



Clear Progress

A Summary Report
on the Findings
of Canada's
National
Dioxin Sampling
Program
from 1989 to 1994

Ramona K. Duncan



Fisheries and Oceans
Canada

Pêches et Océans
Canada

Canada

Cover Photo:

Denise Helm, Victoria, British Columbia

The cover photo captures the interlace between the aquatic marine environment, with its habitat and fisheries resources, the harvesters that fish for those resources and the coastal land area.

The photo was taken looking towards the east coast of Vancouver Island, British Columbia, near Kuper Island.

The Dungeness crab (*Cancer magister*), a key species used in Canada's National Dioxin Sampling Program, is illustrated on the cover.

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Ramona K. Duncan

This document summarises, in non-technical terms,
the findings of Canada's National Dioxin Sampling Program
in its first five years of operation: 1989-1994.

The sampling and analytical data on which this report
is based are available on request from:

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Table of Contents

Acknowledgement	i
Table of Contents	iii
List of Tables	v
List of Figures	vi
Program Overview	1
Dioxins and Furans	5
Properties	5
Sources	6
Presence in the Environment	7
Health Effects	7
Canada's National Dioxin Sampling Program	11
Preliminary Phase	12
Expanding the Program	12
Sampling Methodology	13
Field Operations	13
Logistics	14
Human Health Risk Assessment	14
Pacific Region	17
British Columbia Interior Mills	18
Thompson River	18
Williston Lake-Peace River	19
Fraser River	20
Fraser Estuary	21
Kootenay River	21
Columbia River	21
Kitimat River	21
British Columbia Coastal Mills	21
Howe Sound	21
North Coast	24
Prince Rupert	24
Kitimat Arm	26
Strait of Georgia	27
Powell River	27
Vancouver Island, East Coast	30
Crofton	30
Nanaimo	31
Campbell River	31

Vancouver Island, West Coast	34
Port Alice, Quatsino Sound	34
Gold River, Nootka Sound	35
Port Alberni, Alberni Inlet	37
Other Coastal Sampling	37
Ocean Falls, Central Coast	38
British Columbia Harbours	38
Prairie Region	39
Alberta	40
Wapiti River	40
Athabasca River	40
Saskatchewan	40
Manitoba	40
Ontario Region	41
Wabigoon River	41
Rainy River	41
Lake Superior - North Shore	42
Mattagami River	43
Spanish River	43
Upper St. Lawrence River	43
Laurentian (Quebec) Region	45
Quévillon River	45
Ottawa River	45
St. Maurice River	46
St. Francois River	47
Mistassini River	47
Saguenay River	47
Gulf of St. Lawrence	47
Atlantic Region	49
New Brunswick	49
Madawaska River	49
St. John River	49
St. John Harbour	49
Restigouche River	50
Miramichi River	50
Nova Scotia	50
Prince Edward Island	51
Newfoundland	51
Conclusion	52
For Further Reading	54

List of Tables

Table 1.	A list of the interior pulp and paper mills of British Columbia included in Canada's National Dioxin Sampling Program	19
Table 2.	A list of the coastal pulp and paper mills of British Columbia included in Canada's National Dioxin Sampling Program	22
Table 3.	A list of the pulp and paper mills in the Prairie Region included in Canada's National Dioxin Sampling Program	39
Table 4.	A list of the pulp and paper mills in the Ontario Region included in Canada's National Dioxin Sampling Program	41
Table 5.	A list of the pulp and paper mills in Quebec included in Canada's National Dioxin Sampling Program	45
Table 6.	A list of the pulp and paper mills in the Atlantic Region included in Canada's National Dioxin Sampling Program	49

List of Figures

Figure 1.	A map of Canada indicating the location of the 46 bleached kraft pulp and paper mills and 2 control sites studied in Canada's National Dioxin Sampling Program	2
Figure 2.	Structural formulae of polychlorinated dibenzo- <i>p</i> -dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)	5
Figure 3.	Structural formula for 2,3,7,8-tetrachloro-dibenzodioxin showing chlorine atoms attached to the 2,3,7 and 8 positions of the molecule	6
Figure 4.	A map of the Pacific Region, indicating the location of the pulp and paper mills included in the study	18
Figure 5.	A map showing the location of fisheries closures and consumption advisories in Howe Sound, as of August 1995	23
Figure 6.	Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Howe Sound, from 1989 to 1994	24
Figure 7.	A map showing the location of fisheries closures and consumption advisories in Prince Rupert as of August 1995	25
Figure 8.	Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Prince Rupert, from 1989 to 1994	26
Figure 9.	A map showing the location of fisheries closures and consumption advisories in Kitimat Arm, as of February 1995	27
Figure 10.	Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Kitimat Arm, from 1990 to 1994	28
Figure 11.	A map showing the location of fisheries closures and consumption advisories in the vicinity of Powell River, as of August 1995	29

Figure 12. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the Powell River area, from 1990 to 1994	30
Figure 13. A map showing the location of fisheries closures and consumption advisories in the Crofton area and part of the Harmac area near Nanaimo as of August 1995	32
Figure 14. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Crofton, from 1990 to 1994	33
Figure 15. A map showing the location of fisheries closures and consumption advisories in the Campbell River area as of August 1995	34
Figure 16. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Campbell River, from 1990 to 1994	35
Figure 17. A map showing the location of fisheries closures and consumption advisories in the Gold River area as of August 1995	36
Figure 18. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Gold River, from 1988 to 1994	37
Figure 19. A map of the Prairie Region, indicating the location of the pulp and paper mills included in the study	39
Figure 20. A map of the Ontario Region, indicating the location of the pulp and paper mills included in the study	42
Figure 21. A map of the Laurentian Region, indicating the location of the pulp and paper mills included in the study	46
Figure 22. A map of the Atlantic Region, indicating the location of the pulp and paper mills included in the study	50

Program Overview



Chlorinated dioxins and furans are the by-products of several industrial and combustion processes, and are considered among the most toxic and persistent chemical substances in the world. As very small quantities of these chemical contaminants come into contact with freshwater and marine sediments, they can accumulate in various marine and freshwater animals, and humans can be exposed to them from the foods they eat. Indeed, when dioxins and furans enter the aquatic environment, they accumulate up the food chain from organisms that feed on bottom sediments to other fish and shellfish and eventually to humans.

Chlorinated dioxins and furans are complex chemical substances that contain chlorine, carbon and oxygen elements. In Canada, the main sources of dioxins and furans have been: pulp and paper mills that used chlorine to bleach their products; sawmills and shipping terminals that used chlorophenols to preserve cut wood; and the wood itself as chlorophenol treated woodchips used in the making

of paper by the pulp and paper mills. Until the use of treated woodchips in the making of pulp ceased, the use of chlorophenols became strictly controlled, and technological changes were employed by the mills to reduce dioxin and furan formation, dioxins and furans were found in the wastewaters emanating from pulp and paper mills as well as from operations involving chlorophenol-treated lumber. Typically these facilities are located adjacent to rivers or coastal waters, into which they used to directly release their wastewaters. The chemical contaminants in these wastewaters were found to affect the fish and shellfish caught in commercial, recreational and aboriginal fisheries.

Improvements in analytical instrumentation in the 1980's have made it possible to measure dioxins and furans at concentrations that, while potentially hazardous to human health, were previously undetectable. As this new technology produced evidence of dioxin and furan concentrations in Canadian ecosystems in the late 1980's,

public concern mounted. In a 1991 federal government report, polychlorinated dibenzodioxins and polychlorinated dibenzofurans were classified as toxic to the environment under the *Canadian Environmental Protection Act*.

In 1992, federal government regulations came into effect that required pulp and paper mills to eliminate dioxins and furans from their effluents. Aware that these regulations were coming, some companies had begun to modify their bleached pulp and paper mills as early as the late 1980s. The purpose of this document is to summarise the scope, methodology and results of a major Canadian environmental study, Canada's National Dioxin Sampling Program, in the first five years of its operation: 1989 to 1994. Although sampling has continued after 1994, primarily on the west coast, the majority of data collection occurred during the first five years of the program. During the course of the first five years, dramatic reductions of dioxin and furan concentrations in the aquatic biota have occurred. Although the subject report does not

contain detailed information on the findings in later sampling initiatives, some qualitative observations based on more recent analytical results and human health assessments, have been included in some instances.

Federal government scientists from Fisheries and Oceans Canada (DFO), Environment Canada (EC) and Health Canada

(HC) collaborated with provincial governments as well as the pulp and paper industry in the collection and analysis of biota and sediments across Canada. The Program focused on watersheds and coastal areas likely to be influenced by the 46 pulp and paper mills that were using chlorine to bleach their products. To establish points of reference, samples of fish and shellfish were

collected and analysed for the program in the vicinity of other mills that had never used chlorine and from areas without pulp and paper mills. A map of Canada indicating the location of the 46 bleached kraft pulp and paper mills studied in Canada's National Dioxin Sampling Program is shown in Figure 1.

Figure 1.
A map of Canada indicating the location of the 46 bleached kraft pulp and paper mills and 2 control sites studied in Canada's National Dioxin Sampling Program.



Program Goals

The initial primary goals of the Program were: (1) to define the extent of dioxin and furan concentrations in fish, shellfish and sediments in watersheds and coastal areas likely to be influenced by the 46 pulp and paper mills that were using chlorine to bleach their products; (2) to determine whether the concentrations of dioxins and furans found in the biota posed a threat to human health; and (3) to track the effectiveness of the industry's cleanup measures in reducing dioxin and furan concentrations in the environment.

As the Program progressed, sampling and analysis of fish and sediments quickly revealed higher concentrations of dioxins and furans close to some mills. However, the situation was not uniform across the country.

In Canada, the highest dioxin and furan concentrations in biota were measured near pulp and paper mill sites in British Columbia. In Ontario, Quebec and the prairie provinces, there was evidence of intermediate dioxin and furan concentrations. In the Atlantic Region, primarily low dioxin and furan concentrations were identified.

In view of the information collected in support of the initial goals, the Program emphasis shifted to the areas that exhibited the highest concentrations of dioxins and furans in biota, and where fisheries closures and consumption advisories were required.

Following the discovery of elevated dioxin and furan concentrations in the biota, the later years of sampling and analysis began to show steady,

and in some cases dramatic, declines in dioxin and furan concentrations. Some areas are characterised by a slower rate of recovery, and therefore, are still under study.

In areas characterised by a dramatic decline in dioxin and furan concentrations, the sampling and monitoring objectives were expanded to include species-specific and area-specific data collection to meet criteria established for reopening closed fisheries and lifting consumption advisories.

Additional monitoring is ongoing by the pulp and paper industry in accordance with government requirements.

Dioxins and Furans

Properties

Dioxins and furans are two large groups of 210 chemically-related chlorinated organic chemicals whose structural formulae are shown in Figure 2. Of these 210 related substances, 75 are dioxins and 135 are furans. These compounds have several characteristics in common. All are made up of chlorine and carbon atoms attached to the same basic skeleton of carbon and oxygen molecules. Varying numbers of chlorine atoms, from one to eight, are positioned on this framework to yield the different dioxin and furan combinations.

Understanding the importance of dioxin and furan contamination starts with a recognition that within these chemical families, some chlorine-atom combinations are more toxic than others based on available information when studying their effects in animal models. What determines the toxicity of a given chlorinated dioxin or furan is not only the number of chlorine atoms but their positions on either molecular skeleton as well. Scientific studies have shown that the most toxic chlorinated

dioxins and furans are those in which four chlorine atoms are attached to specific carbon atom positions, designated as 2, 3, 7 and 8 as shown in Figure 2.

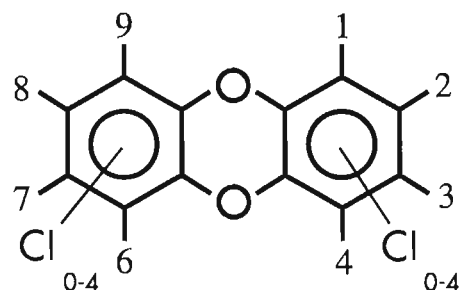
The chemical names of two of these congeners are 2,3,7,8-tetrachlorodibenzo-*para*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF). These two substances

are the main topics of this study and in the interests of simplicity they will be referred to hereafter as 2,3,7,8-TCDD and 2,3,7,8-TCDF. The structural formula for 2,3,7,8-TCDD is shown in Figure 3.

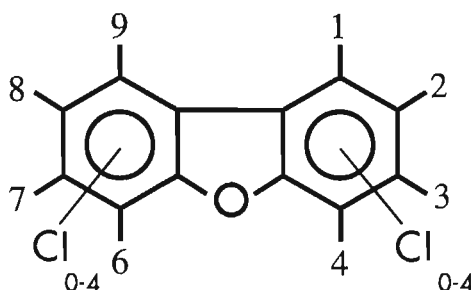
These compounds have been the topic of substantial concern because they have been shown to be acutely toxic, to be

Figure 2.

Structural formulae of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).



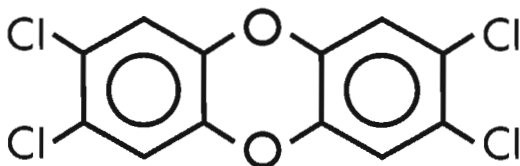
polychlorinated dibenzo-*p*-dioxin
(PCDD)



polychlorinated dibenzofuran
(PCDF)

Figure 3.

Structural formula for 2, 3, 7, 8-tetrachlorodibenzodioxin showing chlorine atoms attached to the 2, 3, 7 and 8 positions of the molecule.



2,3,7,8 - tetrachlorodibenzo-*p*-dioxin
(2,3,7,8 - TCDD)

extremely persistent and resistant to chemical and microbial degradation, as well as to be accumulated in biological tissues. When discharged into bodies of water, they may constitute a hazard (a) to human health through consumption of contaminated fish, (b) to fish which may be affected by exposure to very low concentrations of dioxins, and (c) to the ecosystem in general where they may accumulate and magnify up the food chain. In aquatic ecosystems, they become attached to sediment particles where they may persist for several years before they are eliminated or buried by uncontaminated sediments. They tend to accumulate in the organic portions of soil, sediments or in the fatty segments of biological tissues. They can enter the food chain when sediments are ingested by bottom feeding organisms. In animals, they accumulate in some tissues, particularly in the fat and fat-rich organs.

Sources

Chlorinated dioxins and furans are not used in commercial applications, but are formed as unintentional by-products of a number of processes. They have entered the Canadian environment from four main sources:

1. Commercial chemicals that contain traces of these substances, particularly chlorophenols, which in the past, the forest industry used as wood preservatives, and other agricultural industries used as herbicides. Use of these chemicals is now strictly controlled and new techniques to produce chlorophenols have resulted in considerably lower concentrations of dioxins and furans in these chemicals. Other significant sources, in fact the most significant potential sources of furans, are the polychlorinated biphenyls (PCBs). PCBs are part of another family of persistent chlorinated organic chemicals

that can accumulate in the environment. They were formerly used in electrical equipment such as transformers. While the use and storage of PCBs is now strictly controlled, the potential for releases through accidental spills, or fires in equipment containing PCBs, remains.

2. Dioxins and furans are produced by the incomplete combustion of chlorinated industrial chemicals and emitted during the incineration of municipal and hazardous wastes.

3. Natural sources of dioxins and furans are forest fires and volcanoes. There are no data specific to these sources. However sediments that are 300 to 1000 years old have been found to have low concentrations of the less toxic dioxins and furans.

4. Dioxins and furans are generated as by-products of industrial manufacturing processes and are released with their effluent into the environment. In Canada, the most significant source of chlorinated dioxins and furans has been the 46 pulp and paper mills that previously used chlorine in their bleaching process. Typically, they are located on the banks of rivers, next to lakes or near coastal waters into which they release their effluents.

Until the early 1990s, pulp and paper mills used defoamers that contained dioxin and furan precursors and chlorine to bleach the pulp. Both practices generated chlorinated dioxin and furan by-products at parts-per-trillion concentrations in effluents discharged by these mills and in paper products. A part per trillion is comparable to one cent in 10 billion dollars or 10^{-12} gram per gram of effluent or paper.

Another source of dioxin and furan contamination originates from forest industry operations, particularly in British Columbia where it is important industry. The use of commercial chemicals such as chlorophenols by sawmill operations to protect cut lumber from fungal attack find their way into the environment and can leach into watersheds in proximity of these mills.

Presence in the Environment

As in other industrialised countries, all animals, humans and other parts of the ecosystems in Canada are exposed to dioxins and furans. This is confirmed by studies showing that dioxins and furans are present in every part of the environment including air, water, soil, sediments, fish, birds, other animals and foods. They have been found in the tissues of animals both near and

far from known sources of pollution; for instance in the eggs of herring gulls from the industrialised Great Lakes region, and in polar bears, seals and whales in the Canadian Arctic.

Also, dioxins and furans have been detected in food consumed by humans. In Canada, although these chemicals have been identified in fish, beef, pork, poultry, eggs and milk, the concentrations are very low. Thus, the consumption of these foods is not considered to pose a hazard to human health when they are part of a well balanced diet. In fruits, vegetables and wheat-based products, the concentrations of dioxins and furans found are very low or are below analytical detection limits.

Health Effects

Research has shown the compound 2,3,7,8-TCDD, and to a lesser extent, the other 2,3,7,8-substituted dioxins and furans as well to be highly toxic to mammals, although there is a wide variation in sensitivity among species. In test animals they have caused death in amounts ranging from less than one microgram to a few milligrams per kilogram of body weight. Longer-term exposure of test mammals to lesser amounts has affected reproduction, caused birth

defects, liver damage and suppressed the immune system. Exposure to elevated doses of 2,3,7,8-TCDD was shown to cause cancer in rodents. In addition, scientists have discovered that some fish and bird species are more sensitive to short-term exposure of 2,3,7,8-TCDD than most mammals that were tested.

Because dioxins and furans enter the environment as ingredients of a wider mix of industrial by-products, it is difficult to isolate and measure their effect on humans. Scientists do know that when dioxins or furans are absorbed by humans, they accumulate in all parts of the body, but particularly in fatty tissues, blood and the liver. Short-term but intense exposures resulting from industrial accidents have produced skin lesions, sight impairment and a range of neurological and psychological effects. In a poisoning episode in Taiwan, exposure to furans in rice oil over a three- to nine-month period was associated with higher post-natal deaths, reduced birth size and other effects. On the basis of research, Canadian scientists have concluded that human intakes of these substances should be below 10 picograms (10^{-12} of a gram) in *toxic equivalents* (TEQs) per kilogram of body weight per day averaged over a lifetime of 70 years.

