shore Installations	$ 64.8 x 10^6$
New Capital Investment	$ 36.2 x 10^6$
Total Investment	$533.2 x 10^6$

Table 4

Great Lakes Recreation Fishery (1980)

	Anglers	Fishing Effort (Days)
Resident	857,000	12,536,600
Non-Resident	166,000	1,859,700
Total	1,023,000	14,396,300

Value = $124,967,800

Table 5

Sportsfish Consumption Advisories

Location	Sites Tested	Advisory	%
Superior	43	31	72
Huron	27	13	48
Georgian Bay	32	16	50
St. Clair	1	1	17/19 Species
Erie	12	7	58
Ontario	34	25	73
St. Lawrence	13	12	92

3.3 WESTERN FISHERIES RESOURCES ZONAL OVERVIEW

by
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Introduction

Canada has 25% of the world's freshwater. This figure includes water in storage, such as that found in groundwater and lakes. Canada has 1/3 of the world's freshwater lakes. These lakes cover a surface area of about 756,000 km^2, which is larger than the province of Alberta. One hundred and thirty-two of these lakes have a surface area of over 400 km^2, and 565 have areas larger than 100 km^2. Included are the huge northern lakes of Great Slave and Great Bear, which are larger than Lake Erie.

Canada has 9% of the world's renewable freshwater supply. This supply is defined simply as total river flow rate, which is 6.3 million m^3/min in Canada. Canada's renewable supplies are less than those contained in the USSR and Brazil, but they exceed those of fourth place China and fifth place USA. Canada's mighty rivers include the Mackenzie which is about 4,400 km in length, and the Nelson and St. Lawrence each exceeding 2,600 km.

Freshwater lakes and rivers within Canada are subject to wide ranges of climatological, geological and hydrological conditions. For example, annual precipitation values range from less thn 400 mm in the interior plains to greater than 3,200 mm in some parts of British Columbia. Snowfall constitutes a major fraction of annual precipitation in some regions of Canada with amounts varying according to winter temperatures and air flow patterns. There are considerable differences in water temperatures of Canadian freshwater lakes. For example, lake ice-free dates range from the first part of April in southern areas to the first part of August in Arctic regions. Lake freeze-over dates range from the middle of September to late December. The chemical composition of Canadian freshwater also varies over wide ranges. For example, water hardness, expressed as calcium carbonate, ranges from greater than 700 mg/L in some prairie pothole lakes to less than 10 mg/L in oligotrophic lakes on the Precambrian Shield. Other natural chemical constituents, such as major cations, anions and buffering capacity, vary over ranges of differences of up to 1 and 2 orders of magnitude.

These wide ranges in parameters referred to as environmental factors are extremely important considerations in evaluating chemical hazards on freshwater fisheries. The accumulation and adverse effects of chemicals are generally modified, sometimes to a very large degree, by the physical and chemical properties of the water. In the absence of proven ecological and toxicological diagnostic indicators of pollutant-induced stress, the sensitivities of freshwater fisheries to acidic deposition are being defined by using only water chemical properties of alkalinity, bicarbonate, calcium and conductance. The lack of relevant, early-warning biological indicators of pollutant-induced stress, and the need to know the effects of all relevant environmental modifying factors on the accumulation and adverse effects of hazardous chemicals are two major research issues in this fisheries zone.

The diverse freshwaters of Canada provide the habitat for a simple, but extremely valuable, fishery. The relatively recent retreat of the Pleistocene glaciers have resulted in a total freshwater fish fauna of 24 families and 177 species in Canada. Four additional species, the brown trout, carp, goldfish and tench have been introduced by man. About 70% of Canada's freshwater fish are members of only 5 families; namely the salmonids, cyprinids, catostomids, percids an cottids. Compared to some other areas of the world, these 181 species represent a lack of species richness.

When compared to commercial fisheries on the Atlantic and Pacific coasts, the value of the inland commercial freshwater fishery is small. In 1983, the total landed value of this fishery was estimated to be $51 million. This estimate represents 16%, 26% and 17% of the landed value of coastal groundfish, pelagic and estuarial fish, and shellfish, respectively.

To individuals and communities relying on these $51 million revenues, however, this income is vital. In his address to the Inquiry on Federal Water Policy, John Fraser recently states that "in many small communities in Ontario and in the prairies . . ., freshwater commercial fishing is the major industry in town". According to the Freshwater Fish Marketing Corporation, whitefish, pickerel and northern pike are the top 3 species on a quantity basis; generally representing greater than 70% of the total harvest. Pickerel and whitefish account for 70% of the total landed value of commercial fish in Alberta, Saskatchewan, Manitoba, northwestern Ontario and the Northwest Territories.

The economic value of the recreational ("sports") fishery is larger than the total value of exported commercial fish products. These exports valued at about $1.57 billion represent about 70% to 75% of the total commercial fish products. A survey of sports fishermen taken about 5 years ago demonstrated that anglers spent over $1.7 billion a year on activities directly attributable to sports fishing. This figure includes many diverse purchases, such as boats, motors, fishing equipment, land, buildings, package deals in northern lodges, and guiding services. All purchases, however, had a common theme of being directly attributable to an individual's sportfishing activity.

The species preferred by anglers include pickerel, pike, trout, bass and salmon. While most of these species are found in freshwater there is really no national favorite. The survey demonstrated that there are strong regional influences in species preferences; viz where lake trout is preferred in the Yukon and Northwest Territories; rainbow trout is favoured in British Columbia, and brook trout is the species of choice in the Atlantic provinces. Although pickerel were preferred by about 27% of all anglers, this species only accounted for 13% of fish landed by anglers. Anglers generally eat the fish that they catch. Over 153 million fish weighing about 73 million kg were caught by anglers in 1980. Almost 63 million kg (about 85% of the total catch) were consumed by anglers and their families.

Estimates of the economic value of the native food fishery are not usually made in the same manner as commercial or sports fisheries. The costs of chemical pollution of a fishery important to native groups, however, can be immense in social, health or political terms. For example, popular books, such as No Safe Place by Warner Troyer, describing pollution of native fisheries do not provide a favourable impression of the Canadian freshwater fishery.

The chemical pollution problems in the zone are diverse as would be expected from the range of human activities in the zone. Specific pollution problems in freshwaters in the Great Lakes and the Arctic are described in this volume in the chapters written by D.M. Whittle and W.L. Lockhart, respectively. The population centres in the southern prairies (and parts of the Dakotas and Minnesota) are virtually all in either Arctic Ocean or Hudson Bay River drainages, so pollutants can travel more readily from sources in the south to remote areas in the north. Ocean currents also transport chemicals from both the Atlantic and Pacific Oceans to the Arctic Ocean. Recent studies have also revealed that pollutants travel effectively by air either as gases or absorbed to particles borne in the wind. Air movements at points in the northern part of the zone have been traced back to the Soviet Union and to Europe as well as to North America, so understanding the sources and movements of pollutants in the zone forces us to think in a hemispheric context.

The sources of chemical pollution in the region include the large scale use of agricultural pesticides and fertilizers in the prairies, forest spraying in the Canadian Shield and the eastern slopes of the Rocky Mountains, metals from mining and smelting operations throughout the region including mines in the Arctic Islands (and from abandoned mines), radionuclides from mining and milling of ores, petroleum production from the U.S. border to the high Arctic, acidification of rainfall with sulphur or nitrogen oxides from regional sources like metal smelters and automobile exhaust, construction of hydroelectric reservoirs with associated erosion of previously frozen permafrost shorelines and concomitant mobilization of mercury, industrial chemicals associated with other major activities like petrochemicals, transportation, transmission of electricity, food processing, lumber and paper production, northern military bases, and domestic wastes.

Given the diversity of pollutant sources and the magnitude of the freshwater and Arctic fishery resources potentially affected, the Western Region has been investing the full-time efforts of about 70 scientists, biologists, chemists, and technicians in efforts to understand the environmental dynamics and effects of chemical pollutants on many kinds of aquatic life from freshwater algae to Arctic seals and whales. It was recognized that some facility was needed to examine the links between input of pollutants and response of aquatic ecosystems and this led to the establishment of the Experimental Lakes Area, a research situation unique in the western world. Regional staff and visiting scientists from around the world have been studying the effects of chemicals like metals, acid, radionuclides, phosphorus, and even dioxins on the functioning of the lakes. Studies are continuing on more and better ways to diagnose cases of chemical poisoning with experimental toxicology studies and observations on aquatic populations under chemical stress. Other regional staff are devoted to examining fish products prior to export to certify that contaminant levels permitted in buyer countries are not exceeded. Many large-scale energy projects are planned for the region, and other regional staff serve on committees to review the implications of these projects for fish and marine mammals, and to prevent habitat deterioration.