Measuring Toxicity

Dioxins and furans do not enter the environment as separate elements but rather as ingredients of a chemical mixture. To separate and study each type of dioxin and furan in a given mixture would be a time-consuming and unmanageably expensive task. Fortunately, there is another way. Research has defined, in precise and measured terms, the toxic effects of the dioxin and furan compounds. On the basis of these findings, toxicologists have developed a method for assessing the toxicity of a given mixture of dioxins and furans in relative terms, using an internationally accepted system of comparison known as “toxicity equivalent factors” (TEFs). TEFs (in effect, toxicity values) are assigned to each dioxin and furan compound in the mixture on the basis of comparison with the most toxic dioxin of all, 2,3,7,8-TCDD. The most potent congener 2,3,7,8-TCDD was assigned the TEF value of 1.0. Comparison of relative potency data showed that 2,3,7,8-TCDF is about one-tenth as toxic as 2,3,7,8-TCDD and hence its TEF value is 0.1. The Program monitored for the 17 toxic forms of 2,3,7,8-substituted dioxins and furans. The concentrations of these 17 compounds are multiplied by the equivalency factors to convert them into a number which represents the overall toxicity relative to the most toxic form of dioxin, 2,3,7,8-TCDD. This is done by multiplying the TEF of each component by its concentration to arrive at the Toxic Equivalent (TEQ). The sum of the TEQs describes the total dioxin and furan toxic potential. The number is expressed in parts per trillion toxic equivalents (TEQ) of 2,3,7,8-TCDD. The analytical results for each sample are submitted to Health Canada for assessment of the human health significance of the findings.

Health Canada uses the TEQ method accepted by the North Atlantic Treaty Organization’s (NATO) civilian-co-operation arm, the Committee on the Challenges of Modern Society (CCMS). The method is described in the NATO/CCMS Report No. 176, August 1988 (see Further Reading Section).

On average, exposure of Canadians to dioxins and furans from the foods they consume is well below this concentration. However, within these limits there are exceptions including people whose regular diet includes fish or shellfish from waters containing dioxins and furans. Tests have shown relatively high concentrations of dioxins and furans in the blood of people exposed routinely to these contaminants in their work or through accidents (involving PCB filled transformers, chemical spills and fires etc.). In some instances, new-borns may be at higher risk if dioxins and furans are transferred through breast milk, a storage area for these contaminants due to its high fat content.

The Ministers of the Environment and of Health have concluded that PCDDs and PCDFs may enter the environment in quantities that have both immediate and long-term harmful effects on the environment and which constitute a danger in Canada to human health. Hence, these substances are considered “toxic” as defined in Sections 11 (a) and 11 (c) of the *Canadian Environmental Protection Act (CEPA)*.

Jurisdictional Responsibilities: A Co-operative Approach

To simplify this description of Canada's National Dioxin Sampling Program, this report will usually describe the executing agency as "The Government."

Three federal government departments, Fisheries and Oceans Canada (DFO), Health Canada (HC) and Environment Canada (EC), as well as the provincial governments and the pulp and paper industry, fostered a co-operative arrangement in the Program. Government of Ontario agencies, the Ministry of Natural Resources with assistance from the Ministry of the Environment, conducted 90 per cent of the sampling of mills in that province. The Alberta, Saskatchewan and Manitoba provincial fisheries agencies collected all the samples within their respective jurisdictions for the Program. The British Columbia Ministry of Environment, Lands and Parks conducted much of the province's freshwater sampling, for the Program.

At the outset of the program DFO and other government agencies conducted most of the fish sampling. Since 1990, most of the sampling and analysis has been conducted by individual pulp and paper mills and their consultants.

In the case of federally managed fisheries, DFO is responsible for fisheries management measures such as fishery closures and reopenings and the issuing of fish consumption advisories.

Health Canada provides advice on the human health significance of the concentrations of dioxins and furans measured in the samples collected under the Program to the federal or provincial agency responsible for taking these fisheries management measures.

The announcement of the fisheries management measures is co-ordinated by all departments involved in order to provide the public with convenient access to information. The Government announced fisheries closures and/or consumption advisories in joint news releases by DFO, Health Canada and Environment Canada. Accompanying these are information backgrounders on dioxins and furans, on closure and reopening criteria and as well as on related matters.

Canada's National Dioxin Sampling Program

Public concern about the health effects of dioxins and furans generated by pulp and paper mills dates back to a 1986 study by the U.S. Environmental Protection Agency (EPA), which detected these substances in the effluents, sludges and pulps of five bleached kraft pulp and paper mills in the United States (see Further Reading Section, Amendola et al. 1989). In the early 1980s, Health Canada concluded that dioxins and furans were a potential danger to human health and established regulations to reduce exposure of Canadians to 2,3,7,8-TCDD.

In 1988, based on the analytical results from a sediment sample taken near a Vancouver Island pulp mill, Greenpeace issued a public warning urging Canadians not to eat fish caught near pulp and paper mills. Canada's National Dioxin Sampling Program for fish and shellfish near pulp and paper mills started in May 1988, with the first closure enacted in 1989.

In 1990, the Government of Canada concluded that dioxins

and furans could be entering the environment in quantities that could cause immediate and long-term harm to the Canadian environment and endanger human health. In 1991, the Government placed them on the List of Toxic Substances as defined in the *Canadian Environmental Protection Act (CEPA)* and recommended that regulations be made to control the release of these substances by pulp and paper mills, thereby reducing their discharge into the ecosystem.

In 1992, new federal regulations under *CEPA* required all pulp and paper mills using chlorine bleaching to implement process changes to prevent the formation of dioxins and furans.

The *CEPA Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations* prohibited the discharge of effluent with measurable concentrations of chlorinated dioxins or furans. These regulations specify that pulp and paper mills using chlorine bleaching, in operation prior June 1, 1990, must not discharge effluent with

measurable concentrations of chlorinated dioxins or furans as of January 1, 1994. Mills starting operation after June 1, 1990, have to meet the regulations upon promulgation of the regulations, or at the time of start up. In general, the pulp and paper industry recognised the urgency of the situation and began to take necessary action to eliminate and prevent the release of dioxins and furans, prior to the regulations coming into force. Some of these measures included reducing the amount of chlorine used in the chlorination bleaching stage, making changes in the pulping process, as well as substituting chlorine dioxide for chlorine.

A further *CEPA* regulation, the *Pulp and Paper Mill Defoamer and Wood Chips Regulations* required mills to immediately cease using contaminated defoamers and wood chips that may generate dioxins and furans. The pulp and paper industry, particularly on the west coast, took action in advance of these regulations by eliminating the use of wood chips contaminated with pentachlorophenol and by

using reformulated defoamers free of dioxin and furan precursors. In addition, the regulations require mill operators to monitor the concentrations of dioxins and furans in their final effluents.

Preliminary Phase

In 1988, the federal government launched Canada's National Dioxin Sampling Program. One goal was to build a data base on dioxin and furan concentrations in biota for the planning of health and fisheries protection measures, including assisting with the development of *CEPA* regulations. The other objective of the program was to check progress in the cleanup of contamination. Sampling and analysis of fish and sediments under the Program, combined with similar work by provincial authorities, as well as mandatory monitoring by the pulp and paper industry, would show how well the cleanup measures were working.

The Program began with a four-month preliminary survey of dioxin and furan concentrations in fish at 14 of the 46 Canadian pulp and paper mills in the chlorine-using category; eight in British Columbia, three in New Brunswick, two in Alberta, one in Saskatchewan plus one control site in Manitoba (a pulp mill not using chlorine in their bleaching sequence).

After sampling and analysing fish and sediment at these locations, the survey found no evidence of a health hazard in fish fillets consumed by Canadians. However concentrations were well above Health Canada's defined tolerance concentrations in the hepatopancreas (digestive gland) of Dungeness crabs (*Cancer magister*) on the Pacific coast which are a food item for some Canadian ethnic communities and aboriginal peoples. Dioxin and furan concentrations were also above tolerance concentrations in oysters, invertebrates and shellfish such as shrimps and prawns collected in specific locations on the British Columbia coast.

In mid-1988, on the basis of these findings, the Ministers of Fisheries and Oceans, of Environment and of Health jointly announced that their departments would extend the fish and sediment sampling program to include all 46 mills in Canada that were using, or had used, chlorine to bleach their pulp.

Expanding the Program

The expansion of a small sampling program to one of national scope confronted scientists in the three departments with a proportionately larger challenge

in terms of organisation and technical implementation.

In the sampling phase, for example, fish and shellfish samples would need to be as representative of the resources at risk in the area of all 46 sites. To assess potential effects on human health, the study would have to focus on species and portions that people actually eat. And, to ensure consistency, scientists would need a standardised Canada-wide procedure for collecting, handling, processing and storing fish and shellfish samples.

On the administrative side, the Program was also breaking new ground. No sampling study of this scale and cost, concerned with attempting to assess the presence and implications of contamination at the ultra-low concentrations associated with dioxins and furans, had ever taken place in Canada.

To tackle these issues, scientists from DFO, EC and HC joined forces to produce standardised protocols and methods. With adjustments based on experience as the work progressed, scientists and technologists, in the Government and in contracted private laboratories, used this common approach. The pulp and paper industry employed the same approach in its own sampling and analysis as well.

In the course of the Program, federal government agencies collaborated closely with provincial governments.

Sampling Methodology

The fish sampling plan called for collection of a minimum of four fish or shellfish samples (each sample comprising several individual animals) for each pulp and paper mill.

Three samples were collected in waters close to the point at which the mills discharged effluents into rivers, estuaries or other receiving waters. The fourth sample collected was the control or reference sample. It was collected upstream from the mill in a section of the water body isolated from the contaminant source by distance or by physical barriers. When such a site could not be found, the reference sample was collected from a nearby, uncontaminated, water body supporting the same species of fish or shellfish.

The Program focus of attention was on species of importance to commercial, recreational and aboriginal fisheries. Within these categories, highest priority was assigned to long-lived predator species at the top of the food chain; these fish normally accumulate the highest concentrations of dioxins and furans. In

freshwater bodies, the priority list included fish such as carp and suckers that feed on potentially contaminated bottom sediments and are susceptible to accumulating dioxins and furans. Where possible, DFO scientists collected these fish close to the points where the sediment samples were collected. The sediment samples were collected and analysed by Environment Canada at its own laboratories, the results are reported elsewhere (see L. Trudel, Further Reading Section).

Biota composite samples were prepared, each comprising from 4 to 10 fish or shellfish of similar size. This allowed scientists to compensate for natural variations in the dioxin and furan concentrations from one animal to the other. It also provided a more complete snapshot of contamination at the limited number of sites that could be sampled within the Program budget.

In the case of freshwater species, the plan called for collection of most samples in the late fall, when fish are at their peak in terms of lipid or fat content and their bioaccumulation of contaminants. In selected cases, samples were taken during the spring thaw to assess the effects of dioxin and furan concentration build-up during winter. Marine species

were collected in the late winter.

In order to relate the sampling to the forms in which people eat fish, samples were analysed either as fillets or as whole organ tissues. In fish that contain fatty livers, the livers were removed and analysed separately. This was done because in the case of some species, these organs are consumed by humans and also because these contaminants tend to concentrate in the liver. In the case of crabs and lobsters, technicians prepared samples from both the digestive gland (hepatopancreas) and the muscle tissue.

Field Operations

Regional personnel planned and organised the field operations. This use of people familiar with sampling sites, species, fisheries, mills and other characteristics of the target area, ensured precise focusing of the Program in every region.

At each site, the sampling team collected information on the following aspects: (1) the nature of the fisheries resource sampled and the importance of the site as a habitat for these species; (2) the importance of these resources to commercial, recreational or aboriginal fisheries in the area; and (3) the type, size, history and product

lines of each mill. Maps indicating the geographical location of each pulp and paper mill, as well as the locations of effluent discharges and sampling sites were prepared.

Logistics

Analysis of samples was done in both government and selected private laboratories. The government institutions were the DFO Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) in Burlington, Ontario, and, in the latter part of the program, the DFO Institute of Ocean Sciences (IOS) in Sidney, B.C. GLLFAS in Burlington received and processed all samples and retained five private consultants to assist in the analytical work. All samples from Ontario were analysed by Health Canada. In addition, Burlington was the base for planning and co-ordinating the Program and for selection and quality control monitoring of all participating laboratories.

To ensure the integrity of the samples, they were shipped by air in frozen form to the central DFO laboratory at Burlington. At the Burlington laboratory, technicians took special measures to protect samples from cross-contamination and deterioration, and for storing processed samples in specially cleaned glass containers at -20°C before analysis.

Analytical methods changed as the work progressed and the analytical instrumentation improved. As a result, the Program evolved over the period covered in this report. At the outset, all samples were analysed using low-resolution mass spectrometry (LRMS). In 1990, two years into the Program, laboratories involved in the analytical work, including the two DFO institutions, acquired high-resolution mass spectrometry (HRMS) instruments. This made it possible to detect dioxins and furans at lower concentrations than before and also provided more reliable results. There was also a positive trend in the economics of the Program with the cost-per-sample declining from \$1,300-\$1,500 at the start to \$850 in 1994. This was largely the result of the increase in competitive bidding that occurred as more commercial laboratories acquired the instrumentation and expertise to conduct HRMS analysis.

Another evolution was in the targeting of species and specimen types for analysis. The most significant example related to a highly popular and commercially important Pacific Coast crustacean, the Dungeness Crab. Other species, such as prawns and oysters were also targeted, but in these species, dioxin and furan concentrations tended to decline more quickly than in

crabs. Sampling and analysis in the Program showed that in the Dungeness crab, dioxins and furans can build up to particularly high concentrations in its hepatopancreas (digestive gland). As a result, where dioxin and furan concentrations in the hepatopancreas were deemed by Health Canada to pose a human health hazard, the Government issued consumption advisories to recreational and aboriginal fishers and in some cases closed commercial fisheries. In the Pacific Region, wherever non-commercial consumption advisories on crab hepatopancreas were necessary, the commercial crab fisheries were always closed as well.

Human Health Risk Assessment

Health Canada (HC) provided the expert advice needed to determine the human health implications of data generated by Canada's National Dioxin Sampling Program.

Health Canada's advice was based on concentrations of dioxins and furans found in fish and shellfish samples forwarded from government agencies or government-approved laboratories. The HC assessments were based on several factors, one being the concentrations of the different dioxin and furan congeners and others relating

to the tolerable daily intake that should not be exceeded by consumers.

The method HC uses to assess human health risks associated with dioxins and furans in fish, involves three main steps:

The first is to determine the Tolerable Daily Intake (TDI) of dioxins and furans. The TDI is the quantity of these chemicals that the average person could consume each day over a lifetime of 70 years without danger to health. As noted earlier, Health Canada, consistent with the findings of the World Health Organisation (WHO), has estimated the TDI to be 10 picograms per kilogram of body weight per day. Toxicologists base these on studies of laboratory animals in which they determine the threshold of contamination (i.e. the concentration at which no ill effects have been observed in the animals). A 100-fold safety factor is then added to

this value to compensate for variations in tolerance between individuals and between species.

The second step in the process is to estimate Probable Daily Intake (PDI) of dioxins and furans by consumers potentially exposed. Evaluators calculate this exposure on the basis of concentrations of dioxin and furan congeners found in fish and shellfish samples, expressed in TEQs. They then multiply the total TEQs by the amount of fish consumed per day. This requires information on food consumption patterns, as well as other factors such as location, cultural background, socio-economic status, gender and age of consumers. In determining PDIs, evaluators allow for not just average but above-average consumption rates, and the special vulnerability to contamination of certain sub-groups such as elderly people and young children.

The third step is comparison of the TDI and the PDI. If the PDI exceeds the TDI, the Government must consider measures to reduce the risk. The various risk management options include recommending limits for the consumption of fish and shellfish harvested at specific sites; restricting the sale or distribution of food from a contaminated area; and the closure of commercial and non-commercial fisheries until contamination in fish and shellfish has declined to concentrations that would no longer pose a threat to human health.

Before taking any of these actions, the Government weighs the potential advantages and disadvantages for the local population and its sub-groups, making each decision on a case-by-case basis.

Pacific Region

During Canada's National Dioxin Sampling Program, fish and shellfish samples were collected and analysed from the vicinity of 24 pulp and paper manufacturing mills in British Columbia, which used the chlorine bleaching process. A map of the Pacific Region, indicating the location of the pulp and paper mills included in the study is shown in Figure 4. From 1990 on, sampling and analysis under the program was conducted and paid for by the mills, under the direction of the British Columbia Ministry of Environment, Lands and Parks, DFO and Environment Canada (EC). In nearly all cases, these mills had already taken steps towards compliance with federal regulations requiring them to reduce concentrations of dioxins and furans in their wastewaters.

For purposes of organisation and focus, the pulp and paper mills were divided into 12 *interior* and 12 *coastal* mills.

As the term is used in this document, an *interior* mill is one whose effluents or wastewaters discharge into freshwater habitat, impacting primarily freshwater fish and other organisms. A *coastal* mill is one whose effluents

discharge into marine or estuarine waters, affecting marine habitat and its sea-dwelling organisms.

In some cases, however, the distinction between interior and coastal mills is not clearly defined. At New Westminster, for example, the effluent from the Scott Paper and the Paperboard Industries mills discharge into the Fraser River estuary where incoming tides from the Pacific push saltwater wedges upstream past the area of the mill. The Scott mill is in the *interior* category because the main impact of the mill effluent is on freshwater fish in the estuary, including juvenile Pacific salmon in their pre-ocean stage. By contrast, the Eurocan Pulp & Paper mill at Kitimat, about seven kilometres from the sea, qualifies as a *coastal* mill because it is known to have affected crabs living in the marine habitat.

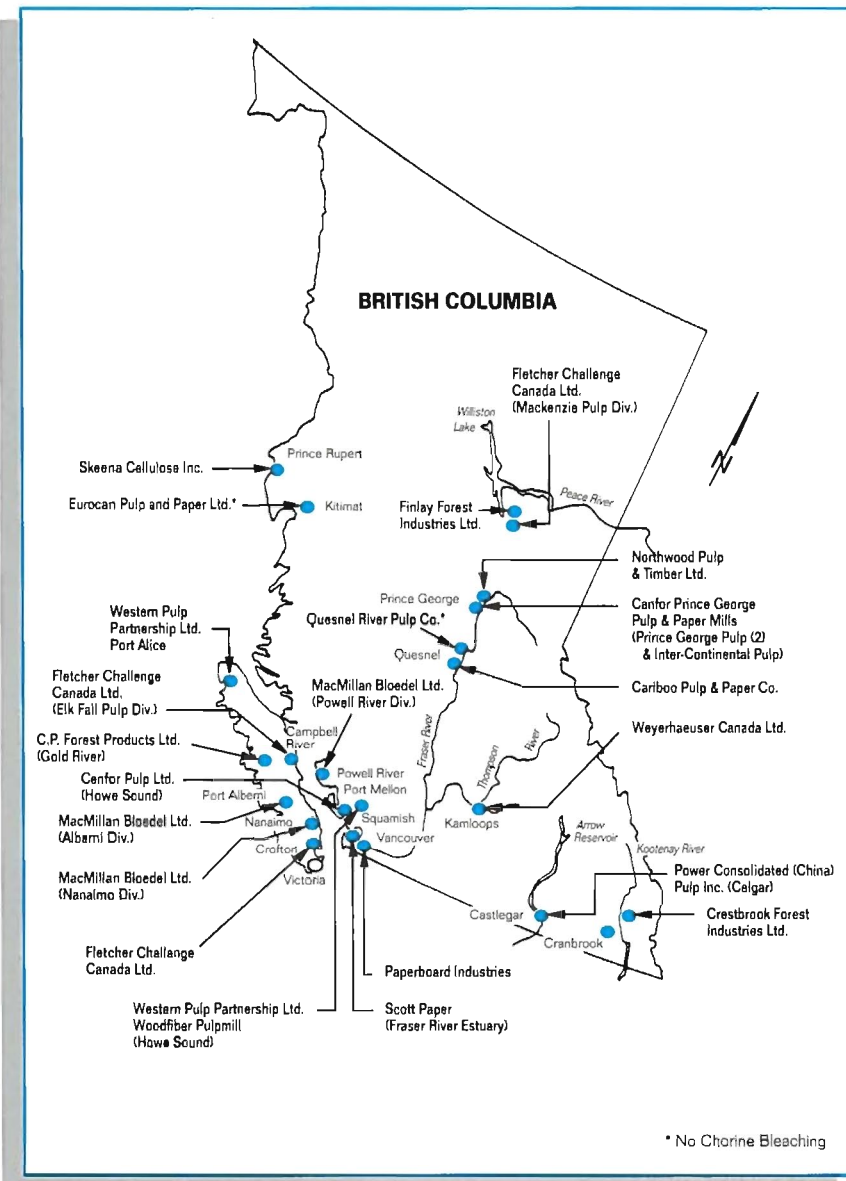
In certain areas, studies under the Program revealed dioxin and furan concentrations sufficient to warrant government measures to protect human health and the wholesomeness of Canadian fish products. These included total closures of certain commercial and non-

commercial fisheries and the issuing of consumption advisories, recommending restricted portions of fish consumption. The fishery closures involved crab, prawns, shrimps, clams and oysters harvested near coastal mills. The Government also issued a general advisory recommending against consumption of all liver tissues of bottom-feeding fish harvested in the vicinity of coastal mills.

In the course of the Program, analyses have shown declines in dioxin and furan concentrations in most areas. For example, based on an average of concentrations in crab hepatopancreas collected at one outfall site at each pulp mill, dioxin and furan TEQs fell by an average of 85% at six out of seven sites, measured by sampling in 1990 and 1993. These declines are the result of cleanup measures taken since 1991 by the pulp and paper industry. Monitoring, most of it by the pulp and paper industry under direction from EC and DFO continues. On an annual basis, the results of these studies are forwarded to HC for assessment of their human health implications.

Figure 4.

A map of the Pacific Region, indicating the location of the pulp and paper mills included in the study.



interior mills also included reference or control samples at sites upstream from the mills. The survey covered 22 species comprised of chinook, coho, sockeye and kokanee salmon, steelhead, Dolly Varden char, rainbow and cutthroat trout, burbot, walleye, longnose and largescale sucker, peamouth chub, mountain and lake whitefish, white sturgeon, northern squawfish, northern pike, eulachon, Coast Range and prickly sculpin as well as crayfish. Additional sampling and analysis conducted by the British Columbia Ministry of Environment, Lands and Parks is reported elsewhere (see Further Reading Section).

Thompson River

Kamloops

The Thompson River supports four species of Pacific salmon. These include the famed Adams River sockeye salmon whose run peaks every four years.

The Program focused on the influence of the Weyerhaeuser Canada Ltd. mill at Kamloops, one of the largest in British Columbia, and a producer of bleached and semi-bleached softwood and pulp. Like the other mills that historically used chlorine bleaching, this mill has dramatically reduced dioxins and furans from its wastewater discharge into the Thompson River.

British Columbia Interior Mills

The freshwater pulp and paper mills are located primarily in the Fraser-Thompson, Columbia and Peace watershed systems. A list of the interior pulp and paper mills of British Columbia

included in Canada's National Dioxin Sampling Program is presented in Table 1.

In this part of the Program, the analyses conducted near

During the Program, samples were collected from the North and South Thompson Rivers upstream from the mill, along with samples from Corbett Lake, a reference site, not exposed to pulp mill effluent. The species mix included samples of rainbow trout, mountain whitefish, suckers and Dolly Varden. In most cases, the samples analysed included both whole fish and muscle (fillet). The analysis indicated highest dioxin and furan concentrations at sites immediately downstream from the outfall, with TEQ values decreasing with distance

downstream from the outfall. Furthermore, the dioxin and furan concentrations were below analytical detection limits in the reference samples from Corbett Lake.

As a result of the dioxin and furan concentrations in samples of the Thompson River, the Government took the following action:

May 1989: Health Canada issued consumption advisories on mountain whitefish, northern squawfish and peamouth chub caught within

8 kilometres downstream of the Weyerhaeuser mill.

April 1990: Health Canada issued further consumption advisories on fish from two locations. One applied to fillets of Dolly Varden char caught at Tranquille, at the head of Kamloops Lake, about 6 kilometres below the outfall. The other covered fillets of rainbow trout from the Deadman Creek area, about 36 kilometres downstream from the mill.

Williston Lake-Peace River

During the Program, fish and sediments were sampled near two mills that could be expected to affect fish in the Peace River System.

The first was Fletcher Challenge Canada's bleached pulp mill at MacKenzie, near the southern end of Williston Lake. Analysis of samples of rainbow trout, burbot, longnose sucker and lake whitefish taken upstream and downstream from the mill in 1988 showed dioxin concentrations to be below the analytical detection limit. However, moderate concentrations of furans were detected.

DFO carried out no further sampling and HC issued no consumption advisories.

Table 1.

A list of the interior pulp and paper mills of British Columbia included in Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Kamloops	Weyerhaeuser Canada Ltd.	Thompson River
MacKenzie	Fletcher Challenge Canada Ltd.	Williston Reservoir
MacKenzie	Finlay Forest Industries Ltd.	Peace River
Taylor	Fibreco Pulp Inc.	Peace River
Prince George	Northwood Pulp & Timber Ltd.	Fraser River
Prince George	CANFOR Prince George Pulp & Paper Mills (2 mills, combined outfall) Prince George Pulp Intercontinental Pulp	Fraser River
Quesnel	Cariboo Pulp & Paper Ltd.	Fraser River
Quesnel	Quesnel River Pulp Company	Fraser River
Cranbrook	Crestbrook Forest Industries.	Kootenay River
Castlegar	Celgar Pulp Company Ltd.	Columbia River
New Westminster	Scott Paper Ltd.	Fraser River
Burnaby	Paperboard Industries Ltd.	Fraser River

The second mill in the system was Fibreco Pulp Inc.'s bleached pulp operation at Taylor. Samples from both upstream and downstream sites on the Peace River showed dioxin and furan concentrations to be below the analytical detection limit.

In 1989, DFO field personnel collected reference or control samples from the Pine and Peace Rivers, upstream from the mill. The species included: northern pike, mountain whitefish, walleye, longnose sucker and large scale sucker. Again, the dioxin and furan concentrations were below the analytical detection limit.

This was the only testing done at these sites during the Program.

Fraser River

Fish were sampled on the Upper Fraser River to gauge the possible impact of three pulp and paper mills located on the Fraser River at Prince George: Northwood Pulp and Paper's mill, and two facilities operated by Canadian Forest Products (CANFOR).

In 1988 and 1990, analysis of fish samples taken close to the mills revealed detectable concentrations of 2,3,7,8-TCDDs and 2,3,7,8-TCDFs in the livers of a variety of fish including juvenile chinook

salmon, rainbow trout, Dolly Varden char and suckers. In 1990, white sturgeon samples were collected at Stuart Lake and Stoner, 20 km downstream of Prince George. Consumption restrictions were put into place based on elevated dioxin and furan concentrations. In 1991, DFO sampled fish at Stoner and found high dioxin and furan concentrations in mountain whitefish liver. Further analysis of samples at the Stoner site in 1992, found that these concentrations had fallen dramatically.

About 100 km downstream from Prince George, the Program analysed fish samples taken in the vicinity of two mills operated by Quesnel River Pulp Company and the Cariboo Pulp and Paper Company. The first plant never used chlorine and its effluent receives both primary and secondary treatment before discharge into the Fraser River. The other plant at Quesnel is an older bleached kraft pulp mill operated by Cariboo Pulp and Paper Company.

DFO sampling and analysis near these sites in 1988 suggested a seasonal fluctuation in concentrations. Samples of juvenile chinook, salmon, burbot and longnose suckers collected in September had low dioxin and furan concentrations. However, analysis showed increased

concentrations in samples of the same species taken just after the spring break-up in the following year. These high concentrations tended to occur during the winter months when the flow of the Fraser River was at its lowest.

Program sampling on the Fraser River over a two-year period indicated that dioxin and furan concentrations in the system were on the decline. For example, scientists collected samples in 1990 and 1992 at a site 20 km downstream of Quesnel, where the influence of all four mills on the river could be assessed. The 1990 testing showed high concentrations of dioxins and furans in mountain whitefish. Sampling two years later at the same site showed a dramatic fall in concentrations.

DFO also sampled large scale sucker and mountain whitefish upstream from Quesnel in 1990 and 1992, analysing both muscle and liver tissues. On the basis of very limited sampling, it appeared that dioxin and furan concentrations in samples from this site had also fallen significantly.

Additional sampling, not included in this report, conducted under the direction of British Columbia Ministry of Environment, Lands and Parks has since resulted in most of the consumption advisories being lifted due to drastically

reduced dioxin and furan concentrations.

Fraser Estuary

New Westminster

Sampling in the estuary area focused on waters near the Scott Paper Ltd. plant at New Westminster, which manufactures paper products and groundwood, and which has never used chlorine. One purpose of sampling was to determine the influence of the scouring of sediments upstream on the Fraser River during spring runoff, and the resulting dislodgement of contaminated materials from the riverbed. In 1988 and 1989, DFO collected samples of white sturgeon and cutthroat trout downstream of the plant. Dioxin and furan concentrations were low in both years.

Kootenay River

In 1989, DFO collected and analysed fish from points upstream and downstream of the Crestbook Forest Industries kraft mill at Skookumchuk. The mill produces bleached kraft and subjects its wastewaters to primary and secondary treatment. The upstream samples did not contain measurable dioxin and furan concentrations. The downstream samples had low

concentrations of furans. No advisories were issued. The results of further sampling undertaken by the provincial government and the mill are reported elsewhere.

Columbia River

The Celgar Pulp Company operates a bleached kraft mill at Castlegar and discharges its wastewaters into the Columbia River. Samples of walleye and burbot collected by DFO, 200 metres downstream from the plant in 1988 and 1989, showed concentrations sufficient to warrant the B.C. Ministry of Health to issue an advisory, limiting the consumption of mountain whitefish to one meal per week.

Extensive sampling along the Columbia River in 1994 yielded low dioxin and furan concentrations in every case. Further sampling and analysis conducted by the provincial government resulted in the lifting of the consumption advisory.

Kitimat River

The Program categorised the Eurocan Pulp & Paper Co. plant as a coastal mill, and DFO concentrated its attention on marine species. However, field personnel did some sampling and analysis of freshwater species upstream and downstream of the mill. Only one sample, a Dolly Varden, showed detectable dioxin and furan concentrations.

British Columbia Coastal Mills

There are 11 coastal pulp and paper manufacturing sites in British Columbia, including the mill at Kitimat which has never used chlorine. A list of the coastal pulp and paper mills of British Columbia included in Canada's National Dioxin Sampling Program is presented in Table 2. The table, which contains 12 sites, includes the abandoned mill site at Ocean Falls.

Howe Sound

Howe Sound supports commercial fisheries for shrimp, prawn and Dungeness crab as well as recreational and aboriginal fisheries for a variety of species.

Two of the oldest pulp and paper mills in British Columbia are located on Howe Sound. One is at Port Mellon and the other at Woodfibre, close to the mouth of the Squamish River.

Table 2.

A list of the coastal pulp and paper mills of British Columbia included in Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Port Mellon	Howe Sound Pulp & Paper Ltd.	Howe Sound
Woodfibre	Western Pulp Ltd. Partnership	Howe Sound
Prince Rupert	Skeena Cellulose Inc.	Chatham Sound
Kitimat	Eurocan Pulp & Paper Ltd.	Kitimat River
Powell River	MacMillan Bloedel Ltd.	Malaspina Strait
Crofton	Fletcher Challenge Canada Ltd.	Stuart Channel
Nanaimo	MacMillan Bloedel Ltd.	Strait of Georgia
Campbell River	Fletcher Challenge Canada Ltd.	Discovery Passage
Port Alice	Western Pulp Ltd. Partnership	Neroutsos Inlet
Gold River	Canadian Pacific Forest Products	Muchalat Inlet
Port Alberni	MacMillan Bloedel Ltd.	Alberni Inlet
Ocean Falls	Abandoned site	Fisher Channel

This is the site of active recreational and aboriginal fisheries for salmon and steelhead trout.

Although both plants used chlorine in their bleaching processes for most of their history, they have since reduced the concentrations of dioxins and furans in their wastewaters. As the Program progressed, researchers developed a special interest in the mill near Port Mellon because of evidence that tides and currents were transporting dioxins and furans from the mill site to points

further from the mill. As a result, more samples were analysed in the vicinity of this mill, than for any other pulp and paper manufacturing site in Canada. The Program focused mainly on Howe Sound's commercial fisheries for Dungeness crab partly because of its economic importance, and partly because of its use as an effective indicator species. Analysis of these samples showed high dioxin and furan concentrations in the muscle and hepato-pancreas of this species. Concentrations were also high in shrimp and prawn.

Analysis of chum salmon samples revealed that dioxin and furan concentrations were below analytical detection limits. Although the muscle tissue of rockfish and sole had dioxin and furan concentrations below analytical detection limits, the liver samples from the same fish had high concentrations. A general, coast-wide advisory was issued in 1990, recommending against the consumption of livers from bottom-feeding fish taken in the vicinity of pulp and paper mills.

Samples of softshell clams and mussels taken close to the mill, had concentrations that did not pose a threat to human health.

On the basis of these findings and advice from Health Canada, the Government took the following action in Howe Sound.

November 1988: The initial closure pertained to all harvesting of crab, prawns and shrimp in three areas of Howe Sound.

June 1989: The total harvest closure on crab, combined with closures on commercial shrimp and prawn fisheries, was extended to some further areas in Howe Sound. Other areas remained open to recreational and aboriginal fishing, however, in these cases, Health Canada issued advisories to limit

consumption of crab hepatopancreas.

August 1993: After further sampling and advice from Health Canada, DFO maintained the existing harvesting restrictions in Howe Sound.

February 1995: Shrimp and prawn fisheries were reopened. The crab closure was extended to the Reception Point area. It is important to note that the northern areas of Howe Sound were reopened to non-commercial crab fishing, with an advisory on the consumption of the crab hepatopancreas.

August 1995: The need for the consumption advisory for crab hepatopancreas was rescinded. However, the area remained closed to commercial crab harvesting pending management consultation. These consultations were held and the area reopened to fishing in July 1996.

April 1996: The western portion of Howe Sound, in the area of the mill near Port Mellon, was reopened to non-commercial fisheries and an advisory was issued.

In general, when dioxin and furan TEQ concentrations in Dungeness crab hepatopancreas exceed 30 pg/g the area is closed to commercial fisheries and an advisory is issued to non-

commercial fishers. When concentrations exceed 15 pg/g in crab, oyster, prawn or shrimp muscle tissue, the fishery is closed to both commercial and non-commercial fishing. In this report, dioxin and furan concentrations that exceed the above concentrations and warrant fishery closures and consumption advisories are considered to be high concentrations. The TEQ concentration of 15 pg/g is highlighted on the figures that

indicate the annual TEQ concentrations for specific sampling sites identified on the maps.

A map showing the location of fisheries closures and consumption advisories in Howe Sound, as of August 1995 is shown in Figure 5. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Howe Sound, from 1989 to 1994 are presented in Figure 6.

Figure 5.

A map showing the location of fisheries closures and consumption advisories in Howe Sound, as of August 1995.