Specific Western Contaminant Problems

a) Organic Compounds

Fish and marine mammals throughout the region are contaminated with levels of stable organochlorine compounds, but the levels are low relative to many parts of the world. The Arctic is of particular interest because these compounds have not been used locally but are thought to be transported from more southerly latitudes by air and water, and possibly by river flows. Some compounds like PCBs seem to be decreasing over time, but others like chlordane and DDT seem to be about the same. Recent research projects have involved surveys of organochlorine contaminants in ringed seals from the Lancaster Sound region and in beluga whales from the Eastern (Baffin Bay) and Western Klugmallit Bay) Arctic.

b) Pesticides

Herbicides and insecticides are widely used in prairie agriculture, and some of these, notably 2,4-D and lindane, have become widely distributed in prairie waterways. Some western rivers have a long history of regular treatments with pesticides to kill blackfly larvae; methoxchlor is now used for that purpose. It contaminates the fish for long distances from the site of treatment. Research in the Western Region has concentrated on methods to detect both the pesticides using chemical and biological methods, and also to detect ways to tell whether the pesticides are doing biological damage to fish or the other aquatic life that fish depend on for food. Recent research projects have included development of toxicity tests for the herbicide glyphosphate using aquatic plants, studies on the availability of methoxychlor and other pesticides to insect larvae in sediment and water, and studies on the fate and effects of pyrethoid insecticides such as deltamethrin.

c) Energy

i) Hydrocarbons

The Western Region is the principal Canadian producer of petroleum and frontier exploration currently being carried out in northern Canada promises to be of increasing importance. In low concentrations, petroleum hydrocarbons are toxic to fish and impart a characteristic unpleasant flavour to fish products. Therefore, spills of crude or refined petroleum products are of continuing concern. The toxic components of petroleum tend to be those materials that volatilize readily from water to air, but the water in the region is ice-covered for much of the year, and in these cases, the harmful components remain for long periods of time and move with the currents. Other hydrocarbon components include the polyaromatic fraction. It has been widely studied because a number of these materials are strong carcinogens. These compounds originate both from natural sources like forest fires and from human activities like oil spills and production of metallurgical coke. They have been found in Arctic air samples, so that it is difficult to associate a particular polyaromatic hydrocarbon with a particular source, but whatever the sources, these materials appear to be widely distributed in Arctic fish. Recent research projects include surveys of Arctic marine fish (mainly cod) for polyaromatic hydrocarbons, studies of the toxicity to fish of the water soluble fraction of crude oil and studies on the fish toxicity of dispersents that many be used against oil spills.

ii) Radionuclides

Use of nuclear energy will increase over the next few decades; explorations are currently underway to determine the site of Canada's first, and urgently required, permanent nuclear waste disposal site. Uranium mining (particularly in hard-rock areas of north central Canada) will accelerate in future years because Canada's reserves are second in abundance in the Free World; and, recent incidents such as COSMOS 954 and Three Mile Island have resulted in an extremely sensitive public. As a result, Western Region has developed a modest radionuclide program, the emphasis of which to date has been to begin establishing natural background rates of U-series runoff (supply) to freshwater and Arctic estuarine ecosystems, and to delineate key biologocal pathways, rates of transfer, and accumulation in these systems. As well, limited work has been carried out aimed at assessing the potential for alteration of radionuclide cycles in anthropogenically acidified freshwater systems.

iii) Hydroelectric

Safe, secure, and renewable, hydroelectricity continues to be the preferred option for electrical power generation and will, undoubtedly, lead to major hydroelectric development in every Canadian province or territory. Particularly massive in scale, and potentially of greatest impact, will be those in very sensitive, northern, permafrost regions. Since 1972, the Western Region has been studying the environmental problems that new reservoirs and river diversions can create for commercial, subsistence, and sport fisheries, by means of a case study of the impoundment of Southern Indian Lake and Churchill River Diversion. This project has identified and quantified several critical processes occurring in new reservoirs; for example, shoreline erosion, sedimentation, nutrient release and mercury mobilization which affect fisheries and the food chains on which they depend. The results of these studies have been recently collated and reported at length in the Canadian Journal of Fisheries and Aquatic Sciences (Volume 41, No. 4, 1984).

d) Long Range Transport of Atmospheric Pollutants (LTRAP)

i) Acid Precipitation

Acidification of softwater lakes lying on the Canadian Precambrian Shield, particularly by atmospheric transport, transformation, and deposition of oxides of sulphur and nitrogen, has been described as the environmental problem of greatest significance in Canada to-day. Western Region has utilized its unique whole ecosystem manipulative approach at the Experimental Lakes Area, combined with laboratory-based biochemical/physical studies in Winnipeg, to address a number of questions key to understanding the phenomenon and, thereby, resolving the problem, and also key to providing the scientific support necessary to Canada's emissions reductions negotiations with the U.S. Specifically, it is anticipated that the work will contribute significantly towards answering the following questions:

- what is the evidence of historical changes in biological communities related to acidification? What are the causes of these changes?

- What is the potential for further acidification and ecological degradation in the future as a result of LRTAP stress?

- What are the processes leading to acidification and resulting biological damage, particularly on the fisheries resource in the aquatic environment?

- What is the relative importance of long-term average deposition and short-term episodes of regional input of acid (acid shock)?

- What are the effects of acid deposition on Canada's wetlands? Particularly, what potential do acidified wetlands have for increasing inputs of heavy metals and other pollutants inhabited by sensitive fish species?

- What is the adequacy of the present target of 20 kilograms wet sulphate deposition per hectare per year to preserve and restore all but the most sensitive aquatic ecosystems?

- What other targets (elements or compounds other than sulphates) are required to protect the aquatic ecosystem?

Recently, the results of the Experimental Limnology Project's first whole lake acidification experiment (Lake 223) begun in 1976, were summarized in Science (Volume 228, pp. 1395-1400, 1985). Findings ranged from alteration of community structure of the phytoplankton, disappearance of certain key species of benthic crustaceans, to cessation of lake trout reproduction, and indicated that irreversible stresses on aquatic ecosystems occur earlier in the acidification process (higher pH) than was formerly believed. Changes described (observed) were caused by the hydrogen ion alone and not by the secondary effect of aluminium toxicity.

ii) CO2

Carbon dioxide in the atmosphere, from the burning of fossil fuel, will probably change the world climate. Climate models predict increases in mean temperature to 2 to 6°C in southern and mid-latitudes and 6 to 10°C in northern latitudes. Mid-continental areas are likely to be most affected because they lack the dampening effect of the oceans. Changes in weather patterns and precipitation are expected.

There are a number of potential effects on inland fisheries and aquatic habitats. Longer ice-free seasons and warmer water temperatures could alter primary productivity and fish growth and result in a redistribution of species. Altered precipitation could result in major changes in water flow, including potential evaporative dessication of shallow lakes. Changes in Arctic coastal fish habitat are possible if the sea level rises and coastal flooding occurs. In the longer term, changes of a few degrees in mean temperature would result in permafrost boundary movement of hundreds of kilometres northwards. Melting of permaforst would increase sediment loading to lakes and rivers lowering water clarity. Changes in clarity have been shown to alter significantly fish distribution and market quality in Southern Indian Lake, and similar effects are anticipated on other northern fisheries. Dissolved components in water would also increase with permafrost melt.

The Western Region has no program directed toward the study of effects of human alteration of the world's climate. However, regional studies have examined similar aquatic ecosystems over a range of climate conditions near Kenora, Ontario, at Southern Indian Lake, and near Chesterfield Inlet, N.W.T. Interpretation of existing data in the context of climate change, coupled with a new program specifically designed to determine the climatic controls on fish distribution, production and quality, could be used to predict the effects of climate change. In particular, Canada's $1.7 billion sport fishery, which is based entirely on coolwater fisheries in close proximity to the U.S., may ultimately be at risk.

e) Inorganic Chemicals

i) Metals

In North America, environmental contamination by metals has been recognized for over a century. Mining and smelting in northwestern regions of Canada contribute large quantities of metal contaminants, a to aquatic systems and the atmospheres. Metals emanate from a variety of other activities and sources including automobile exhausts, pulp mill effluents, flooding and acidification. Their input to the aquatic environment results in a variety of effects ranging from death, impaired reproduction and change in migratory behaviour of fish, reduction of biomass and species diversity of aquatic invertebrates and vegetation, to increased concentrations in all segments of the aquatic food web. Projected variances in Arctic metal mining will likely result in the introduction of substantial quantities of contaminants into freshwater and marine ecosystems, the fragilities and sensitivities of which are currently unknown.