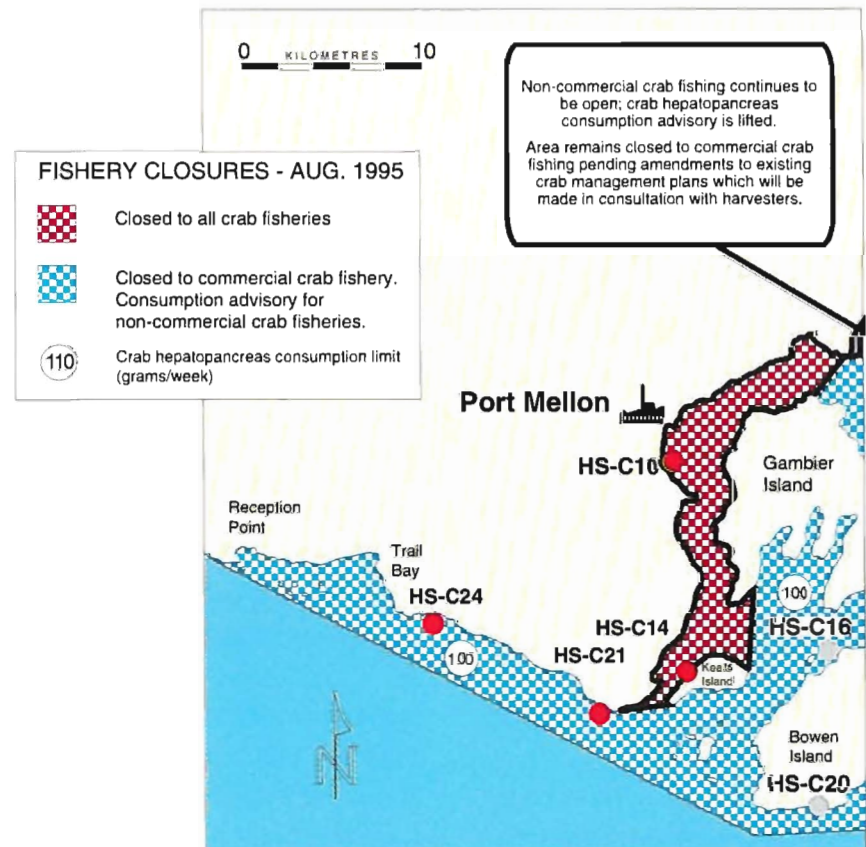
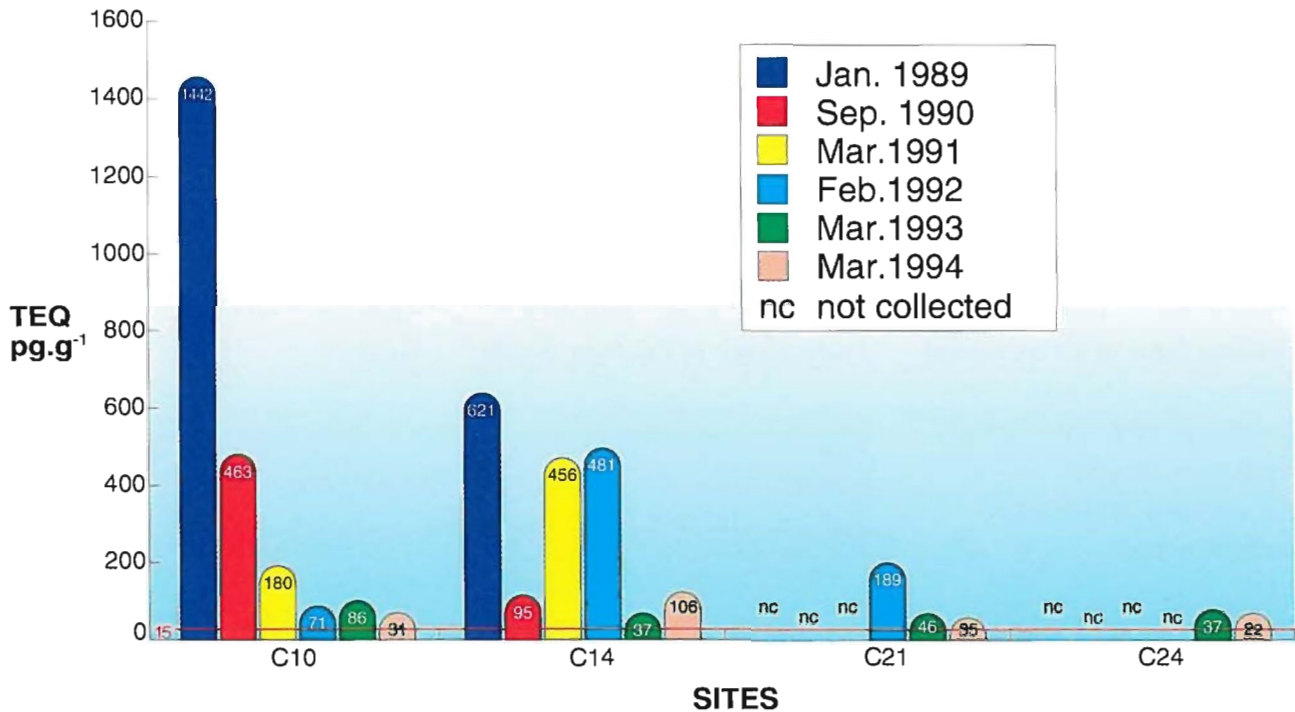


Figure 6.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Howe Sound, from 1989 to 1994.



North Coast

Prince Rupert

The Prince Rupert area has several commercial, aboriginal and recreational fisheries for shellfish and other species. It is also the site of two pulp and paper mills operated by Skeena Cellulose Inc., which used chlorine in their pulp bleaching processes until 1993 when process changes were implemented which resulted in a major reduction of dioxins and furans in the effluents.

Sampling and analysis during the Program showed the two areas that exhibited high

concentrations of dioxins and furans to be Wainwright Basin and Porpoise Harbour in the waters between Kaien Island and the mainland.

On the basis of these data and advice from Health Canada, the Government took the following action in the Prince Rupert area:

November 1988: Closure of Porpoise Harbour and Wainwright Basin to all crab harvesting.

June 1989: Extension of the closure north and east to include Morse Basin. In this case, DFO left non-commercial crab harvesting open, with an advisory on the consumption of crab hepatopancreas. At the same time, DFO closed all shrimp fishing in Porpoise Harbour and the area of Coast Island.

August 1993: On the basis of 1992 sampling and Health Canada advice, DFO extended the commercial crab fishing closure to include Prince

Rupert Harbour and issued a consumption advisory on consumption of crab hepatopancreas for the area west of Kaien Island.

1990-93: Sampling of shrimp in this period showed a steady decline in dioxin and furan concentrations.

February 1995: DFO reopened shrimp and prawn fisheries but maintained the closure of commercial crab fishing in Porpoise Harbour and Wainwright Basin and commercial harvesting in Morse Basin and Prince Rupert Harbour.

August 1995: The need for a contamination related closure was lifted in Morse Basin, however, the area was not reopened to commercial crab fishing, since it was a management decision to allocate the area to non-commercial harvesters only. Wainwright Basin was and continues to be closed to all crab harvesting.

April 1996: Non-commercial crab fishing was always open in the Coast Island area, with a consumption advisory on the crab hepatopancreas. In April 1996, the need for an advisory was rescinded. This left the area potentially open to commercial crab fishing: a management decision to reopen the area to commercial

crab harvesting was made in September 1996.

Studies of data collected on Dungeness crab at Prince Rupert from 1987 through 1993 show a greater than tenfold drop in dioxin and furan concentrations. A map showing the location of

fisheries closures and consumption advisories in the Prince Rupert area as of August 1995 is shown in Figure 7. Trends in dioxin and furan TEQs for Dungeness crab hepatopancreas samples collected in the vicinity of Prince Rupert, from 1989 to 1994 are presented in Figure 8.

Figure 7.
A map showing the location of fisheries closures and consumption advisories in Prince Rupert as of August 1995.

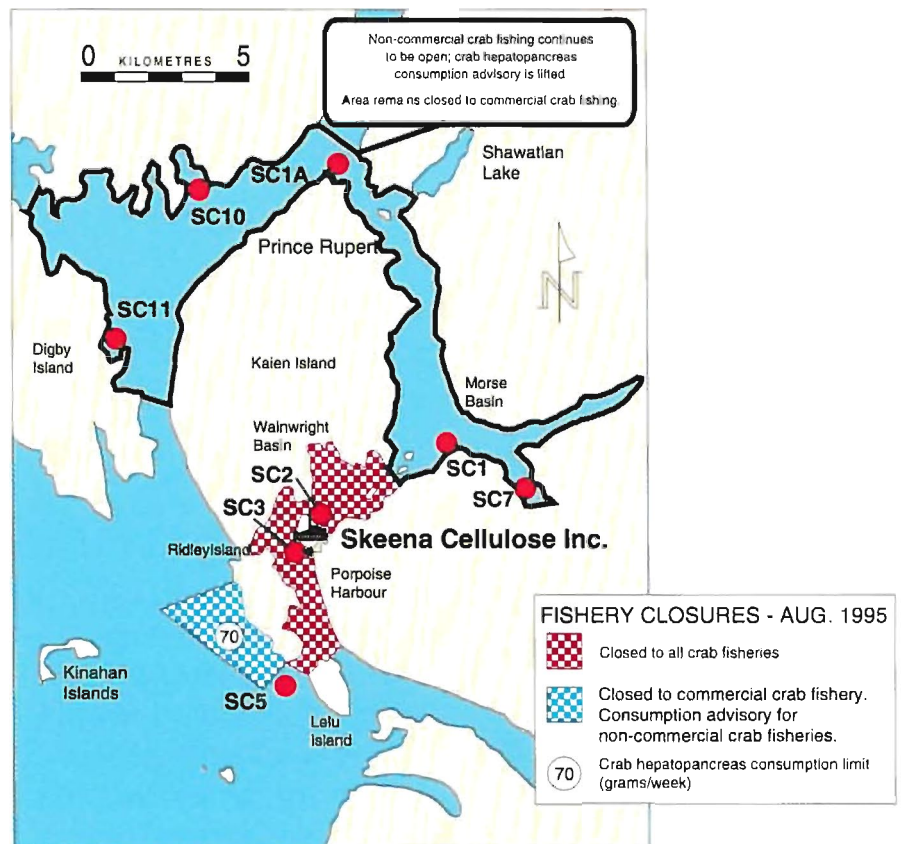
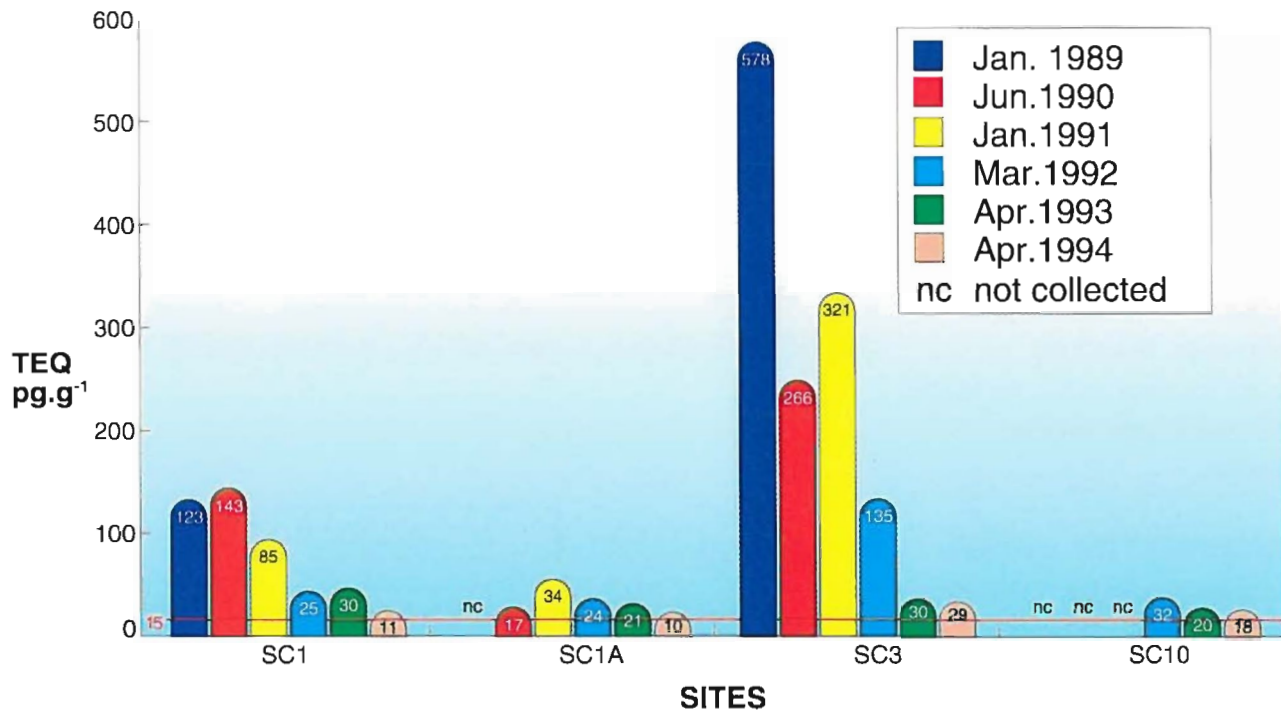


Figure 8.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Prince Rupert, from 1989 to 1994.



Kitimat Arm

The Eurocan Pulp & Paper mill at Kitimat was an atypical case in this study since it makes unbleached pulp and has never used chlorine. However, for a large part of its history, the mill processed wood chips contaminated with pentachlorophenol. The mill treats its wastewaters before discharging them into the Kitimat River about 7 km from the sea. In addition, Kitimat is a highly industrialised area with

an aluminium smelter and a methanol plant.

During the Program, samples of both marine and freshwater species were collected from the Kitimat River and in Kitimat Arm. Low concentrations of dioxins and furans were found in only one sample taken from the river. In that the remainder of samples had dioxin and furan concentrations below analytical detection limits, it was

concluded that the Kitimat River is not contaminated with dioxins and furans. However, 1989 sampling in Kitimat Arm showed high dioxin and furan concentrations in crabs. Further sampling of the same area by the mill's consultants in 1995 indicated a ten-fold reduction in dioxin and furan concentrations.

On the basis of these findings and advice from Health Canada, the Government took the following action in Kitimat Arm.

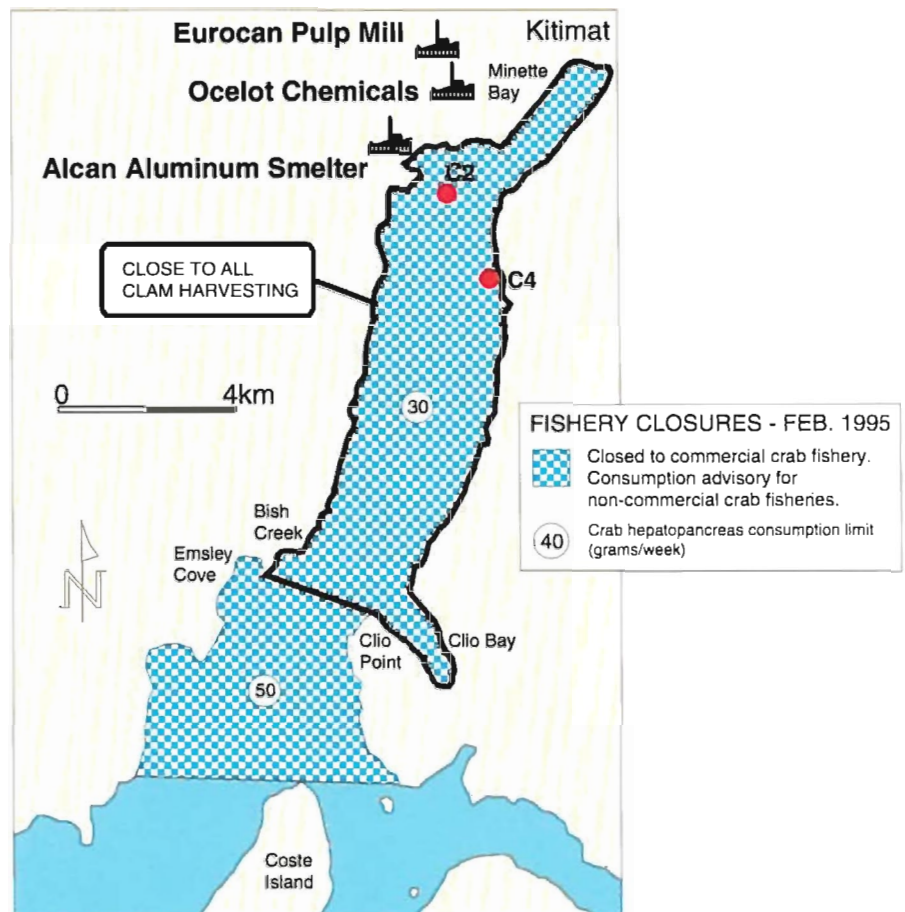
November 1989: Closure of the northern portion of Kitimat Arm to commercial crab harvesting and to all clam harvesting. Although the Government imposed no ban on aboriginal or recreational harvesting of Dungeness crab, it did issue an advisory recommending limited consumption of crab hepatopancreas.

November 1990: The Government extended the geographical area of the commercial crab closure and issued a consumption advisory to aboriginal and recreational harvesters in the area.

April 1996: The Dungeness crab fishery was reopened and no dioxin-mediated advisories were required. The dioxin and furan mediated closure for clams remains in effect.

A map showing the location of fisheries closures and consumption advisories in Kitimat Arm, as of February 1995 is shown in Figure 9. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Kitimat Arm, from 1990 to 1994, are presented in Figure 10.

Figure 9. A map showing the location of fisheries closures and consumption advisories in Kitimat Arm, as of February 1995.



Strait of Georgia

Powell River

Powell River, on the east coast of the Strait of Georgia, is an area of diverse and valuable fishery resources. Oyster farming is an important and growing industry in nearby Desolation Sound and Malaspina Inlet.

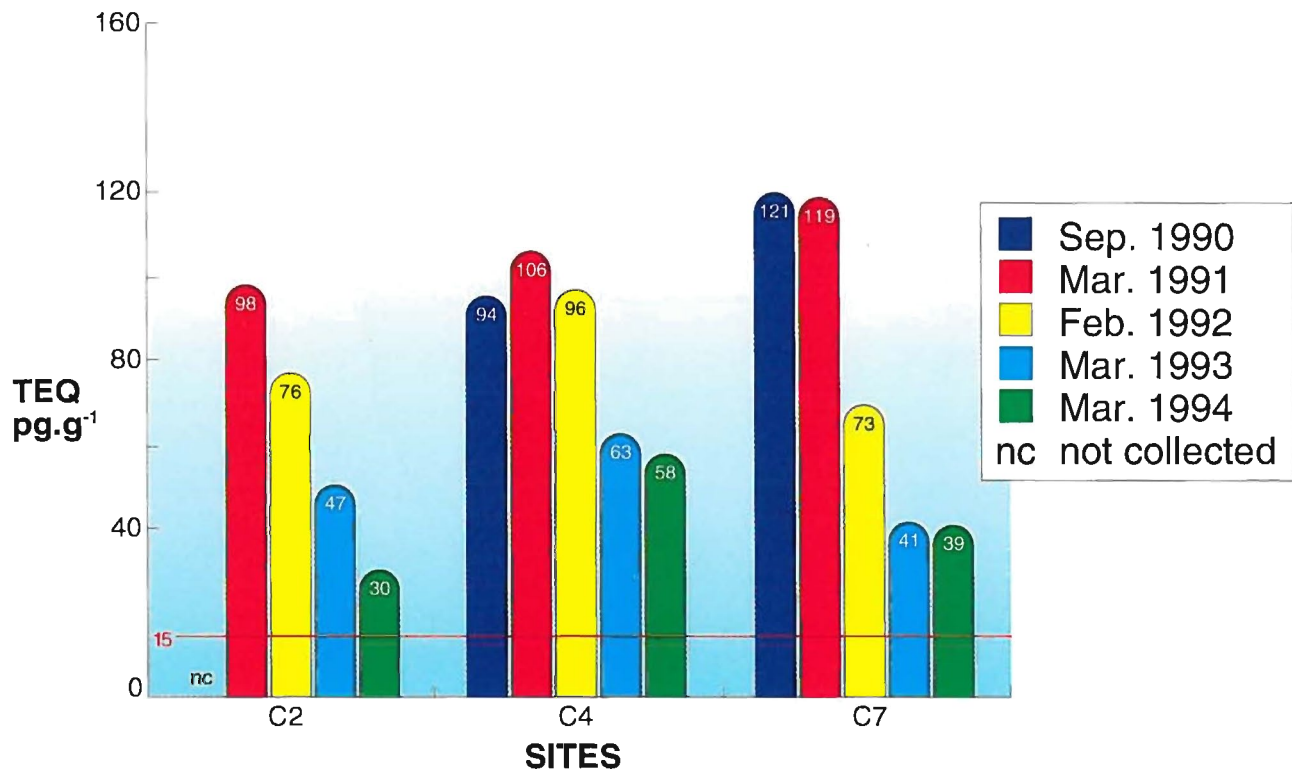
The Program focused on the impact on these resources from the MacMillan Bloedel Ltd. pulp mill at Powell River. By 1993,

the plant had replaced 80% of the chlorine used in the bleaching process with chlorine dioxide and had installed a secondary treatment system.

In this area DFO analysed a sample mix that included oysters, crabs, clams, prawns, shrimps, and a variety of fish. From 1990 onward, sampling and analyses were conducted by the mill's consultants.

Figure 10.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in Kitimat Arm, from 1990 to 1994.



When the Program began, a portion of the coastal area had already been closed to oyster harvesting because of coliform contamination. Sampling and analysis in 1988 showed low concentrations of dioxin in rockfish and sole, as well as in prawn, pink shrimp and clam samples. Sampling of fish in 1990 revealed low dioxin concentrations in muscle tissue but higher concentrations in liver. Sampling of oysters showed elevated concentrations of dioxins close to the mill, and lower

concentrations further downstream.

In view of these findings, the Government took the following action:

November 1989: Closure of all crab harvesting in the immediate vicinity of the pulp mill and closure of some oyster harvesting areas.

November 1990: The geographical area of the commercial crab fishery closure was widened. Recreational and

aboriginal fisheries stayed open subject to a consumption advisory on hepatopancreas of Dungeness crab and box crab. At this time, an advisory was issued recommending against consumption of livers of bottom-feeding fish caught near this mill as well as all other B.C. coastal mills.

August 1993: A further extension of the geographical area of the commercial crab harvesting closure was issued.

February 1995: Responding to declining dioxin concentrations in samples, the dioxin-mediated ban on oyster harvesting was lifted, but the fishery remained closed in some areas because of continued coliform pollution. Portions of the area closed to non-commercial crab harvesting were reopened, subject to a consumption advisory on hepatopancreas tissue.

August 1995: The Harwood Island area reopened to non-commercial crab harvesting and a consumption advisory was issued. The remainder of the closed area was reopened and no consumption advisory was issued. Consultations were held concerning the commercial crab harvesting and the area reopened in 1996.

A map showing the location of fisheries closures and consumption advisories in the vicinity of Powell River, as of August 1995, is shown in Figure 11. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the Powell River area, from 1990 to 1994, are presented in Figure 12.

Figure 11.
A map showing the location of fisheries closures and consumption advisories in the vicinity of Powell River, as of August 1995.

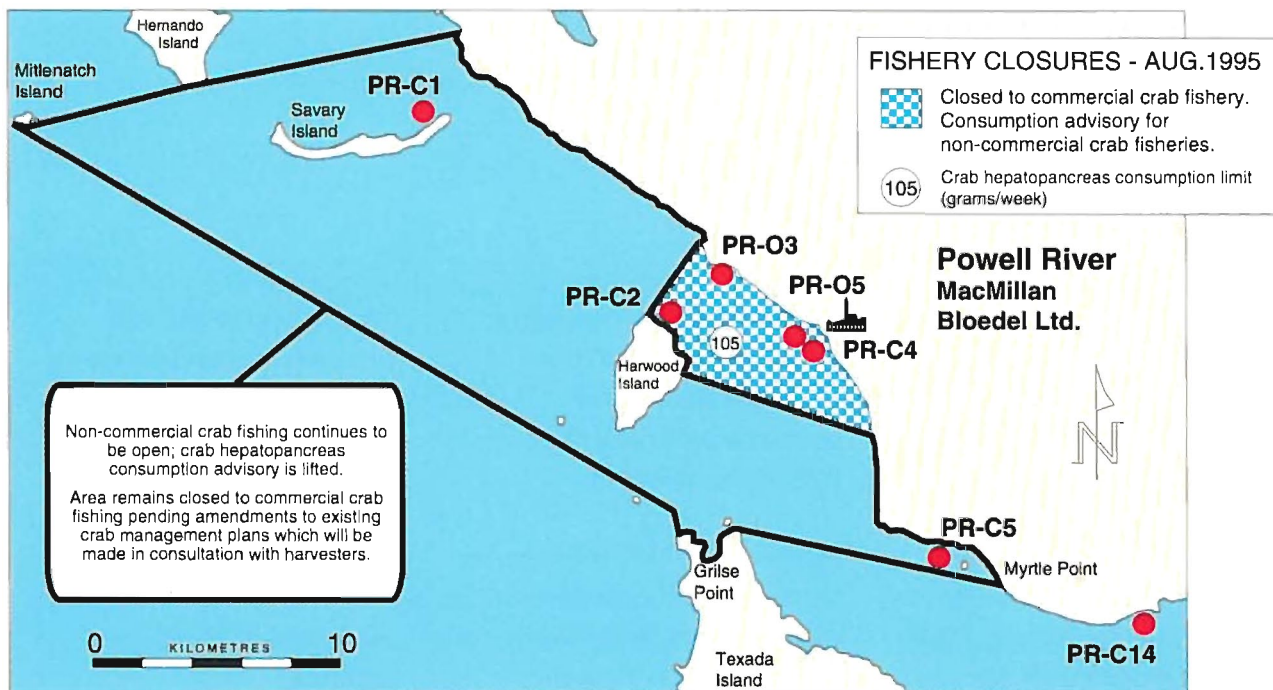
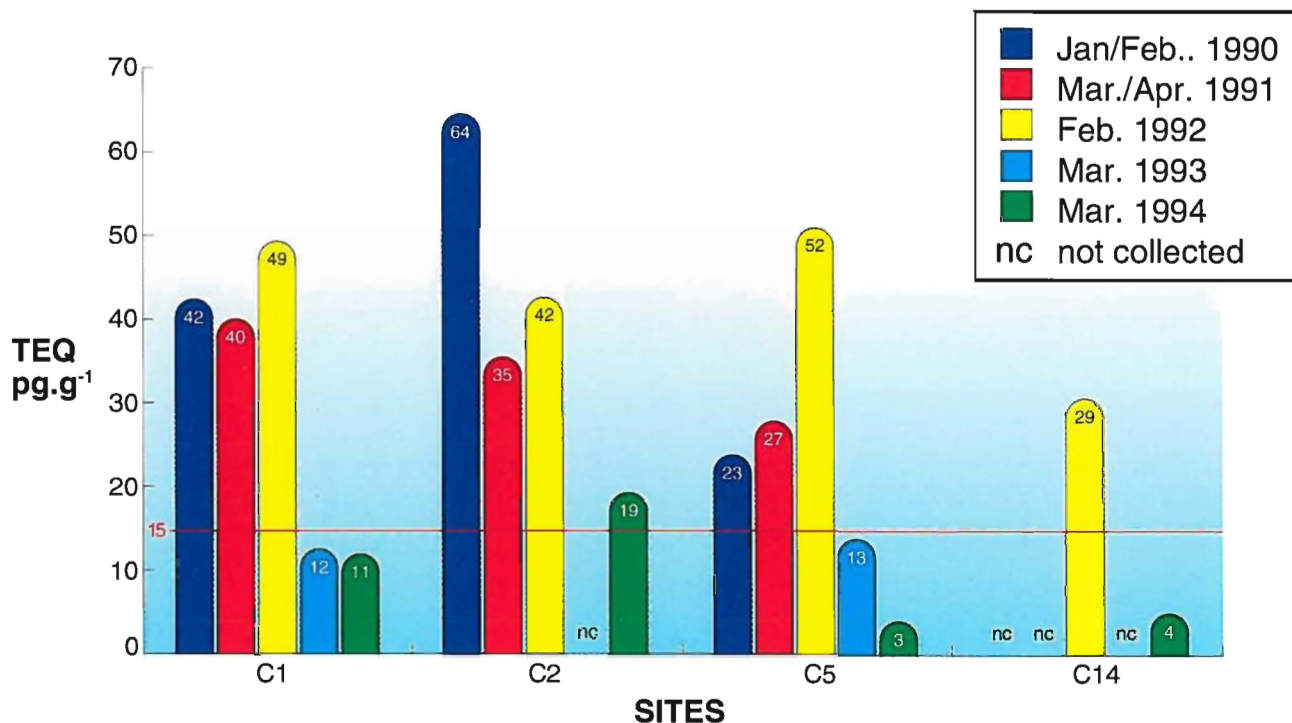


Figure 12.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the Powell River area, from 1990 to 1994.



Vancouver Island, East Coast

Crofton

Located at Crofton on the east coast of Vancouver Island, the Fletcher Challenge Canada mill produces both bleached pulp and newsprint. By 1993, the mill had drastically reduced dioxins and furans in its mill effluent. The mill discharges its effluent into a well-swept tidal channel inhabited by fish and shellfish, and that supports commercial crab as well as other fisheries. After 1990, sampling and analysis was conducted by the mill's consultants.

On the basis of emerging data, and advice from Health Canada, the Government took the following actions:

November 1989: Closure of all commercial crab harvesting, and a consumption advisory on hepatopancreas for non-commercial fisheries was imposed in Stuart Channel and Cowichan Bay. Oyster harvesting was prohibited in a defined area, much of which had been closed earlier due to coliform contamination.

November 1990: The commercial crab harvesting closure was extended to include Burgoyne Bay on Saltspring Island. Non-commercial harvesting remained open subject to a human health advisory on the consumption of hepatopancreas.

August 1991: The commercial closure and non-commercial consumption advisory on hepatopancreas were extended to Ladysmith Harbour and to Maple Bay.

August 1993: Revised advisories on crab hepatopancreas were required, relaxing the consumption limit.

February 1995: The ban on oyster harvesting was lifted, but much of the area remains closed due to faecal coliform contamination.

August 1995: Cowichan Bay, an area allocated to aboriginal fishers, was reopened. No consumption advisory was issued.

Nanaimo

Harmac Pacific operates a bleached-pulp mill at Harmac near Nanaimo. By 1993 the mill had markedly reduced their dioxin and furan concentrations in their effluent.

All sampling in this area was conducted by the mill's consultants. From 1990 to 1993 samples of Dungeness crabs and rock crabs were collected at various sites. Analysis revealed low (less than 15 pg/g TEQ) to non-detectable dioxin concentrations in the muscle tissues, but high concentrations in hepatopancreas.

In view of these findings and advice from Health Canada, the Government took the following actions:

November 1989: A closure of commercial crab harvesting

was imposed in two areas in the vicinity of the mill from Vancouver Island to Gabriola Island. Non-commercial crab harvesting remained open at these locations subject to an advisory to recreational and aboriginal fishers on the consumption of crab hepatopancreas.

November 1990: A northward extension was added to the commercial crab fishing closure, again accompanied by a consumption advisory for crab hepatopancreas.

August 1991: A further extension northward and southward was added to the commercial crab fishery closure, with a consumption advisory for crab hepatopancreas.

August 1993: The commercial crab fishery closure was extended southward.

February 1995: The government announced that although dioxin concentration in Dungeness crabs had fallen, existing closures would remain in force pending further sampling. Revised advisories on crab hepatopancreas were issued, relaxing the consumption limit in the area closest to the outfall.

August 1995: The Northumberland Channel was reopened for harvest and no

advisory was issued. As of early 1997, Kulleet Bay remains closed to commercial crab fishing with a consumption advisory in effect for non-commercial fisheries.

A map showing the location of fisheries closures and consumption advisories in the Crofton area, and part of the Harmac area near Nanaimo as of August 1995, is shown in Figure 13. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Crofton, from 1990 to 1994, are presented in Figure 14.

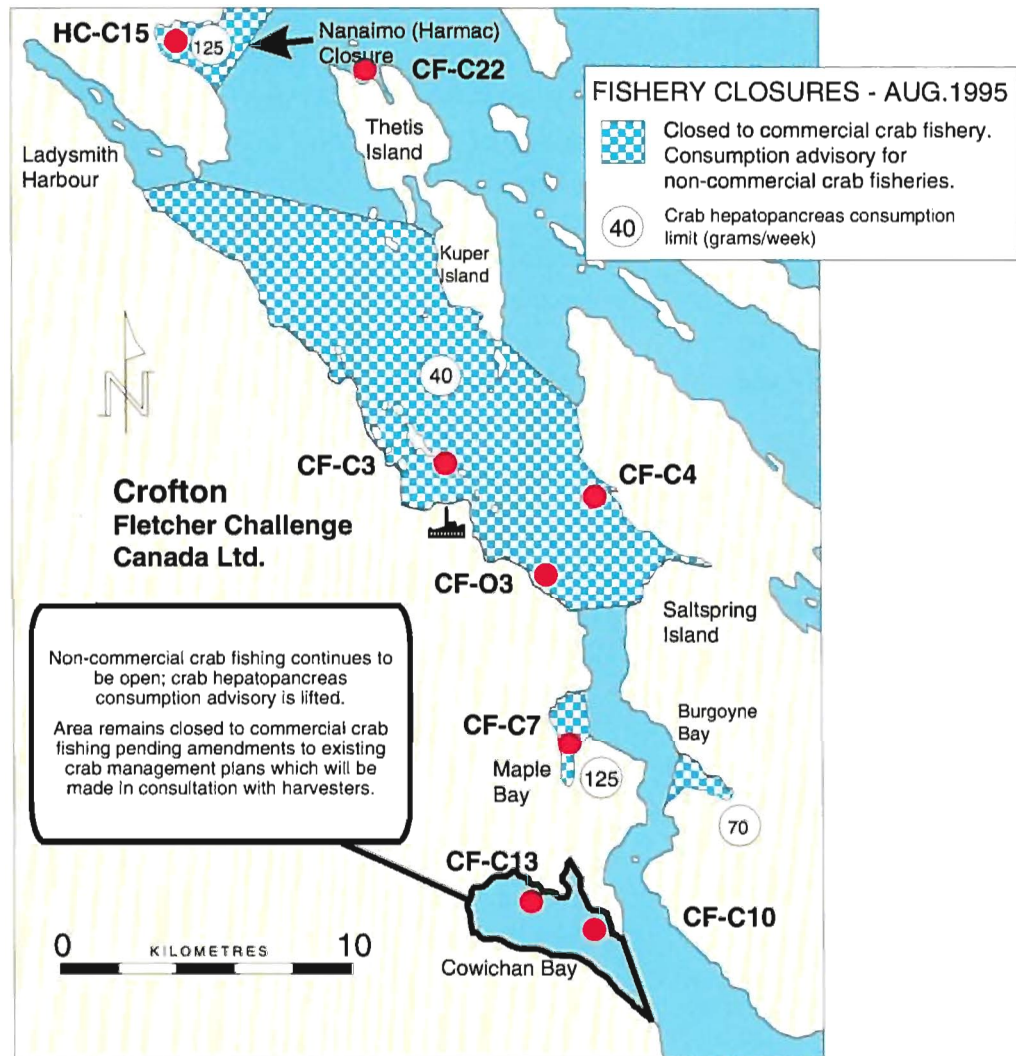
Campbell River

Fletcher Challenge Canada Ltd. operates a mill at Elk Falls near Campbell River, that produces newsprint, kraft paper and bleached kraft pulp. By 1993 the company had also reduced the concentrations of dioxins and furans in its effluents.

From 1988 to 1994, shellfish and fish samples from the area were collected and analysed. They included stocks of prime economic importance to commercial, recreational and aboriginal fisheries. Analyses showed high dioxin and furan concentrations in the hepatopancreas of Dungeness crabs and in the livers of bottom fish samples.

Figure 13.

A map showing the location of fisheries closures and consumption advisories in the Crofton area, and part of the Harmac area near Nanaimo as of August 1995.



In view of the findings, the Government took the following management actions in this area:

November 1989: Commercial harvesting of crabs was closed in the western portion of Discovery Passage and a consumption advisory on hepatopancreas was issued to non-commercial harvesters. A

consumption advisory for bottom fish livers has been in effect since 1989. Although recent data indicate declining concentrations, the advisory remains in place to 1998 pending further sampling.

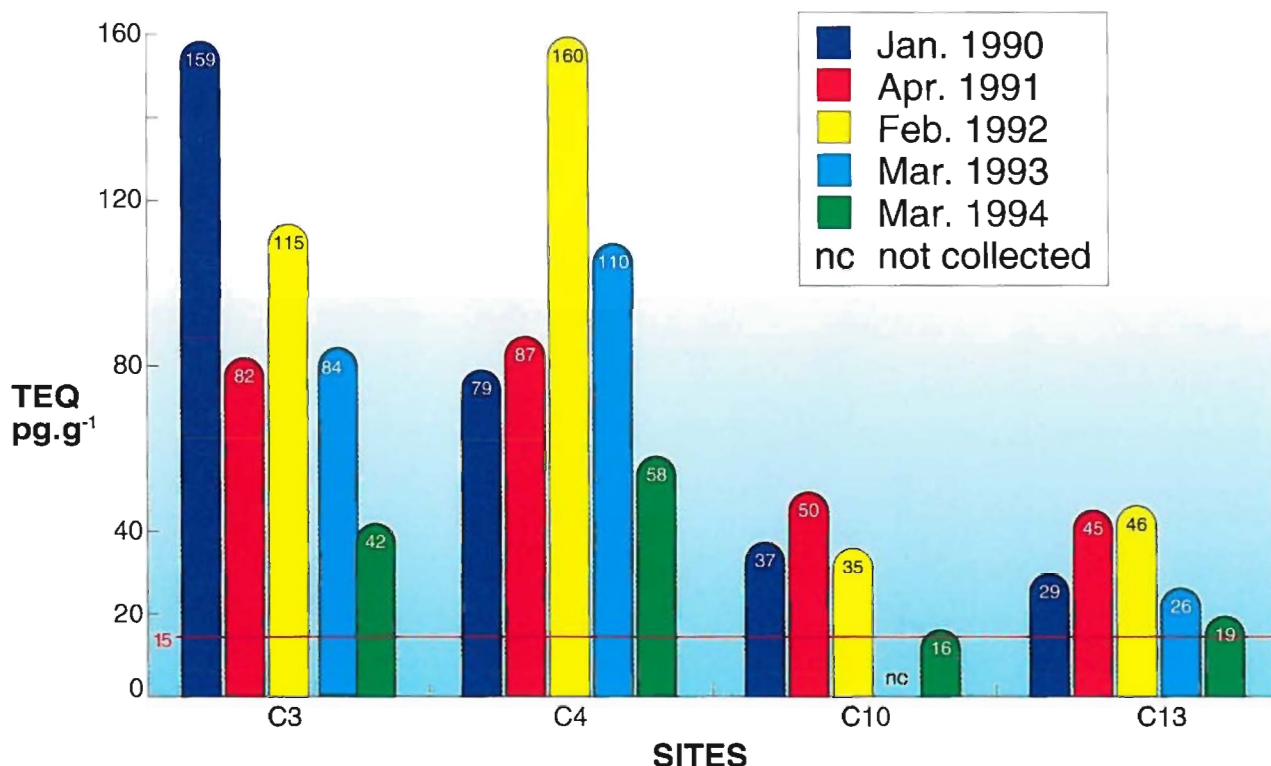
November 1990: The commercial crab fishery closure was extended. The consumption advisory was revised,

further restricting the recommended limits for consumption of hepatopancreas.