The Western Region has been a leader in the research of mercury pollution problems since their discovery in the early 1970's, having contributed significantly to the work on, and formulation of, amelioration and management strategies for systems such as the English Wabigoon Rivers (pulp mill effluent - special series of papers published in CJFAS, Volume 40, pp. 2206-2259, 1983) and Southern Indian Lake (flooding caused by hydroelectric reservoir construction - also see section on energy above). Currently, regional metals studies are focussed on sources, biological pathways and processes, and toxic effects, particularly as emanating from, or in combination with, anthropogenic acidification (see also LRTAP section above). Biochemical indicators such as metallothionein levels and lipid peroxidation are being evaluated as tools for assessment of metal contamination, especially those low levels associated with atmospheric deposition.

ii) Nutrients

From the late 1960's to mid-1970's a significant portion of the Western Region's studies, particularly those at the Experimental Lakes Area, were devoted to resolving the problem and controversy of eutrophication. Whole lake and experimental mesocosm eutrophication and Nitrello-Triacetate (NTA) studies played a major role in the decision to ban phosphate detergents, and focus Canadian eutrophication management on phosphorus control; results presented to the 19th International Congress on Limnology caused attending scientists to endorse unanimously phosphorous control as a global strategy for eutrophication control; and, results have also furnished key evidence for phosphorous control in several American states. Today, eutrophication work in the Western Region is limited to continuation of the study begun in 1969 in Lake 227, the current objective of which is the study of effects of long-term fertilization on eutrophication and processes related to new equilibrium with higher nutrient input. The critical equilibrium question is currently being addressed by the International Joint Commission (IJC) with respect to management of nutrient inputs and expected sediment returns in the lower Great Lakes.

3.4 ARCTIC FISHERIES RESOURCES ZONAL OVERVIEW

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Introduction

The Canadian "Arctic is not formally defined but may be regarded approximately as the Yukon and Northwest Territories and those regions of Quebec and Labrador north of about 55 degrees north latitude. In attempting to understand the presence of chemical pollutants in the Arctic one must consider not only the region itself but also the drainage basins and the exchanges of air and water between the region and other parts of the planet. Canadian Arctic Ocean and Hudson Bay drainages are each over 3,500,000 sq km, and each exceeds in area the combined Canadian portions of Atlantic and Pacific drainage basins. It is known that chemical processes operate at rates partially controlled by temperature, thus processes take longer in the Arctic than in warmer climates. This implies that natural processes will be slow to cleanse the Arctic after it becomes polluted.

Inputs of water to the Arctic Ocean have been estimated at about 61% Atlantic, 36% Pacific, 2% rivers, and 1% precipitation. Outflows from the Arctic Ocean are through the East Greenland current (which moves south around Greenland and then returns northward into Davis Strait and Baffin Bay before turning back southwards to reach the Atlantic along the Labrador coast), and through a number of channels in the Canadian archipelago. Atlantic Ocean water is supplied by currents which flow westward from the central Atlantic, then northeasterly off eastern North America and across the Atlantic, past the British Isles and northern Europe, and then into the Arctic basin around Spitzbergen. Pacific water flows westward just north of the equator and then northerly to pass the Asian coast and Japan, and then back across the north Pacific where some water flows into the Arctic through Bering Strait. These current patterns indicate that major industrial centres of the northern hemisphere in eastern North America, the British Isles and northwestern Europe, and in eastern Asia and Japan, all lie near ocean currents supplying water to the Arctic Ocean. It should not be surprising to find that industrial pollutants have spread throughout Arctic regions. For example, radionuclides discharged from the Windscale plant on the Irish Sea have reached the LOROX sampling station near the North Pole in a sub-surface flow extending to a depth of 1.5 km, within a time of 8-10 years (Livingston and co-workers, 1984). The major rivers providing freshwater to the Arctic are principally Siberian; three large rivers there supply over 60% of the input. By comparison, the largest Canadian source is the Mackenzie River which supplies some 9% of total river water input.

Arctic air has been attracting scientific interest for several years and a special issue of the journal "Atmospheric Environment" was devoted to the topic in 1981. More recently a special session on atmospheric transport of pollutants was included in a conference held in Yellowknife in April of 1985, on the pollution of Arctic waters. Meteorologists have developed models which allow calculation of where a given air mass may have been at various times prior to its arrival in the Arctic. While there is always some uncertainty in any back calculation of this type, there is agreement that air arrives in the Arctic from many sources including North America, Europe and Asia. This air has been found to bring with it a wide variety of pollutants including organic compounds, heavy metals, radionuclides, and nutrients. An independent line of evidence has come from the analysis of pollen in samples of Arctic air; Barrie and co-workers (1981) reported that over 80% of the pollen in air samples from Mould Bay originated outside the Arctic.

Precipitation and river flows form only a small proportion of the input to the Arctic Ocean, but they appear nontheless to be an important vehicle for the delivery of some pollutants, particularly to near-shore waters. They represent part of the more general phenomenon of "Long range transport of atmospheric pollutants". For example, tritium is produced in the air during atmospheric testing of nuclear weapons, and it appeared in Arctic precipitation following such tests in the early 1960's (Dorsey and Peterson, 1976). As a result of these inputs the surface layer of the Arctic Ocean became several times richer in tritium than did the North Atlantic, raising the question of whether air circulation patterns make the Arctic Ocean a sink for the deposition of pollutants which subsequently flow out to the north Atlantic.

Not all pollutants arrive in the Arctic from southern sources. Arctic lands are themselves rich in a variety of mineral resources, the extraction of which can be expected to grow in economic importance. For example, the Canadian Arctic has a number of mines producing various metals (gold, arsenic, lead, zinc, tungsten, copper), and western Greenland also has working metal mines. A number of uranium mines have operated in the Arctic, and rich deposits remain available to be developed as market conditions dictate. The Mackenzie River watershed, drains the oil-sands area of Alberta, the uranium-mining area of northern Saskatchewan, and contains the third-largest producing oilfield in Canada at Norman Wells.

One of the most consistent sources of pollution in the Arctic has been spills of material during transport, and this can be expected to increase as greater volumes of materials are transported. Also, new Transport Canada regulations regarding the transport of dangerous goods are improving the reporting of spills, and so the number of spill events that require investigation and remedial action can be expected to increase. A computerized inventory of spills is maintained by the Environmental Protection Service (Beach, 1985) and it contains reference to almost 900 such cases in the Yukon and Northwest Territories from 1974 to 1983, most of which involved petroleum products.

About a third of all spills were directly attributed to human error and most of the others could be attributed to error indirectly through inadequacies in design or materials. With increased movement and storage of materials in the Arctic continued spills can be anticipated since the human error factor probably cannot be eliminated.

The distinction between natural and anthropogenic sources of contaminants will arise repeatedly, particularly if claims of damage are made as a result of pollution by oil, metals, or radionuclides. Parties claiming damage may contend that pollution originated from some local source such as an oilfield, a mine, or a spill; whereas parties contesting the claim may contend that any damage resulted from natural sources. In these instances it will be especially important to have sound data on natural levels of the pollutants in question, and on the range of natural variation in those levels. Other pollutants, however, are exclusively synthetic (organochlorines, freons, siloxanes, etc.) and in these cases the question is not whether the source is anthropogenic but rather what pathways and processes may have led to contamination in the Arctic.

Regardless of the source of pollution, a number of questions commonly arise as to the meaning of the pollutant(s) to the organisms themselves and to the use of those organisms by people. This is perhaps the greatest void in current knowledge and it will become increasingly apparent as the Department is called upon to make judgements of what levels of pollutants are acceptable. The problem is common to fish and wildlife agencies generally in which damage to individuals is acceptable but damage to populations and communities is not. (An exception to this applies to endangered species like bowhead whales.) In the Arctic the margin for error in judgement is smaller because the low overall rate of biological production will mean that population and communmity damage will take longer to recover than it might in warmer climates. Several scientists at this meeting have made the plea for more and better "early warning" tests which could give advance notice of impending ecological changes before those changes occur, and I endorse that plea. Some of the tests showing promise in this area have been reviewed in the recent volume, "Contaminant Effects on Fisheries" (Cairns and co-editors, 1984.) However, most test results are generally not well enough understood to allow their interpretation in terms of ecological consequences for populations and communities, particularly in the Arctic. Furthermore, the range of natural variation in test parameters needs to be established in order to know when a given result is in fact an early sign of pollution-related pathology. It seems that much work with these tests remains to be done in order to find the empirical and theoretical linkages between the test results and the ecological consequences. The alternative is to monitor the populations and communities themselves, but this approach can only detect the damage after it has occurred. Pathologists examining dead grey whales on the west coast, and beluga in the St. Lawrence have suggested chemical pollution may have contributed to the causes of death. Some populations in the Arctic are already so marginal (bowhead, walrus, narwhal) that the consequence of simply waiting and watching to see what happens may be extinction.

Specific Arctic Contaminant Problems

a) Organic compounds

Organochlorine compounds have been detected in the most remote regions of the planet, removed from any known local use of the compounds. Among the organic compounds detected are isomers of DDT, PCBs, dieldrin, heptachlor epoxide, chlordane, toxaphene, hexachlorocyclohexane, chlorobenzenes, chlorinated dioxins, and chlorinated dibenzofurans. Its seems likely that the list will grow as analysts become increasingly able to detect and identify small quantities of materials, since these compounds are known to be distributed widely by air movements. Many of these compounds tend to accumulate in the fat tissue of living organisms, and so marine mammal blubber has been analyzed frequently because concentrations are highest there, and these high concentrations are the easiest to measure. Many of the data for marine mammals up to the early 1980's have been tabulated by Wagemann and Muir (1984), and detailed works on harp seals (Ronald and co-workers, 1984) and polar bears (Norstrom and co-workers, 1985) have appeared recently. The concentrations of DDT, chlordane and PCB were determined in ringed seal blubber in the early 1970's and again in the early 1980's, with the result that PCBs seem to be declining but chlordane and DDT have not declined to the same extent over the period (Muir and co-workers, 1985; Addison, 1985.) The concentrations of organochlorines in Arctic marine mammals are still well below those in seals from the Baltic Sea, where these compounds have been associated with the pathology of reproductive failure.

The question of risk to people is somewhat more complicated because most analyses are not on meat but on blubber, and so the human exposure due to consumption of traditional foods is still poorly understood even with regard to the best known organic pollutants. Some blubber is eaten as a component of muktuk and some families use blubber oil for cooking. It is of interest that the Government of the Northwest Territories encourages the local use of traditional foods including fish and marine mammals. Health and Welfare Canada has initiated a study of contamination of diet items in one Actic community, namely Broughton Island. The questions of risk to people can only be evaluated after exposure ranges have been established.

The list of other organic compounds is very large (Zitko, 1985, this workshop) but the implications of these for the Arctic are not clear. Surprisingly high concentrations of polydimethylsiloxane have been found in Arctic air (Weschler, 1981) but these appear to have little biological activity. Aryl phosphate oils are used in some Canadian pipeline compressor stations and some of these materials are chronically toxic to fish and other vertebrates including man. The extent, if any, to which aryl phosphates will be (are?) used in the Arctic is not known. Arctic air samples contained several phthalates (Weschler, 1981). Freons have been measured in Arctic waters (Bullister and Weiss, 1983), and these, along with CO_2, methane, and nitrous oxide in the air have implications for climate changes.

b) Pesticides

Many of the chemicals considered under "organic chemicals" above are in fact pesticides but were included there because of the definition adopted for that class of chemicals. The more-recently-developed pesticides have been favoured in North America and western Europe partly because of their non-persistence. However, because of their low cost and biological effectiveness, the organochlorines may remain in extensive use in "third world" and possibly Soviet Bloc countries. Mehrle (1985, this workshop) has described the growth in pesticide use expected until the year 2000, and we can expect continued input of organochlorine pesticides into the Arctic for the foreseeable future.

With regard to non-organochlorine pesticides, direct application seems likely to remain very localized in the Arctic for such needs as biting fly and mosquito control in communities and military bases, clearing of weeds from navigation channels, possibly storage of perishable commodities during summer, and pressure testing of pipelines. Even local use of some exceptionally toxic new materials like pyrethroids will call for great care in application for such problems as mosquito control. Provided non-persistent materials are used most of these applications should not pose environmental problems beyond the community and season of use. Non-persistent pesticides are very widely used in the Arctic Ocean and Hudson Bay watersheds in Canada, and in the Arctic Ocean watershed of Canada and the Soviet Union, in the north Atlantic watershed en route to the Arctic in northwestern Europe, and in the Pacific watershed en route to Bering Strait in eastern Asia, and Japan. The question of whether non-persistent materials will appear in the Arctic is still open, however, because the analyses have not been reported. We should not be surprised, however, if future research reveals the transport of a number of pesticides into the Arctic, notably herbicides like triallate, and especially when sorbed to suspended particles in rivers.

c) Energy

The Arctic is of great interest with regard to chemical contaminants associated with energy developments not so much because of special inherent sensitivity of the organisms living there but because the unique ecosystem affords great opportunity for exposure (Vandermuellen, 1985, this workshop). Energy developments in the Arctic are expected to include oil and gas, uranium mining, and hydroelectric reservoirs, each with its own pollution implications.

The distribution of existing and potential hydrocarbon exploration and production in the Arctic has been shown in map form by Percy and Wells (1984). The extent of these areas is circumpolar with large deposits in the Soviet Union, Alaska and Canada, and with offshore deposits off those same countries and off Norway and Greenland as well. Investigations of the presence or effects of oil in the Arctic will be confounded by the presence of natural seepage sources. For example, a number of natural oil seepage areas have been tabulated by Wilson and co-workers (1973) and Canadian seep areas on land were estimated to lose somewhat under 100 bbl per day. These same authors estimated that 1,648,000 sq. miles of Arctic Ocean were of "moderate" seepage potential (largely Siberian) and that the amount of seepage oil released within the Arctic basin was between 5200 and 214 000 metric tonnes per year. An area of high seepage potential along western North America and in the Gulf of Alaska could also contribute to Arctic Ocean loading by currents through Bering Strait. The Mackenzie River conveys hydrocarbons from sources in its watershed to the southern Beaufort Sea (Wong and co-authors, 1976).

The recent expansion at Norman Wells, N.W.T., has made it Canada's third-largest producing oilfield with wells drilled land and on artificial islands in the Mackenzie River (Bone and Mahnic, 1984). Downstream of this development complaints have been made by DENE communities that fish from the river have become inedible due to a dark discolouration of liver and to a watery consistency of the flesh. Investigation of these complaints is currently a high priority with DFO, DIAND, and the DENE. Since natural seepage occurs at Norman Wells (and indeed led to the discovery of oil there: estimated by Wilson and co-workers (1973) to be less than 5 barrels per day) it is going to be very difficult to determine whether any contamination or pathology in fish downstream from Norman Wells is related to oil at all, let alone to produced oil rather than seeped oil.

Exploration for oil and gas is currently underway in a number of locations in the Canadian Arctic including the Mackenzie River valley and Mackenzie delta, the southern Beaufort Sea, the Arctic Islands, Davis Strait, and central Hudson Bay. Research on the implications of oil production and transport for Arctic marine communities is a focus for such programs as the Northern oil and Gas Action Program (NOGAP) and the National Energy Plan (NEP). Every year spills of refined petroleum products occur in communities, at development sites (e.g., McKinley Bay), or on winter roads and exert local effects on fisheries. For example, one such spill from a tank truck accident on 1 March, 1983, released diesel fuel into the Cameron River north of Yellowknife and resulted in tainting of whitefish after spring breakup. Fortunately a sample of oil from the truck was taken at the time of the spill (D. Tilden, EPS, Yellowknife) and another sample of diesel was recovered from the river several days later on March 9 (K. Hall, DFO, Yellowknife). It was possible to show that the diesel had retained its chemical properties, its toxic properties, and its tainting properties without loss during the period between collection of the two samples. Fish caught at the spill site on August 25 were tainted with diesel and unfit for human use. This evidence was presented in support of court prosecution under the Fisheries Act, and resulted in conviction.

This experience, together with experience with releases from the Suncor synthetic crude plant on the Athabasca River in northern Alberta, has convinced the writer that there is a systematic source of error in the way petroleum materials are evaluated for toxic properties. The testing methods are sufficiently ambiguous to allow systematic removal of toxic materials during the test itself, by aeration of the test water. This criticism should apply particularly to discharges to water covered with ice when volatile compounds cannot escape to the air and also when oxygen from the air cannot reach the water. Furthermore, there is a chronic response to oil and even more to mixtures of oil with dispersants that is not predicted by conventional 96-hr. testing. It would be desirable to review, jointly with EPS, the current practices to see whether testing methods more appropriate to winter conditions can be found.

Crude petroleum oils and some refined products, particularly used oils, contain polyaromatic hydrocarbons (PAH) which have been studied intensively because of their linkage to cancer. Other sources for these materials include combustion of carbon-based fuels (including forest fires), and operations like the production of metallurgical coke and the liquefaction of coal (Uthe, 1979). These materials are widely distributed at low levels throughout the southern Beaufort Sea (Wong and co-workers, 1976). One of these compounds (benzo(a)pyrene, BaP) has been measured in a series of sediment samples from the western Arctic. It was present in all samples, at a range of concentrations from 0.3 to 20.0 ug/kg (wet weight), with highest values from the Mackenzie River delta and adjacent areas of the Beaufort Sea. For comparison, mean BaP in nine Pacific coast sites was 0.4 ug/kg, which rose to 105 ug/kg within harbours (Stich and Dunn, 1980). Recent work on fish in our laboratory has confirmed that several polyaromatic hydrocarbons are widely distributed in Arctic fish, but at low levels. The source of these materials is still speculative, but Daisey and co-workers (1981) identified eleven polyaromatic hydrocarbons including BaP in air samples from Barrow, Alaska, and argued that the source, at least in winter, was combustion processes in mid-latitudes, suggesting that at least some of the PAH in the Arctic is imported. A number of compounds resembling PAH but containing atoms of sulfur or nitrogen or oxygen are also of interest but these have not been examined in Arctic samples.