August 1991: The ban on commercial crab fishing was extended northward, accompanied by a consumption advisory on hepatopancreas to participants in recreational and subsistence fisheries.

Figure 14.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Crofton, from 1990 to 1994.



August 1993: The commercial crab closure was further extended with the closure of two additional areas, with consumption advisories on hepatopancreas. In the newly-closed area southeast of Quadra Island, the recommended consumption limit was zero.

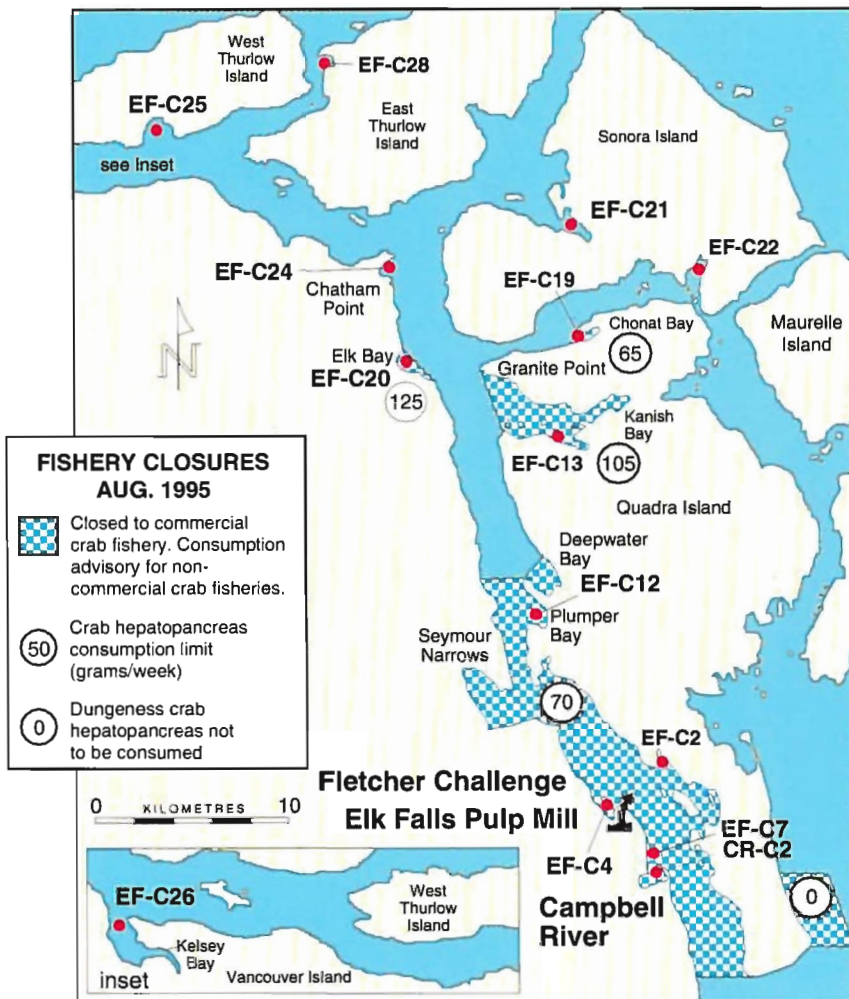
February 1995: Three new closures were put into place at

Elk Falls on the northern coast of Quadra Island with accompanying consumption advisories on crab hepatopancreas in all cases.

April 1996: The commercial crab fishery at Elk Bay was reopened and no advisory was issued.

A map showing the location of fisheries closures and consumption advisories in the Campbell River area as of August 1995, is shown in Figure 15. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Campbell River, from 1990 to 1994, are presented in Figure 16.

Figure 15.
A map showing the location of fisheries closures and consumption advisories in the Campbell River area as of August 1995.



Vancouver Island, West Coast

Port Alice, Quatsino Sound

The Western Pulp Partnership sulphite pulp mill at Port Alice, on Neroutsos Inlet, is nearly 80 years old. For the period of the Program (1989 to 1995), the mill was still using chlorine in its production of bleached pulp. However, the mill fulfilled its commitment to install

facilities for secondary treatment of its effluent by January 1, 1996.

DFO collected and analysed fish and shellfish samples in this area between 1986 and 1989 and found very low concentrations of dioxins. No closures or advisories were issued.

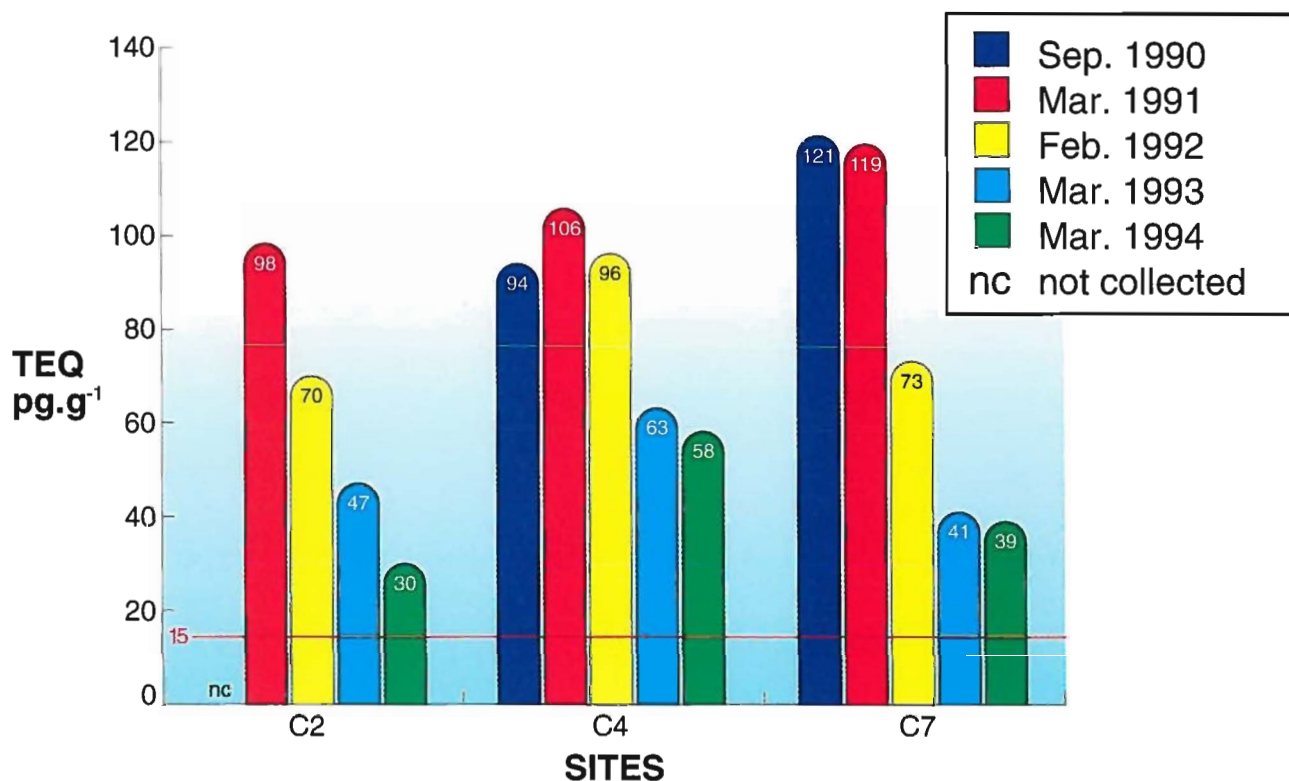
Reopening closed fisheries: how the decisions are made

In the course of the Program, the Government closed certain fisheries in British Columbia to protect the health of consumers and to ensure the wholesomeness of Canadian fishery products. Later, as sampling revealed a decline in dioxin and furan concentrations in the biota, some of these fisheries were reopened. Decisions to reopen the fisheries in British Columbia were based on the following criteria:

1. Data used in reopening decisions are assessed on a species-specific and area-specific basis. This means, for example, that prawn, shrimp and oyster harvesting might reopen in a given area while crab harvesting stayed closed, even though the closure boundaries overlap.
2. Partial lifting of harvesting restrictions (i.e. total closure to all crab fishing may be replaced with a commercial closure, coupled with an advisory on hepatopancreas consumption by non-commercial harvesters).
3. A fishery reopening must encompass at least one-half of the closed area, or an entire discrete portion if the closed area consists of a number of geographically isolated areas. The reopening area must be sufficiently separate to protect against the harvesting of shellfish previously resident in adjacent contaminated areas.
4. Reopening areas requires a minimum of two consecutive years of "clean" analytical data (i.e. probable daily intake by human consumers does not exceed tolerable daily intake) and no increase in TEQ concentrations.
5. In addition to sampling by individual pulp and paper mills, independently collected audit samples may be collected and analysed by DFO to ensure that dioxin and furan concentrations are acceptably low. Pulp and paper mills may be required to do further sampling after fisheries reopen to confirm that the concentrations remain low.
6. The data on which reopening decisions are based are subject to rigorous quality assurance and quality control requirements.
7. Sample collection and analysis are subject to periodical independent audit and/or confirmation procedures.
8. When areas have been closed both for dioxin and furan contamination and for other reasons, they may remain closed for other reasons after the dioxin and furan closures are lifted (i.e. in the case of coliform contamination or navigation hazard).

Figure 16.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Campbell River, from 1990 to 1994.



Gold River, Nootka Sound

Canadian Pacific Forest Products Ltd. operates a bleached kraft mill at Gold River on the west coast of Vancouver Island. By 1993, the company had drastically reduced the concentrations of dioxins and furans in its effluent.

Fish and shellfish samples from this area were collected and

analysed from 1988 to 1994, with a particular focus on Dungeness crabs and prawn. From 1990 onward, sampling and analysis were conducted by the mill's consultants. Analysis of muscle tissues of fish showed only low dioxin and furan concentrations in the samples collected.

In view of the findings and advice from Health Canada, the Government took the following action in the Nootka Sound area:

November 1989: A ban on all harvesting of crabs and prawns was issued for the waters of Muchalat Inlet, lying east of the Gold River Harbour Limit.

November 1990: The closed area was extended to include closure on all crab harvesting in all of Muchalat Inlet.

August 1993: The commercial crab harvesting closure was extended to Hisnit Inlet. Recreational and other non-commercial harvesting stayed open subject to a health advisory on hepatopancreas consumption.

February 1995: The dioxin-mediated closure of prawn harvesting and non-commercial harvesting of crabs was lifted for Muchalat Inlet, subject to a consumption advisory on the hepatopancreas.

August 1995: Hisnit Inlet was reopened and the consumption advisory was removed. Sampling and analysis in this area showed a clear reduction in dioxin and furan

concentrations between 1988 and 1994. Commercial fishing reopened in 1996.

A map showing the location of fisheries closures and consumption advisories in the Gold River area as of August 1995, is shown in Figure 17. Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Gold River, from 1988 to 1994, are presented in Figure 18.

Figure 17.

A map showing the location of fisheries closures and consumption advisories in the Gold River area as of August 1995.

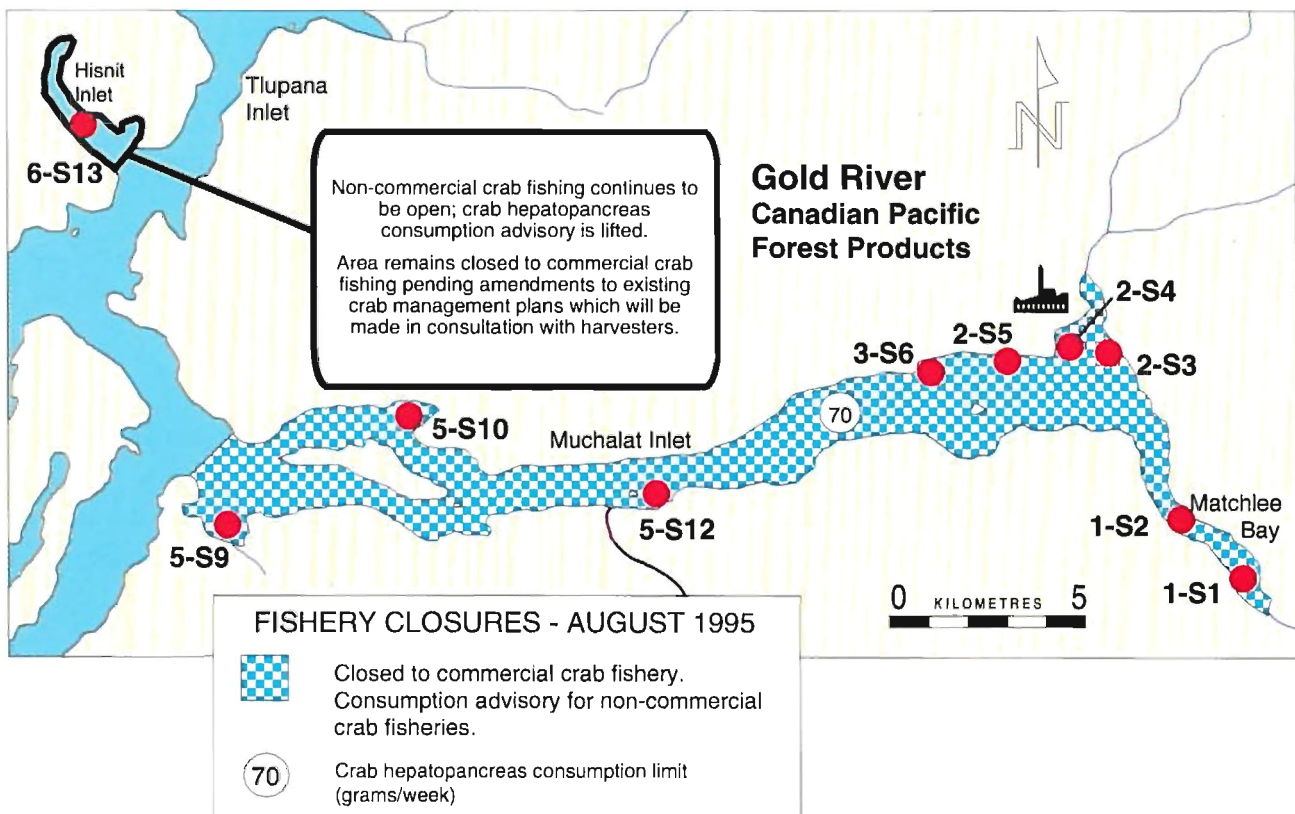
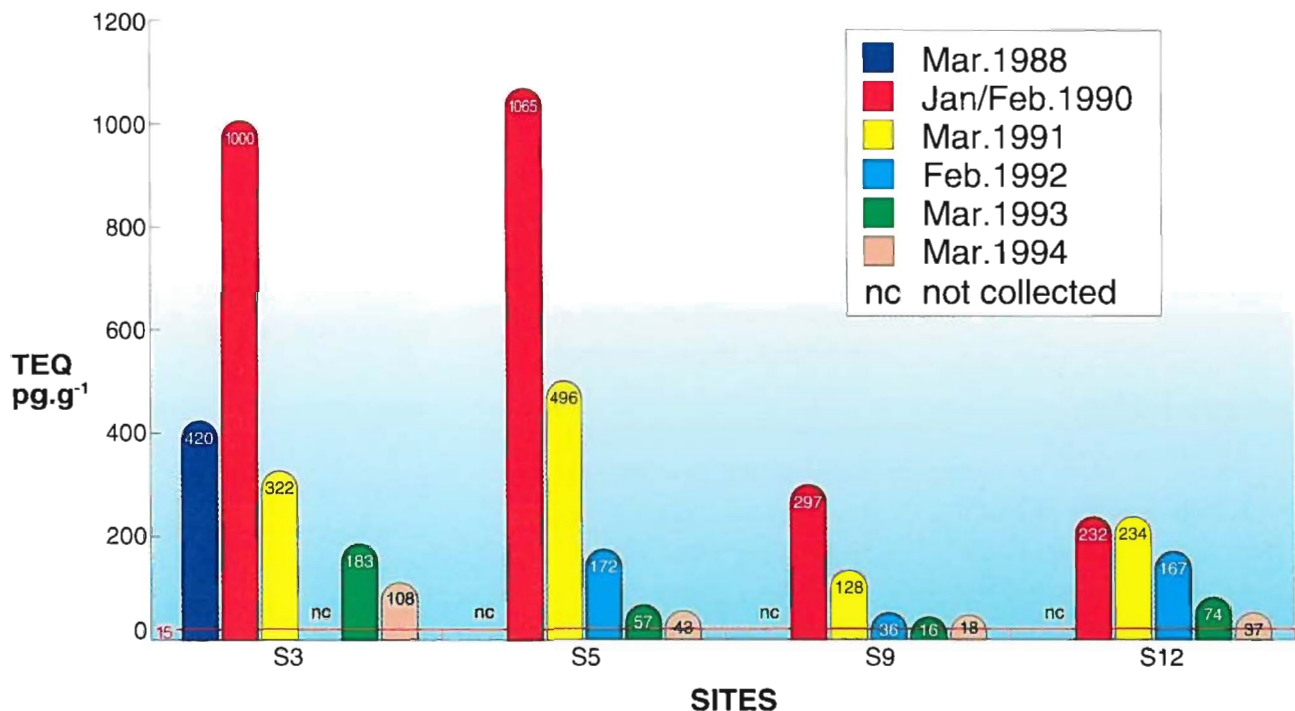


Figure 18.

Dioxin and furan TEQs in Dungeness crab hepatopancreas samples collected in the vicinity of Gold River, from 1988 to 1994.



Port Alberni, Alberni Inlet

The focal point of this part of the Program was Alberni Inlet, a long, coastal fjord on the west coast of Vancouver Island. Up to 1993, MacMillan Bloedel Ltd. operated a semi-bleached pulp mill at Port Alberni. The facility now operates as Alberni Specialities Ltd. producing pulp from both groundwood and chemical-thermal-mechanical pulp mills, using some hydrogen peroxide bleaching.

From 1988 to 1994, DFO analysed fish and shellfish samples from the vicinity of the plant site. Dioxin con-

centrations in samples of bottom feeding fish and Dungeness crab hepatopancreas were the lowest of any taken in the vicinity of B.C. coastal mills.

In view of these findings, the Government did not find it necessary to close fisheries or to issue consumption advisories.