One biological response that has been used successfully to detect subtle effects of oil pollution has been a series of enzymes collectively known as mixed-function oxidases (Payne, 1984). These enzymes are found at measurable levels in fish from the Ft. Good Hope area of the lower Mackenzie River and from Tuktoyaktuk, but so little is known of the normal levels and variations of these enzymes in Arctic species that we cannot yet say whether the amounts measured represent pathology. Experimentally, however, both Arctic fish and marine mammals do show this response when treated with oil. Considering the matter at an ecological level, Johnson (1983) concluded with the question, "Will oil affect Arctic marine fish and marine mammals?", and answered an unqualified, "Yes", but the following question, "By how much?" demands a much deeper understanding than we currently have before it can be answered.

d) Coal and Oil Sands

Wright (1980) listed 17 existing coal mining operations and delineated a large area of southern Alberta and a smaller area of southern Saskatchewan as favourable for development of new mines. These areas are essentially all in the Mackenzie River or Nelson River watersheds, and so both air and water pathways can transport pollutants from these sources to the Arctic. The oil sands region of Alberta and the heavy oil deposits of Alberta and Saskatchewan lie in the same watersheds, and we have already seen that the effluent from one of these plants can pollute long reaches of the Athabasca River following release of effluent under ice in winter.

e) Hydroelectricity

A report by Wright (1980) listed about 40 potential sites promising for hydroelectric development either in or near the Northwest Territories. Excess mercury in fish has been associated with flooding new hydro reservoirs and we have seen this happen as a result of diversion of the Churchill River in northern Manitoba for hydroelectric development of the Nelson River. A series of impoundments were created when dams were built to control water levels, with the result that mercury levels in the fish increased. In these cases the mercury is already present in soils within the flood zone, but it becomes biologically available to fish as a result of microbiological activity in the recently flooded soils (Bodaly and co-workers, 1984). The greater the area of organic soil flooded, the greater the elevation in fish mercury content. Current thinking is that elevated mercury levels in fish can be expected for something like 25 years following flooding of new northern hydroelectric reservoirs.

PCBs were formerly used in electrical equipment, some of which is still in place in Arctic sites (Holtz and Sharpe, 1984). Efforts are being made to remove this older equipment.

f) Nuclear

The issues for the Arctic appear to be mainly with the mining and milling of uranium ores, particularly since much of Canada's store of uranium ore lies either in the Arctic or within Arctic or Hudson Bay drainage basins.Exploration is currently active in the area west of Baker Lake, but only world markets and political considerations will determine the timing of future production. Past production at Port Radium and Rayrock (and at

Uranium City, Sask.) have resulted in abandonment of tailings when mines were closed, and charges by local communities that the Federal Government must be responsible for any radioactive contaminants leaching from tailings. The extent of the radioactive tailings problem in southern U.S.A. was illustrated in a recent editorial by Crawford (1985). Radiation frightens people so much that even if no hazard to fish or fish consumers exists it is still necessary to produce evidence to show the lack of such hazard. Current exploration has provided the impetus for a small project to define the present levels of some isotopes in fish, marine mammals, invertebrate animals and aquatic plants from both freshwater and marine sites at Saqvaqjuac near Rankin Inlet on the west coast of Hudson Bay. Preliminary results (Brunskill, 1985) show that the bioconcentration of ^{238}U, ^{234}U, and ^{137}Cs from water to living organisms is low, in the range of 100- 1000-fold, but bioconcentration of ^{210}Pb and ^{219}Po is surprisingly high (100,000- to 1,000,000-fold) in some organs and tissues. Marine fish are 2- to 5-fold higher in U-series isotopes, because the sea water is much richer in ^{238}U and ^{226}Ra than freshwater. The levels present do not pose a radiation hazard to the animals as far as can be determined since they are well below levels of other naturally occurring radioactive isotopes like ^{40}K; rather they provide a benchmark against which to measure future isotope burdens for determination of time trends.

The disposal of spent fuel wastes could become an Arctic issue depending on the sites chosen. Import of sea-disposed radioactive wastes by ocean currents was mentioned above (Livingston and co-workers, 1984), and bomb isotopes have become distributed globally in aquatic systems (International Atomic Energy Agency, 1976).

There has been some interest in use of small "slow poke" nuclear reactors for isolated communities as an alternative to oil for power generation. If these small reactors are deployed, then there will be need to ensure, and to be seen to ensure, that radioactive materials are contained during all stages of transport and use. Similar arguments apply to any future nuclear-powered ships or ice-breakers.

g) Metals other than uranium

Metals are imported to the Arctic both by ocean currents and by air currents, but the mass balance between imports and exports is not known. It has been estimated that about 80% of the lead entering the Arctic Ocean does so via the atmosphere whereas only about 10% of the aluminum is supplied by air (Rahn, 1981). Cores from Greenland glaciers can be divided into layers for which accurate ages can be determined, and analyses of these cores by Ng and Patterson (1981) revealed a 300-fold increase in lead content associated with human industrial development over the last 3000 years. With lead so widely distributed in the atmosphere it is exceptionally difficult to obtain trace measurements without contamination during sampling, storage, or analyses.

Arctic drainage basins contain many rich mineral deposits and a number of metal mines are in operation. Wright (1980) listed over 50 then current and potential metal mining operations either in the Arctic or in Mackenzie or Nelson River watersheds. (Other deposits must be present in Ontario and Quebec watersheds, but the writer is unfamiliar with that literature.)

The metals involved include zinc, lead, copper, silver, bismuth, cobalt, nickel, gold, tungsten, tantalum, lithium,, cesium, and chromium. Tin antimony, and lead are major waste materials requiring disposal in Hudson Bay drainage of Manitoba (Yee and co-workers, 1985). These lists do not include cadmium and arsenic, but these occur in some of the ores, and are both among several metals found to increase in organisms collected in the vicinity of the Nanisivic mine on Strathcona Sound (Fallis, 1982).

Cadmium is a metal which has come into major industrial use (rechargeable batteries, pigments) only during the present century. It has been found to be stored preferentially in the kidney where the first sign of cadmium-poisoning is observed as excretion of protein in the urine. Surprisingly high levels of cadmium have been found in kidneys of narwhal from the eastern Canadian Arctic (Wagemann, 1985). In fact, if narwhal kidneys show cadmium-induced failure in the same concentration range (160-280 ug/g) as for other animals, then some of the narwhal should be experiencing renal failure. The toxicity of inorganic cadmium to organisms is well recognized and well understood. However, most of the cadmium in marine mammals seems to be associated with a small protein (metallothionein), which appears to render the cadmium innocuous. An answer to the question of the meaning of cadmium to Arctic animals will require further investigation into the association between cadmium and protein.

The contribution from various sources to elevated metal burdens and the frequency of such occurrences is unknown. Data on heavy metals in Arctic marine life are still too few to establish broad "natural" ranges in metal content, although a few site-specific studies are well advanced. It is clear, however, that some Arctic marine mammals have high concentrations of metals in their tissues, similar to marine mammals from areas of high industrial activity, such as- the coast of Netherlands, the coast of California, the Baltic Sea, and the coast of Japan.

The mercury problem assiciated with new hydroelectric reservoirs was mentioned in the energy section, but mercury is widely distributed in fish and marine mammals throughout the Arctic independently of reservoirs. People in Inuit communities in the central and eastern Arctic have consistently higher blood mercury levels than native people in most more southerly communities (Health and Welfare Canada, 1984), although very few people have levels in the range associated with clinical mercury poisoning. The source of this mercury is thought to be higher than normal proportions of fish (and marine mammals?) in the diet. These data illustrate the transfer of mercury from the environment to the people in Arctic coastal communities, and imply a need not only to know the mercury content of the fish but also to be able to detect small changes in that content.

h) Long-Range Transport of Atmospheric Pollutants

The issue of long-range transport of atmospheric pollutants has been mentioned several times above, and is not treated separately here. Acidification of inland Arctic lakes is related both to the inherent sensitivity of the lakes and to the inputs of acid-forming materials. There is no doubt that many lakes in the Canadian Shield formation of the Arctic are sensitive to acidification (Shewchuk, 1985) but inputs seem to be small enough that the likelihood of acidification during the next decade is small (Welch, 1985).

i) Sewage and Oxygen Consuming Wastes

The releases of oxygen-demanding substances as presented in the theme paper covered the pulp and paper industry which is important in both Arctic and Hudson Bay drainage basins, but which is not regarded as an immediate pollution threat within the Arctic itself. Municipal sewage lagoons are operating in over 20 Arctic communities; these appear to be very efficient at removing oxygen-demanding substances during summer, but much less so during winter (Soniassy and Lemon, 1985). This raises the likelihood of discharges high in oxygen demand from these lagoons during winter when receiving waters cannot be readily re-oxygenated from the air because of ice cover. Furthermore snow cover restricts the penetration of light at the same time and limits the rate of oxygen release by algae. These circumstances would result in sub-lethal anoxia or even lethal suffocation of fish or other aquatic life if a large mixing area became depleted of oxygen.

Value of Arctic fishery

Authors of zonal overviews were asked to comment on the value of the fishery resource in their respective zones. In Arctic regions the value is largely in the domestic subsistence fishery with its social and cultural attributes which are difficult to quantify in dollar terms. Dr. R. Campbell has kindly made available recent (unpublished) estimates of the dollar value of Arctic fish and marine mammals. This value is something in excess of $60 million per year (Houston, 1985), exclusive of such materials as ivory, bone, and other items used in works of art.

Summary

Overall the Canadian Arctic presents a unique opportunity for Canada not only to use and protect intelligently those Arctic resources with current economic and social values, but also, and perhaps more importantly in the long term, to understand hemispheric and global processes. The Arctic is not the pristine isolated area of popular imagination, but rather an intimate part of the northern hemisphere with continuous exchanges of heat and materials through movements of water, air, sediments, ice, and through animal migrations.

Understanding these exchange processes will become increasingly necessary as we learn to "manage" the quality of air and water masses on a hemispheric basis in order to conserve the biological communities they support (including ourselves). The quantitative relationships among biological measures and physical/chemical measures of the quality of air, water, and sediments will demand more attention, expecially in the Arctic where long recovery times are needed when biological communities are injured. As responsible stewards of their respective national territories and coastal waters, Canada and other circumpolar countries have particular responsibilities and opportunities for Arctic studies. The processes and relationships which we must come to understand respect neither departmental nor national boundaries. To understand these processes and relationships, Canada will have to invest significant human and material resources and to support mechanisms which foster interdisciplinary and international work.

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3.5 PACIFIC FISHERIES RESOURCES ZONAL OVERVIEW

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Introduction

The Pacific Zone is comprised of British Columbia and the Yukon (Figure 1). B.C. contains an estimated 2 million hectares of freshwater (2% of total province) and approximately 27,000 km of coastline. The freshwater, estuarine and marine environment supports a diverse and socially and economically important fishery resource.

Chemical hazard issues within DFO in the Pacific Zone are addressed in the form of:

i) research activities carried out by the Fisheries Research Branch and Ocean Sciences and Surveys; and,

ii) operational activities involving the assessment and management of specific water quality issues.

The research effort related to the impacts of chemical hazards on fisheries resources is not large; additional effort will be required as a result of growing chemical hazards concerns within the zone. The Department does play an active role, in cooperation with the Environmental Protection Service (EPS), in the administration of Section 33 of the Fisheries Act, including enforcement and impact assessment.

Fishery Resources

Five species of Pacific salmon are found within B.C. and the Yukon. In light of the economic value of salmon to the B.C. and Canadian economy (Table 1), much of the Department's research and management effort is directed at conserving and enhancing salmon stocks. Salmon are harvested in commercial, recreational, and Native fisheries. Increasing demands by these three fisheries and salmon catch projections to the turn of the century, demand that considerable attention be focussed on the existing and potential risks of chemical hazards on salmon stocks.

In addition to salmon, the Pacific Zone supports other valuable fish and associated fisheries. The susceptibility of these species is variable and depends upon a number of factors such as degree of exposure to contaminants, habitat type, and life history characteristics. For example, herring, which spawn and rear in the nearshore coastal environment are more susceptible to effluent discharges than deepwater fish and invertebrates.

Specific Pacific Contaminant Problems

a) Organic compounds

Some of the organic chemicals of concern in the Pacific Zone and their sources are listed in Table 2. Research and monitoring carried out in the Zone has documented the presence of a variety of organic compounds in effluents, water, sediments and fish (e.g., see Birtwell et al., 1983). The potential extent of the problem of organic contaminant accumulation is demonstrated by the work of Malins et al. (1982). In a sampling program carried out in Puget Sound (Washington State) which is contiguous with the Strait of Georgia, Malins et al. recorded more than 500 aromatic hydrocarbons in a chromatogram of one sediment sample and scores of halogenated compounds in certain embayments. Of particular interest and sensitivity is the Lower Fraser River and its estuary, which supports significant populations of salmon and other fish, and into which is discharged a variety of industrial and municipal effluents.

b) Pesticides

Some of the pesticides of concern are listed in Table 3. Most insecticide used in the Pacific Zone are for agriculture and home garden purposes. The toxicity of insecticides, their intensive use in some areas, and the relative lack of regulatory control over agricultural and home use suggest that more monitoring and research is required to address the levels and persistence of pesticides in the aquatic environment and their ecological impact.

The use of herbicides, primarily in forest management, has increased considerably in recent years. Forest areas treated with herbicides have increased from approximately 5,000 hectares/year (average 1975-81) to 15-10,000 hectares/year in 1985. This annual rate will likely continue into the 1990's.

c) Energy

Primary energy issues in the Pacific Zone are offshore hydrocarbon exploration and development, coal mining and petrochemicals (Table 4). Potential renewed hydrocarbon exploration off the B.C. north coast is a current issue. Of primary concern is the impact on salmon and marine fish stocks of a major oil spill. Increased coal mining activities on Vancouver Island and within certain interior watersheds (Table 5) is anticipated as new coal reserves are located and when world market conditions improve. Increased shipments of petrochemicals to the

B.C. coast and the development of coastal storage and shipping facilities increases the threat of spills, during product transfer, into sensitive waterbodies.

d) LRTAP

Little research on LRTAP involving potential impacts on waterbodies has been carried out in the Pacific Zone. Monitoring of waterbodies throughout B.C., however, has revealed that a number of streams exhibit low alkalinity (10 mg/l $CaCO_3$) and are potentially susceptible to acid precipitation. Table 6 identifies some of the potential impacts and technical/management issues related to LRTAP. Of particular interest is the sensitivity and adaptability of juvenile salmon to reduced pH conditions.

e) Inorganics

Inorganic chemical originate from a number of sources. Of particular interest are metals and nutrients. Metals are released into the environment from mining operations, sewage, storm water discharges, metal plating plants and ocean disposal (Table 7). The discharge of effluents containing metals has resulted in documented impacts in a number of freshwater and coastal areas. As indicated in Table 7, there are a number of technical/management issues related to the impact and control of metals, including the probelms of metal speciation and the significance of elevated tissue metals on host and consumer organisms.

While nutrient discharges have not resulted in significant or widespread receiving water problems, specific problems related to nutrient enrichment have been documented in some areas (Table 8). Anticipated increased coal mining activity in B.C., in particular along the east coast of Vancouver Island, will result in discharges containing elevated nutrient levels (primarily nitrogen compounds). New control strategies may have to be developed to protect nutrient sensitive receiving waters.

f) Sewage and Oxygen Consuming Wastes

The assessment and management of sewage and oxygen consuming wastes has received considerable attention in the Pacific Zone. This is the result of the numerous pulp and paper mills within B.C. which discharge large volumes of effluent into sensitive freshwater and coastal systems. Additionally, major sewage discharges, some receiving little (primary) or no treatment, have resulted in documented impacts on fish and other organisms.

Areas of concern regarding sewage discharges and the impacts/concerns are listed in Table 9.

Pulp and paper mill discharges in B.C. (Table 10) have been the subject of considerable research by DFO. The acute toxicity and sublethal effects of mill discharges are a continuing concern in some areas (e.g., upper Fraser River, Neroutsos Inlet). The presence of chlorinated organic compounds in pulp mill effluents and their uptake in, and possible impact on, aquatic biota requires futher attention. A change in pulp preparation technology from traditional craft to thermo-mechanical and chemical thermomechanical (TMP/CTMP) has created new treatment and regulatory problems.

Summary

a) Primary Areas of Concern

Those areas requiring particular attention because of existing or potential threats from chemical hazards are listed in Table 11. The lower Fraser River and estuary is clearly a priority area given the significant salmon populations the river supports and increasing urbanization and industrialization in the vicinity of the Fraser. A number of coastal areas and other systems must also be considered both in terms of existing impacts and long-term threats as a result of increased urban and industrial development.

b) Chemicals/Effluents of Concern

Those chemicals and effluents that are likely to be of primary concern to fisheries resources are identified in Table 11. The list incorporates some traditional issues such as sewage and pulp and paper effluents, and also those issues that will require greater attention into the 1990's (e.g., chlorinated organics, herbicides).

c) Technical/Management Issues

The Department faces a number of challenges as it attempts to keep abreast of existing and emerging chemical hazards issues. The issues listed in Table 11 are some of those which need to be considered in the Pacific Zone; most also apply to the Department on a national level (e.g., the Department's analytical capability).

d) Present and Potential Risks to Fishery Resources

In order to compare graphically the existing and potential risks to fishery resources of the foregoing chemical hazards, Figure 2 is presented. This subjective ranking and comparison indicates that the existing emphasis on inorganics and sewage and oxygen wastes may shift toward the problems of organics, pesticides and energy issues over the next decade. Such a shift is dependent on a number of variables such as changes in industrial activity away from traditional resource-based industries; the success of regulatory initiatives to control major industrial effluent discharges; and adequate capital expenditures to upgrade sewage and industrial treatment plants.

Other Issues

A number of other issues of a technical, legislative and administrative nature will have to be addressed in concert with the foregoing issues. In summary, these are:

1) the general powers of the Fisheries Act will likely continue to be criticized by certain industrial sectors. Attention will have to be devoted toward ensuring that any proposed modifications to the Act do not weaken the fish and fish habitat provisions.

2) The role of national regulations on an industry basis versus site-specific requirements will require further review. The benefits and disbenefits of either approach must be carefully considered before changes are made to the regulatory process.

3) The joint administrative arrangements between DFO and EPS on Section 33 of the Fisheries Act will likely need further examination.