Other Coastal Sampling

At the start of Canada's National Dioxin Sampling Program, scientists collected and analysed fish and shellfish samples at sites along the B.C. coast, far removed from known dioxin and furan sources.

This work was done for two purposes. One was to determine whether atmospheric deposition of these pollutants was a contributing factor to the concentrations found near the mills. The other

was to check on the environmental health of prime shellfish growing sections of the Pacific coast, notably oyster farming areas. The data from these studies show that atmospheric transport is not a significant factor in the dioxin and furan concentrations detected in the sampling program. Some oyster samples yielded elevated dioxin concentrations.

Ocean Falls, Central Coast

Ocean Falls was the site of a Crown Zellerbach pulp mill that closed in the mid-1970s. In 1989, as part of the broad sampling program, DFO collected and analysed samples of Dungeness crabs close to the abandoned site. Dioxin and furan concentrations were below the analytical detection limits in crab muscle tissue, however very low concentrations were detected in hepatopancreas samples. DFO conducted no further sampling at this site.

British Columbia Harbours

As part of Canada's National Dioxin Sampling Program, DFO sampled Dungeness crabs from a group of British Columbia harbours. These included sites at major cities such as Vancouver and Victoria, as well as smaller harbours.

Burrard Inlet

Environment Canada sampling detected dioxins and furans in sediments. The general pattern of contamination suggested that the primary source was past use of chlorophenol wood preservatives.

DFO sampled Dungeness crabs in Burrard Inlet and Vancouver Harbour. Analysis revealed low dioxin and furan concentrations in muscle tissue, however, intermediate to high concentrations were found in the crab hepatopancreas. In 1993, the Government banned all crab harvesting in the area of Vancouver Harbour between Lions Gate Bridge and the Second Narrows Bridge.

August 1995: Although the dioxin-mediated closure was lifted, the area was and will remain closed to harvesting due to navigational hazards. Sampling in 1992 and 1994 showed declining dioxin and furan concentrations in crab samples. Low concentrations were found in samples of clams, crab muscle, shrimp and the muscle tissue of English sole.

Victoria Harbour

DFO sampled Dungeness crabs from Victoria Harbour in 1991 and 1992. Muscle tissues contained very low dioxin and furan concentrations, while

hepatopancreas samples showed elevated concentrations.

In the most recent sampling of Victoria Harbour Dungeness crabs in 1994, DFO analysed only hepatopancreas tissues. Concentrations were high in samples from two harbour locations.

In view of these findings, the Government took the following action :

May 1992: Part of the harbour was closed to commercial crab harvesting, accompanied by an advisory to recreational and aboriginal users on consumption of crab hepatopancreas tissue.

August 1993: Although dioxin and furan concentrations had declined since the previous year, the closure was maintained, pending evaluation of further data. The consumption advisory was revised, allowing for higher consumption portions of crab hepatopancreas.

February 1995: The dioxin and furan concentrations remained elevated, hence the crab harvesting closure and consumption advisory remained in effect.

The Prairie Region

A list of the pulp and paper mills in the Prairie Region included in Canada's National Dioxin Sampling Program is presented in Table 3. A map of the Prairie Region, indicating the location of the pulp and paper mills included in the study is shown in Figure 19.

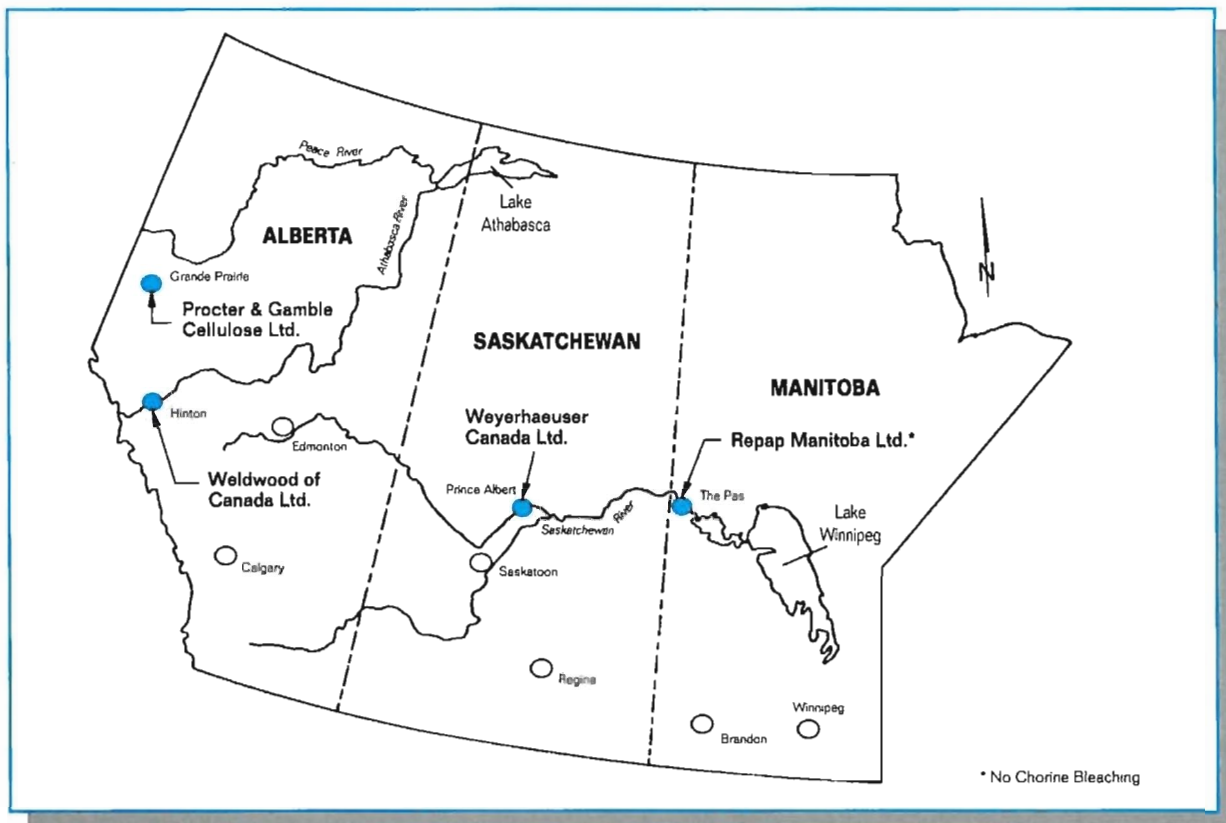
Table 3.

A list of the pulp and paper mills in the Prairie Region included in Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Grande Prairie, Alberta	Procter & Gamble Cellulose Ltd.	Wapiti River
Hinton, Alberta	Weldwood of Canada Ltd.	Athabasca River
Prince Albert, Saskatchewan	Weyerhaeuser Canada Ltd.	North Saskatchewan River
The Pas, Manitoba	Repap Manitoba Inc.	Saskatchewan River

Figure 19.

A map of the Prairie Region, indicating the location of the pulp and paper mills included in the study.



Alberta

In Alberta, samples were taken in the vicinity of the two bleached pulp and paper mills that currently operate in the province.

Wapiti River

Proctor & Gamble Cellulose Ltd. operates a bleached kraft mill at Grande Prairie that releases its effluent, after primary and secondary treatment, into the Wapiti River. On the basis of preliminary sampling in 1987 and 1989, the Government issued a consumption advisory on mountain whitefish caught within 10 km of the mill. Other fish were considered safe to eat.

Athabasca River

Fish samples were collected and analysed from the Athabasca River close to Hinton in southwest Alberta where Weldwood of Canada Ltd. operates a bleached kraft pulp mill. Sampling in 1987 and 1989 showed high concentrations of furans and low concentrations of dioxins. As a result, the Government issued consumption advisories for non-commercial harvesting of whitefish, burbot and bulltrout. There are no

commercial fisheries in the area.

In Alberta, the Program also directed its attention to the then proposed sites of pulp and paper mills. The issue of prime importance was whether contaminants from these mills might reach the food chain in the Slave River system, impacting the fish resources on which the aboriginal peoples of the Northwest Territories depend.

In this phase of the Program, DFO analysed samples near a mill that Daishowa Canada Ltd. later built on the Peace River. Further sampling of walleye, northern pike, lake whitefish,

burbot, longnose sucker from the Slave River was conducted hundreds of miles from the sites of other proposed new mill sites. Dioxins and furans were not detected in fish samples. Low concentrations of furans were detected in burbot livers, a popular delicacy in the aboriginal community. A consumption advisory was issued for burbot liver. The results of additional sampling and analysis concerning dioxin and furan concentrations, conducted under the auspices of the Northern River Basin Study and the Department of Indian and Northern Development Slave River Environmental Quality Monitoring Program, are contained in those reports (see Further Reading Section, L. McCarthy et al. 1996).

Saskatchewan

In 1987 and 1988 DFO analysed fish samples from the North Saskatchewan River near Prince Albert where Weyerhaeuser Canada Ltd. operates a bleached pulp mill. Samples of fish taken downstream from the Prince Albert mill contained extremely

low dioxin and furan concentrations.

On the basis of these findings, the Government issued no consumption advisories for fish from this area.

Manitoba

No pulp and paper mills in Manitoba use chlorine as a bleaching agent. DFO analysed only four composite samples in the province, these were taken as reference samples at the site

of a Repap mill that produces unbleached pulp. None of the samples contained detectable concentrations of dioxins or furans.

Ontario Region

Under Canada's National Dioxin Sampling Program, all nine of the pulp and paper mills in Ontario that have used chlorine as a bleaching agent were studied. The provincial government did most of the sampling in Ontario. The samples collected represent a variety of species that support the commercial, recreational and aboriginal fisheries. The species mix included lake trout, northern pike, longnose sucker, walleye, carp, sturgeon, lake whitefish and yellow perch.

A list of the pulp and paper mills in the Ontario Region included in Canada's National Dioxin Sampling Program is presented in Table 4. A map of the Ontario Region, indicating the location of the pulp and paper mills included in the study is shown in Figure 20.

Following is a summary of sampling and results by watershed and mill site.

Wabigoon River

Dryden

The product line of the Avenor Inc. mill at Dryden, northwestern Ontario, includes

Table 4.

A list of the pulp and paper mills in the Ontario Region included in Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Dryden	Avenor Inc.	Wabigoon River
Fort Frances	Rainy River Forest Products Inc.	Rainy River, Lake of the Woods
Marathon	James River Marathon Ltd.	Peninsula Harbour, Lake Superior
Red Rock	Domtar Packaging Inc.	Nipigon Bay, Lake Superior
Terrace Bay	Kimberly Clark Forest Products of Canada Ltd.	Blackbird Creek, Lake Superior
Thunder Bay	Avenor Inc.	Kaministiquia River, Lake Superior
Smooth Rock Falls	Malette Kraft Pulp & Power	Mattagami River
Espanola	E. B. Eddy Forest Products Ltd.	Spanish River, Lake Huron
Cornwall	Domtar Fine Papers Inc.	Lake St. Francis, St. Lawrence River

bleached kraft pulp. The plant has significantly reduced dioxins and furans in its effluent which is discharged into the Wabigoon River.

Program sampling found low concentrations of dioxins and furans in lake whitefish and northern pike. The highest concentrations of furans were in whitefish.

The government issued no fish consumption advisories related to the Dryden mill.

Rainy River

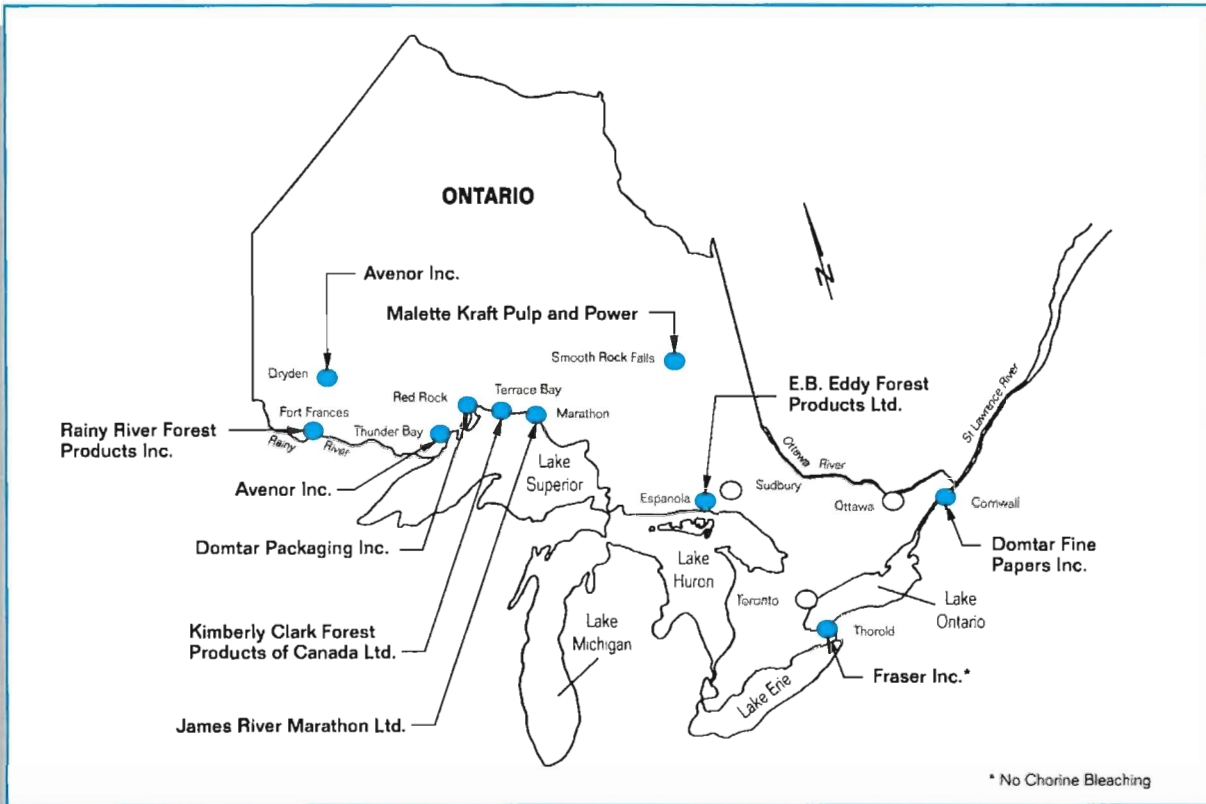
Fort Frances

Rainy River Forest Products Ltd. manufactures bleached kraft pulp and other products at its Fort Frances mill on the Rainy River. Samples of walleye, white sucker, sturgeon and northern pike were collected from the river.

Only one sample, a sturgeon fillet from Manitou Rapids, collected 50 km downstream from the mill, contained

Figure 20.

A map of the Ontario Region, indicating the location of the pulp and paper mills included in the study.



detectable dioxin concentrations. No consumption advisories for this area were issued.

Lake Superior — North Shore

Marathon

James River Marathon Ltd. operates a mill at Marathon, Peninsula Harbour, on the north shore of Lake Superior. The mill's output includes bleached hardwood and softwood pulp.

During the Program, samples of lake trout and longnose sucker samples were collected near this site and analysed in fillet form. Analysis revealed elevated furan concentrations in lake trout samples. Health Canada determined these concentrations did not pose a health hazard.

Terrace Bay

At its Terrace Bay mill, Kimberly Clark Forest Products of Canada Ltd. produces bleached kraft pulp. The mill releases its effluents into Jackfish Bay on

Lake Superior by way of Blackbird Creek.

The earliest Terrace Bay fish samples in the Program data base were collected in 1986 and showed medium concentrations dioxins and furans. During the Program, additional fillet samples of lake trout, longnose sucker and whitesucker were collected from a point about 15 km downstream of the mill and analysed. The analytical data indicated some decline in dioxin and furan concentrations

between 1986 and 1989. This may reflect improvements in the mill's effluent treatment systems during that period. Health Canada issued no consumption advisories.

Red Rock

The Domtar Packaging Inc. mill at Red Rock, on Nipigon Bay, manufactures bleached and unbleached pulp as well as newsprint.

During the Program, samples of lake trout, whitefish and white sucker were collected from waters close to the mill and analysis revealed low concentrations of furan. Additional samples were collected from a reference point (Rosspoint) midway between Red Rock and the site of another mill at Terrace Bay. These showed low furan concentration. No consumption advisories were issued for fish from these waters.

Thunder Bay

The Avenor Inc. mill on the Kaministiquia River at Thunder Bay produces bleached kraft pulp and newsprint, and has significantly reduced dioxins and furans from its effluent.

Lake trout and white sucker fillet samples were collected for the Program. Concentrations were low and Health Canada issued no consumption advisories.

Mattagami River

Smooth Rock Falls

Walleye and white sucker fillets were analysed from this site where Malette Kraft Pulp & Power operates a bleached kraft mill. The highest dioxin and furan concentrations were in white sucker samples. Walleye samples contained both dioxin and furan but at much lower concentrations. In 1992, a consumption advisory was issued for white sucker fillets from this area.

Spanish River

Espanola

From 1986 to 1992, DFO collected and analysed white sucker and walleye samples on the Spanish River. Sampling focused on the site of an E.B. Eddy Forest Products Ltd. mill that produces bleached and unbleached kraft pulp and speciality papers.

In the 1990 sampling, whole fish samples of walleye taken 28 km downstream of the mill were highly contaminated. Reference samples were collected from Agnew Lake and upstream points on the river; samples from these two sites had dioxin and furan concentrations below the limit of detection and very low concentrations respectively.

In 1992, Health Canada issued a consumption advisory recommending upper limits for consumption of Spanish River walleye. The provincial government issued no further advisories for walleye fillets. Since there is no commercial walleye fishery on the river, there were no closures.

Upper Saint Lawrence River

Cornwall

In 1987 DFO collected fish samples near the Domtar pulp and paper mill at Cornwall. This plant manufactures bleached pulp, fine papers, speciality pulps and coated board and releases its wastewaters after primary treatment to Lake St. Francis on the St. Lawrence River. All but one sample from this site yielded low or undetectable concentrations of dioxins and furans. The exception, a muscle tissue sample of carp, contained moderate concentrations of furans and low concentration of dioxins.

The provincial government has an ongoing sport fish contaminant monitoring program and publishes consumption advisory tables annually based on information from Health Canada (see Further Reading Section, Guide to Eating Ontario Sport Fish).

Laurentian (Quebec) Region

During the Program DFO collected and analysed fish and crab samples from sites adjacent to ten Quebec pulp and paper mills. The samples represented 15 different species of fish and one crustacean and included some sea-going species from the Saguenay River, taken downstream of the mill at Jonquière.

A list of the pulp and paper mills in Quebec included in the Canada's National Dioxin Sampling Program is presented in Table 5. A map of the Laurentian (Quebec) Region, indicating the location of the pulp and paper mills included in the study is shown in Figure 21.