4) Increasing strains on existing analytical equipment and restraints on the purchase of new or replacement equipment could become particularly problematic. A thorough evaluation of analytical capability in the Pacific Zone is required, particularly in light of the necessary emphasis which should be placed on the fate and effects of organic chemicals.

5) Fundamental questions on the form and direction of chemical hazards research need to be addressed. These pertain to:

   i) the relationship between laboratory and field research;

   ii) the applicability of laboratory research to the natural environment and regulatory decisions; and,

   iii) the respective emphasis on individual organisms as opposed to population or community research.

6) The public sensitivity in the Pacific Zone about environmental quality and the Department's interest in ensuring public participation in the review of proposed major projects will necessitate an examination of alternative procedures to encompass public consultation as part of the Department's decision-making process.

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FIGURE 1

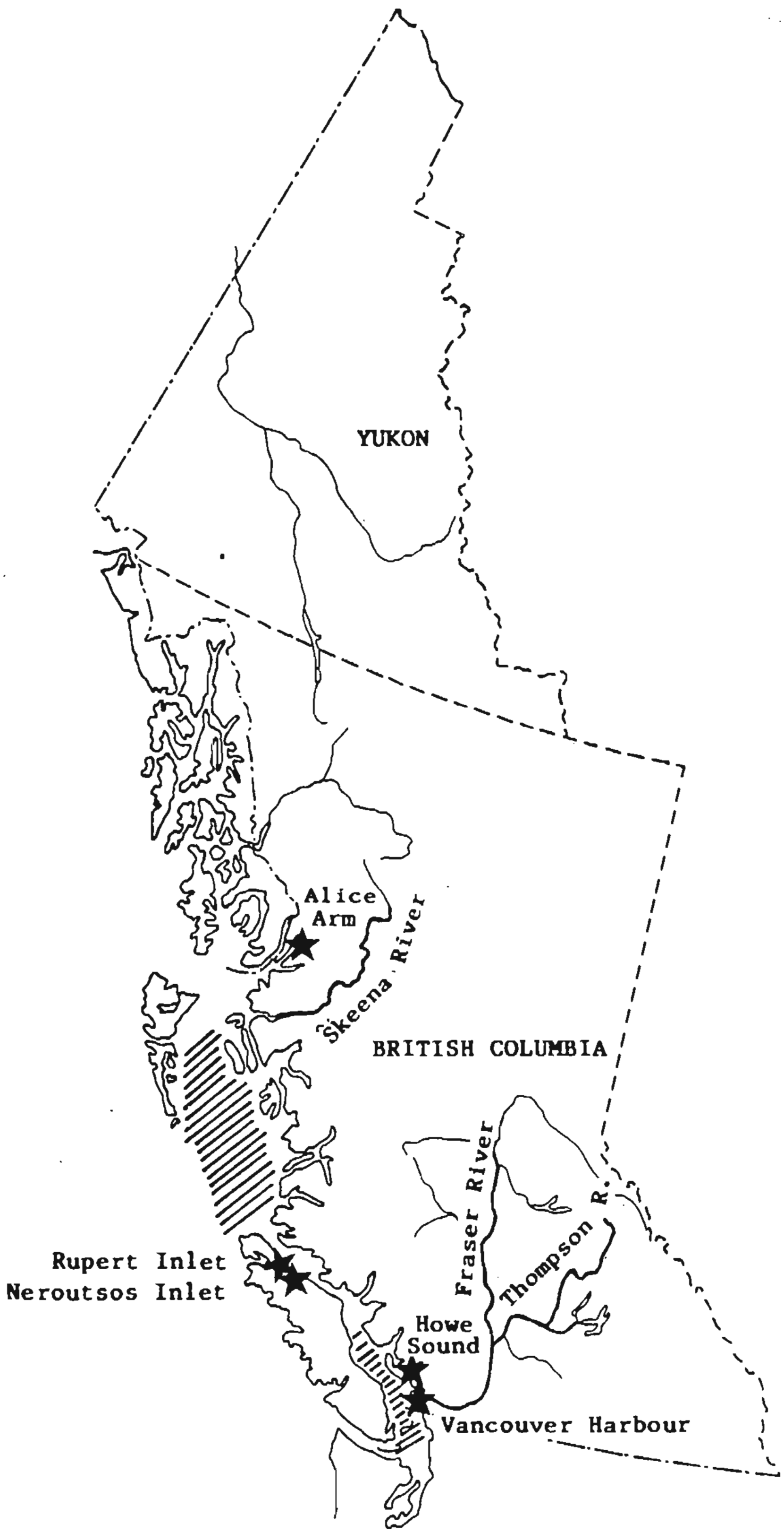
YUKON
Alice
Arm
Skeena River
BRITISH COLUMBIA
Fraser River
Thompson R.
Rupert Inlet
Neroutsos Inlet
Howe
Sound
Vancouver Harbour

FIGURE 2

PRESENT AND POTENTIAL RISKS TO PACIFIC ZONE FISHERY RESOURCES

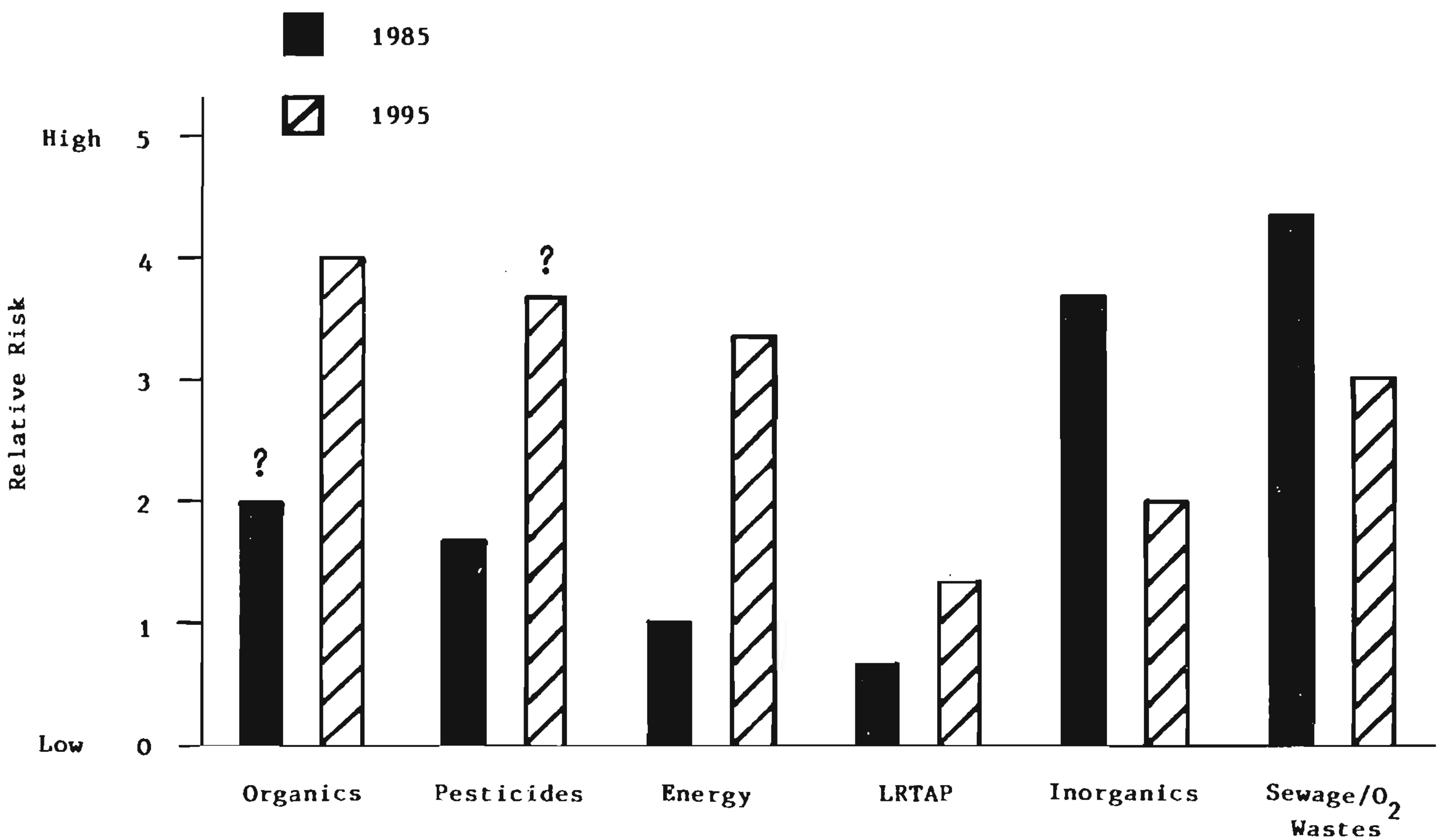

Table 1

PACIFIC VS. CANADIAN LANDINGS - 1984

	Pacific		Canada		Pacific as a % of Canada	
	tonnes ('000)	\$[a] (millions)	tonnes ('000)	\$[a] (millions)	tonnes ('000)	\$[a] (millions)
Salmon	50	145	51	148	98	98
Herring	34	39	166	58	21	67
Groundfish	69	34	809	293	8	12
Shellfish	13	15	144	291	9	5
Other Fish	3	-	115	75	-	-
TOTAL	169	233	1,285	867	14	30

[a]Estimated

Table 2

ORGANIC CHEMICALS

Compounds

1. Chlorinated phenols (TCP/PCP)
   - wood preserving plants, pulp mills, sewage.
2. PAH's - fossil fuels, atmospheric fallout, sewage.
3. PCB's - spills, landfill leachate, sewage.
4. Nonylphenol - sewage.
5. Organotins - agriculture, anti-fouling paints.
6. Phthalates - industrial effluent, sewage.
7. Polychlorinated dibenzo-p-dioxins (PCDD's)
   - chlorinated phenols.