Table 5.

A list of the pulp and paper mills in the Laurentian (Quebec) Region included in the Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Lebel-sur-Quévillon	Domtar Inc.	Quévillon River
Temiscaming	Tembec Inc.	Ottawa River
Thurso	Industries James MacLaren Inc.	Ottawa River
Portage-du-Fort	Les Emballages Stones Inc.	Ottawa River
La Tuque	Carton St-Laurent Inc.	St. Maurice River
Trois Rivières	Corporation Stone Consolidated Inc.	St. Maurice River
Windsor	Les papiers de communication Domtar	St. Francois River
St-Félicien	Donohue St-Félicien Inc.	Mistassini River
Jonquière	Cascades Jonquière Inc.	Saguenay River
Bale Comeau	Quebec & Ontario Paper Co.	Gulf of St. Lawrence

Quévillon River

Lebel-sur-Quévillon

At this site, a Domtar Inc. mill produces semi-bleached and unbleached pulp. The mill discharges its wastewaters to the Quévillon River, which flows into the Bell River about 5 km downstream. Low concentrations of dioxins and furans were found in white sucker and sturgeon samples. Apart from this, there were no detectable concentrations of

dioxins and furans. The Government issued no consumption advisories.

Ottawa River

Temiscaming

Tembec Inc. operates a bleached sulphite mill on the Ottawa River near Temiscaming. Program sampling at this site

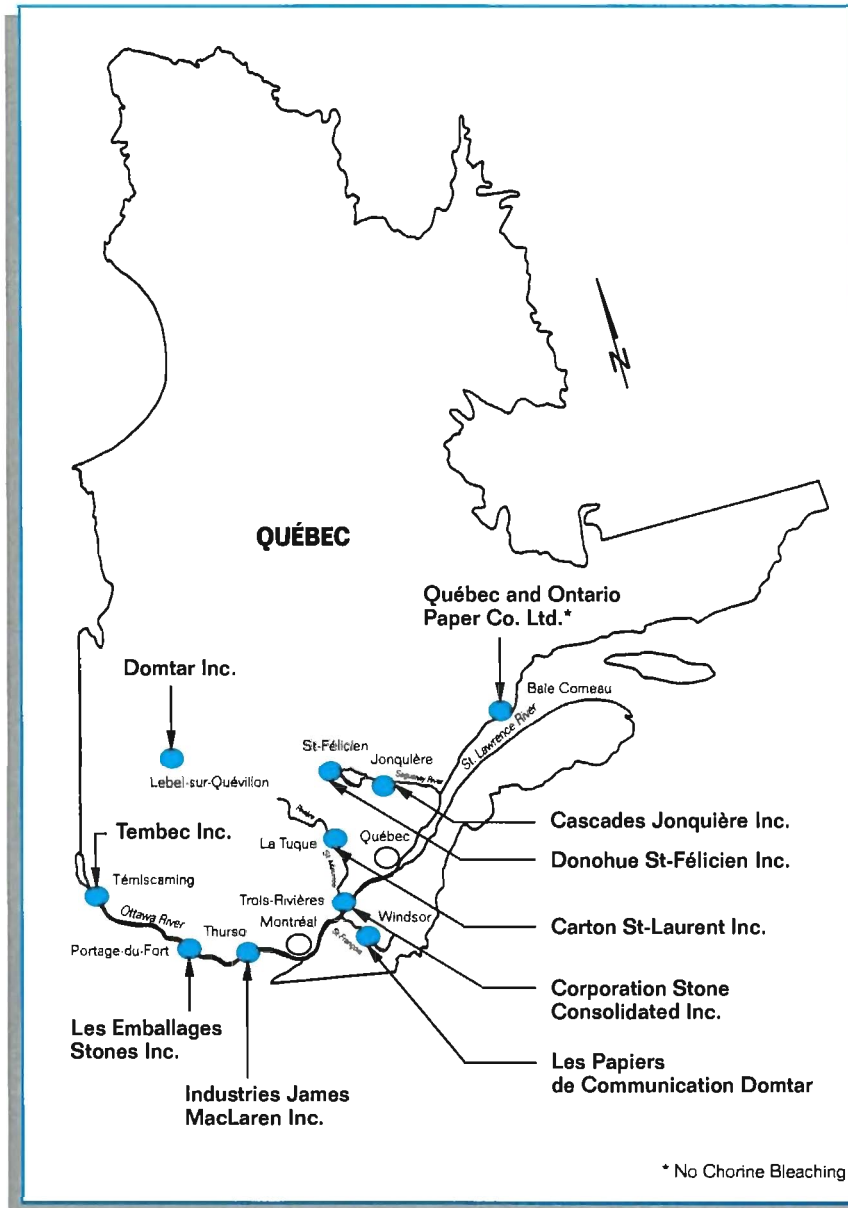
revealed only one whitefish sample with detectable dioxins.

Portage-du-Fort

Samples were collected close to a pulp mill also in at Portage-du-Fort operated by Les Emballages Stones Inc. at Portage-du-Fort. The only detectable dioxins and furans were at low concentrations traces in white sucker samples.

Figure 21.

A map of the Laurentian Region, indicating the location of the pulp and paper mills included in the study.



No consumption advisories were issued for this site.

Thurso

DFO also sampled fish at Thurso on the Ottawa River, where Industries James MacLaren Inc. operates a

bleached kraft pulp mill. Concentrations of dioxins were low except for a whole fish white sucker sample. One northern pike sample had elevated concentrations of furans. The Government issued no consumption advisories for fish from this site.

St. Maurice River

La Tuque

The Carton St-Laurent Inc. mill at La Tuque has been one of the most thoroughly studied plants in Canada. Well before Canada's National Dioxin Sampling

Program, DFO and Environment Canada scientists had investigated the mill's influence on fish in the Saint Maurice River. In fact, these studies provided part of the information base on which the federal government developed environmental effects regulations for Canadian pulp and paper mills.

In 1989, DFO collected and analysed a variety of samples at points downstream of the mill. Since there was no commercial fishery, there were no closures. However, Health Canada issued advisories for restricted consumption of fillets of brown bullhead, walleye, northern pike and smallmouth bass. These advisories are still in effect in 1998. Further sampling is planned for this area.

Trois-Rivières

DFO sampled white sucker, walleye and brown bullhead in the vicinity of the Corporation Stone Consolidate mill at Trois-Rivières on the St. Maurice River. Analysis revealed no detectable concentrations of dioxins and only very low concentrations of furans. The Government issued no consumption advisories.

St. Francois River

Windsor

In 1988 and 1989, the Domtar Inc. mill was under reconstruction. During this time, DFO collected and analysed only three samples at the site. These yielded evidence of low dioxin concentrations in white sucker fillets and elevated furan concentrations in whole fish samples. The Government issued no consumption advisories.

Mistassini River

The Donohue-St Félicien Inc. bleached pulp mill is located on the Chamouchouane River and pumps its wastewaters through a 14-km pipeline to the Mistassini River. DFO sampling under the Program was concentrated just downstream from the mouth of the pipe. Samples showed measurable amounts of dioxin, with the highest concentrations in walleye and brown bullhead.

In 1990, Health Canada issued an advisory to aboriginal and recreational fishermen on consumption of walleye from these waters. Further sampling is planned for this area.

Saguenay River

Jonquière

Cascades Jonquière Inc., located on the Saguenay River, operates a mill that produces bleached kraft pulp and other products. Detectable concentrations of dioxins and slightly higher concentrations of furans were measured in fish samples collected and analysed by DFO. Turbot and crabs taken from a bay as reference samples displayed the same pattern of dioxin and furan concentrations. No consumption advisories were issued for fish taken in these waters.

Gulf of St. Lawrence

Baie Comeau

DFO chose Quebec & Ontario Paper Co. newsprint mill at Baie Comeau as a reference site because it has never used chlorine. Samples of cod, flounder and crab taken close to the mill showed very low concentrations of dioxins and furans. Samples were also taken on the St. Lawrence River, upstream and downstream of Trois Rivières.

The Atlantic Region

DFO conducted sampling and analysis in New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland, looking at both freshwater and marine sites. Assessing the data, Health Canada concluded that the concentrations of dioxins and furans in samples of species that people eat did not pose a health hazard. A list of the pulp and paper mills in the Atlantic Region included in Canada's National Dioxin Sampling Program is presented in Table 6. A map of the Atlantic Region indicating the location of the pulp and paper mills included in the study is shown in Figure 22.

Table 6.
A list of the pulp and paper mills in the Atlantic Region included in Canada's National Dioxin Sampling Program.

SITE	COMPANY	RECEIVING WATERS
Edmunston, N.B.	Fraser Inc.	Madawaska River
Nackawic, N.B.	St. Anne-Nackawic Pulp Co.	St. John River
St. John, N.B.	Irving Pulp & Paper Ltd.	St. John Harbour
Dalhousie, N.B.	Avenor Maritimes Inc.	Restigouche River
Newcastle, N.B.	Repap New Brunswick Inc.	Miramichi River
Port Hawkesbury, N.S.	Stora Forest Industries Ltd.	Strait of Canso
New Glasgow, N.S.	Scott Maritimes Ltd.	Pictou Harbour

New Brunswick

Five pulp and paper mills that have used chlorine are located in New Brunswick. Sampling in the province covered the following five areas and no consumption advisories or fishery closures were required at any of these sites.

Madawaska River

DFO collected samples just downstream of the Fraser Inc. mill at Edmunston which produces bleached and

unbleached sulphite pulp. These fish did not contain detectable concentrations of dioxins and concentrations of furans were barely measurable.

St. John River

The St. Anne-Nackawic Pulp Co. operates a bleached kraft mill at Nackawic on the St. John River. Sampling at this site produced evidence of low dioxin concentration in white sucker.

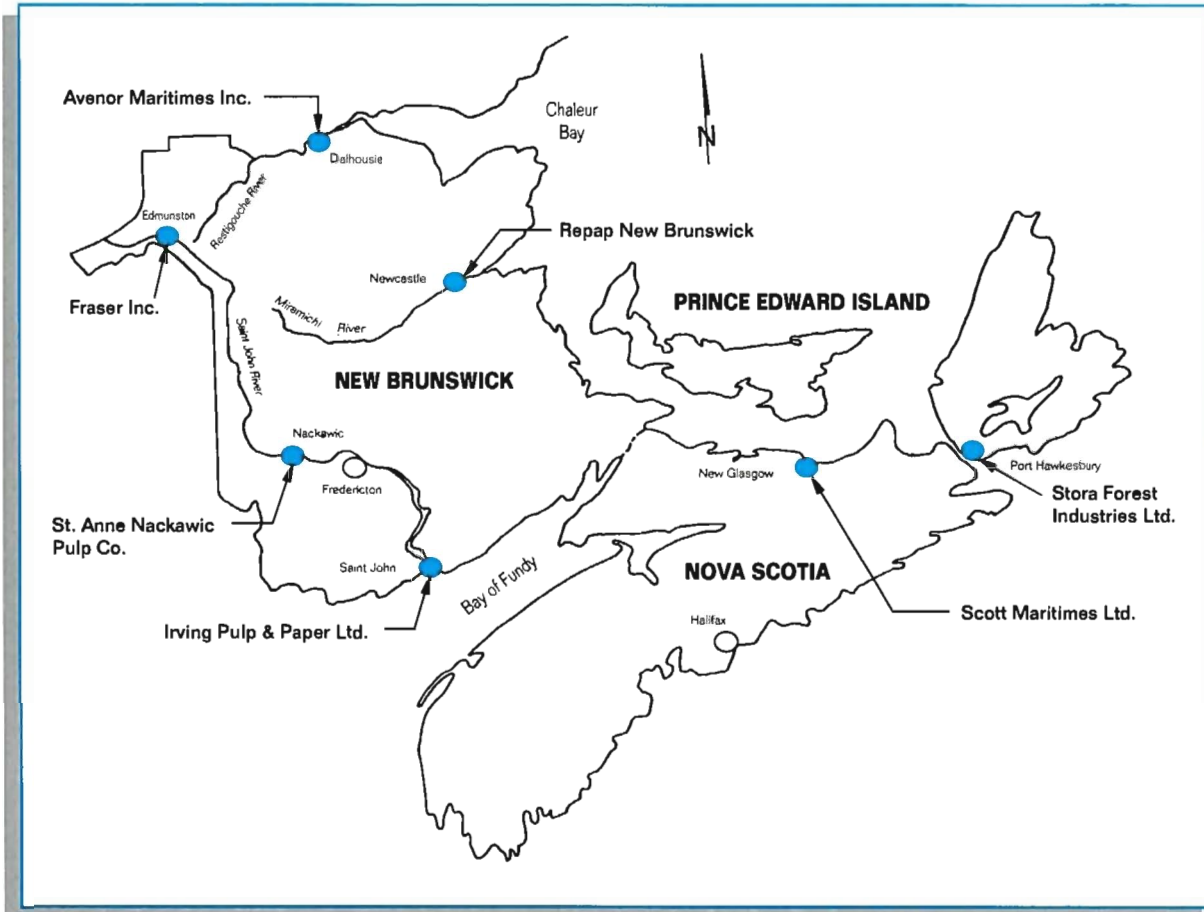
St. John Harbour

DFO collected and analysed rock crab and lobster samples in the harbour below the outfall of the Irving Pulp and Paper Company, a bleached kraft operation.

The dioxin concentrations were below analytical detection limits and the furan concentrations were extremely low in these samples.

Figure 22.

A map of the Atlantic Region, indicating the location of the pulp and paper mills included in the study.



Restigouche River

Sampling downstream of the Avenor Maritimes mill at Dalhousie showed low concentrations of dioxins and higher concentrations of furans.

Miramichi River

Repap New Brunswick operates a bleached kraft mill at Newcastle and DFO collected

more samples here for the Program than at any other site in the Atlantic provinces. Analysis showed only low

dioxin and furan concentrations in white sucker fillets and lobster tissue samples.

Nova Scotia

Two bleached pulp mills operate in Nova Scotia; the STORA Forest Industries mill at Port Hawkesbury on the Strait of Canso and the Scott Maritimes Ltd. operation at

Pictou on Northumberland Strait. Dioxin concentrations were low or undetectable except for three lobster hepatopancreas samples from Pictou Harbour and one from

the Port Hawkesbury site. Furans were measured in lobster and crab hepatopancreas samples. On

the basis of these findings, the Government concluded that no consumption advisories or fishery closures were needed.

Prince Edward Island

The only Program sample collected in Prince Edward Island was of lobster paste prepared from lobsters harvested in the Gulf of St.

Lawrence. This yielded only low concentrations of furans and no consumption advisory was issued.

Newfoundland

There are no operating pulp and paper mills using the chlorine bleaching process in Newfoundland, but DFO collected and analysed samples for the Program at Clarendville, close to Newfoundland Hardwoods Ltd., which used chlorophenols as a wood preservative. Lobster hepatopancreas and Atlantic cod livers showed low concentrations of furans but

dioxin concentrations were low to undetectable in most samples. Two offshore cod liver samples were analysed. Samples of lobster hepatopancreas collected in various Newfoundland bays contained relatively low concentrations of dioxins and furans. The Government has issued no consumption advisories.

Conclusion

This document summarises the scope, methodology and results of a major Canadian environmental study, Canada's National Dioxin Sampling Program, in the first five years of its operation: 1989 to 1994. Although sampling has continued after 1994, primarily on the west coast, the majority of data collection occurred during the first five years of the program. The primary goal was to determine whether dioxin and furan concentrations were present in aquatic biota in the vicinity of pulp and paper mills that historically used chlorine to bleach their products, and whether the concentrations found posed a threat to human health. During the course of the first five years, dramatic reductions of dioxin and furan concentrations in the aquatic biota have occurred. Although the subject report does not contain detailed information on the findings in later sampling initiatives, some qualitative observations based on more recent analytical results and human health assessments, have been included in some instances. Studies of dioxin and furan concentrations in fish and shellfish during this time suggest the following trends across Canada.

British Columbia

The Program focused on this region because of the relatively large number of pulp and paper mills utilising the chlorine bleaching process located in coastal areas. Studies early in the Program revealed elevated dioxin and furan concentrations in the muscle and hepatopancreas of Dungeness crabs and in tissues of other species, notably oyster, prawn and shrimp. These findings triggered closures of commercial fisheries and the issuing of consumption advisories to non-commercial harvesters.

Continued sampling and analysis during the Program has shown a marked, though uneven decline, in the concentrations of dioxins and furans for various species and locations

In coastal waters, TEQ values fell to concentrations that permitted the repealing of all oyster, prawn and shrimp closures. The decline of dioxin and furan concentrations in Dungeness crab has been less uniform and the ban on commercial harvesting of this species in some areas has

remained in force as of 1998. Some areas in which dioxin and furan concentrations had declined remained closed because overlapping closures due to other reasons such as sewage contamination (i.e. oysters) and interference with major navigational routes (i.e. Burrard Inlet). No fin fish from the marine environment showed high dioxins and furan concentrations in muscle tissue.

In B.C. inland waters, early work in the Program showed some dioxin and furan concentrations in whitefish and other freshwater species. There are no reports on the concentrations of dioxins and furans in bottom dwelling shellfish such as crayfish and mussels in the freshwater areas where effluent concentrations of dioxins and furans are high. The Government issued consumption advisories for various species from specific sites on the Thompson and Fraser River systems including mountain whitefish, northern squawfish, peamouth chub, Dolly Varden and white sturgeon. In these cases too, analysis over the course of the Program showed a marked decline in dioxin and furan concentrations between 1989

and 1994. Additional sampling, not included in this report, conducted under the direction of British Columbia Ministry of Environment, Lands and Parks has since resulted in most of the consumption advisories being lifted due to drastically reduced dioxin and furan concentrations.

This pattern of declining dioxin and furan concentrations is believed to be related to actions taken by Canada's forest products industry in compliance with regulations aimed at reducing the discharge of dioxins and furans to surrounding waters. These measures include, the replacement of chlorine as a

bleaching agent, the elimination of contaminated wood chips and defoamers from manufacturing processes, and the installation of improved effluent treatment systems.

Canada, East of British Columbia

In other regions of Canada, Program findings triggered no closures because there were no commercial fisheries in the areas involved. However there were active aboriginal and recreational fisheries in some areas of Alberta, Ontario and Quebec and the appropriate government agencies issued consumption advisories in these cases.

Canada's National Dioxin Sampling Program is still in progress, and sampling and analysis of fish and shellfish continues, although with a change in emphasis. With dioxin and furan concentrations on the decline, attention is shifting from human health risks to environmental issues associated with pockets of residual dioxin and furan concentrations. Issues on which scientists will be focusing include the effect of dioxin and furan concentrations on the collective health of fish populations and on the relationship between the rate of decline in dioxin and furan concentrations under different tidal and current conditions.

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