Areas of Concern

1. Lower Fraser River and estuary.
2. Upper Fraser River.
3. Vancouver harbour.
4. Urban streams.
5. Coastal inlets, eg. Kitimat Arm.

Impacts/Concerns

1. Accumulation in sediments and biota.
2. Acute toxicity.
3. Sub-lethal effects on biota.

Technical/Management Issues

1. Quantification in water, sediments, and tissue.
2. Delineation of uptake/accumulation processes.
3. Documentation of impacts at the individual and population level.
4. Cause - effect relationship between chemicals and etiology of pathological conditions.
5. Inter-relationship with other contaminants.
6. Effluent treatment/chemical disposal.

Table 3

PESTICIDES

A. Insecticides

1. Synthetic pyrethroids - agriculture
2. Dinoseb - agriculture
3. Diazinon - home gardens, agriculture
4. Endosulfan - home gardens, agriculture
5. Fensulfothion - agriculture

B. Herbicides

1. Glyphosate
2. 2,4-D Amine

Areas of Concern

1. Coastal British Columbia
2. Selected interior streams
3. Lower Fraser River and estuary

Impacts/Concerns

1. Acute and sub-lethal impacts, especially on juvenile salmon (eg. smoltification, behaviour)
2. Loss of fish habitat (eg, riparian vegetation) from herbicide use
3. Uptake/accumulation in fish tissue

Technical/Management Issues

1. Increased use of herbicides in forest management (silviculture) and insecticides in agriculture
2. Lack of control over pesticide use in agriculture
3. Public/political sensitivity about pesticide use
4. Insufficient information on sub-lethal or long-term impacts on fish populations
5. Increasing pressure for intensified use of pesticides and relaxed fish/fish habitat protection requirements

Table 4

ENERGY (hydrocarbons, coal, oil recovery, radionuclides)

Major Zonal Issues
A) Offshore Hydrocarbon Exploration/Development
B) Coal Mining
C) Petrochemicals

A. Offshore Hydrocarbon Exploration/Development

Area of Concern

1. West Coast of B.C.

Impacts/Concerns

1. Short and long-term impacts of oil blow-outs on biota
2. Disruptions of fishing activity

Technical/Management Issues

1. Determination of risk
2. Lack of information on potential impacts
3. Compensation for lost fishing opportunities or impacts on fisheries

Table 5

ENERGY

B. Coal Mining

Areas of Concern

1. East Coat Vancouver Island streams
2. North central B.C. streams

Impacts/Concerns

1. Heavy metals (acid mine drainage) impacts
2. Elevated suspended solids and turibidity
3. Nutrient enrichment

Technical/Management Issues

1. Development of techniques for predicting acid mine discharge
2. Effluent standard development and receivng water criteria for nutrients
3. Effluent treatment techniques to control N and P levels

C. Petrochemicals

Areas of Concern

1. Thompson/Fraser River corridor
2. Lower Fraser River
3. Coastal inlets

Impacts/Concerns

1. Toxicity of process effluents
2. Impacts of product spills (eg. train derailment)
3. Uptake/accumulation of organic compounds

Technical/Management Issues

1. Spill contingency planning
2. Risk determination

Table 6

LONG RANGE TRANSPORT OF ATMOSPHERIC POLLUTANTS

Areas of Concern

Selected streams in:

1. Lower Mainland of B.C. (eg. Whonock Creek, Widgeon Creek)
2. North Coastal area (eg. Lachmach River, Diana Creek)
3. Central B.C. Interior (eg. Crooked Lake, Adams River

Impacts/Concerns

1. Impacts of reduced pH and elevated metal levels on salmon populations
2. Deposition, uptake and impact of airborne contaminants from coal-fired power plants, smelters and refuse burning

Technical/Management Issues

1. Determining sensitivity of various salmon life history stages to acid precipitation
2. Monitoring programs to determine local and distant sources of atmospheric depositions
3. Control technologies for future coal-fired generating plants

Table 7

INORGANIC CHEMICALS

A. Metals

Sources

1. Mining
2. Sewage
3. Storm water discharges
4. Metal plating plants
5. Dredgeate disposal (ocean dumping)

Areas of Concern

1. Selected coastal inlets (eg. Alice Arm, Rupert Inlet)
2. Campbell River
3. Lower Fraser River and estuary
4. Streams adjacent to mining operations (eg. Yukon)

Impacts/Concerns

1. Acute and sub-lethal effects on biota
2. Accumulation in organisms and associated impacts
3. Impacts of elevated tissue metals to consumers

Technical/Management Issues

1. Speciation and availability of metals in fresh and marine waters
2. Establishment of effluent standards and receiving water criteria
3. Role of metal binding proteins in detoxification and as an indicator of metal contamination
4. Significance of elevated levels in various tissues
5. Significance of low levels of selected metals

Table 8

INORGANIC CHEMICALS (continued)

B. Nutrients

Sources

1. Sewage
2. Coal mines
3. Fish hatcheries

Areas of Concern

1. Interior B.C. streams (eg. Thompson River)
2. East coast Vancouver Island streams

Impacts/Concerns

1. Benthic algaal accumulation: effects on stream benthic communities including egg incubation and fry rearing
2. Dissolved oxygen depletion in lakes

Technical/Management Issues

1. Establishment of effluent standards and receiving water criteria
2. Insufficient information on N and P limitation
3. Control of nutrients from coal mining

Table 9

SEWAGE AND OXYGEN CONSUMING WASTES

A. Sewage

Areas of Concern

1. Lower Fraser River and estuary
2. Urban streams
3. Coastal inlets and embayments

Impacts/Concerns

1. Acute and sub-lethal effects on biota (esp. juvenile salmon)
2. Uptake of metals and contaminants
3. Dissolved oxygen depression
4. Nutrient enrichment
5. Bacterial/viral contamination of shellfish

Technical/Management Issues

1. Quantification of sewage constituents (esp. organics)
2. Costs of advanced sewage treatment (who pays?)
3. Source control and product disposal
4. Control of diffuse discharges
5. Effluent quality/treatment criteria

Table 10

SEWAGE AND OXYGEN CONSUMING WASTES (continued)

B. Pulp and Paper

Areas of Concern

1. Upper Fraser River and tributaries (eg. Thompson River)
2. Selected coastal areas (eg. Neroutsos Inlet)
3. Kitimat River

Impacts/Concerns

1. Acute and sub-lethal effects on biota
2. Discharge and effects of specific organic and other compounds (eg. chlorinated resin acids and phenols)
3. Fish tainting (eg. Kitimat River)
4. Dissolved oxygen depression (eg. Neroutsos Inlet)

Technical/Management Issues

1. Treatment of TMP/CTMP effluents
2. Uptake and impact of chlorinated and non-chlorinated organics
3. Adequacy of federal effluent regulations
4. Upgrading of older mills (costs)

C. Other Discharges of Concern

1. Agricultural effluents
2. Fish processing effluents

Table 11

SUMMARY

Primary Areas of Concern

1. Lower Fraser River and estuary (salmon)
2. Coastal inlets (eg)
   - Neroutsos Inlet (salmon)
   - Rupert Inlet (herring)
   - Alice Arm (shellfish)
   - Vancouver Harbour
3. East coast of Vancouver Island streams (salmon)
4. Urban streams (salmon)
5. Thompson/Fraser River and Skeena River corridors (salmon)
6. Strait of Georgia (salmon, shellfish, herring)
7. Howe Sound (salmon, shellfish)

Primary Chemicals/Effluents of Concern

1. Major sewage and pulp and paper discharges
2. Chlorinated organic compounds (eg. PCP/TCP, PAH's)
3. Herbicides used in forest management
4. Product spills (eg. derailment of petrochemical cars)
5. Agriculture insecticides
6. Mining effluents

Primary Technical/Management Issues

1. Techniques and resources to analyze organic compounds and assess their environmental significance
2. Speciation and availability of metals
3. Establishment of appropriate effluent standards and receiving water objectives
4. Increased use of herbicides in forest management
5. Information needs related to sub-lethal impacts/implications of contaminants on Pacific salmon (individual and population level)
6. Cause-effect relationships between water-borne and sediment chemicals and pathological conditions
7. Effect of stream flow reductions on assimilative capacity and contaminant levels

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