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MARINE MERCURY POLLUTION IN CANADA

by

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SUMMARY

Mercury contamination of fish in Canada was discovered late in 1969, and in freshwater fish was found to be related in many places to pollution from chlorine-alkali plants. Legislation was introduced to prevent the sale or export of fish containing more than 0.5 ppm (wet weight) of mercury, and an inspection scheme was established. High mercury contents have been found in some marine fish, *viz.* swordfish, tuna, large Atlantic halibut and Pacific dogfish. The swordfish industry has been closed, and a projected Pacific dogfish industry was abandoned. Seals and fish eating whales also have high mercury content, particularly in the livers.

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The ability of fish and shellfish to accumulate toxic metals is well known. It is not uncommon to find oysters coloured green by copper and there is a report that oysters near a smelter in British Columbia contained as much as 20,000 ppm copper and 36,000 ppm zinc. In the 1920's oysters in Britain were found to contain arsenic in quantities above the legal limit. Arsenic has also been found in shrimp. North Sea fish were found to contain a fraction of a part per million of mercury, in 1934, by Stock and Cucuel.

Mercury pollution of water systems was found in Sweden in the 1960's, and in Canada Fimreite in 1968 had presented evidence of a foreseeable problem with mercury.

This problem became urgent after the announcement on 27 November 1969, by Wobeser and his colleagues at the University of Saskatchewan, that fish from the South Saskatchewan River contained up to 10 ppm mercury (see Table 1). This river is part of a large system with several lakes (including Lake Winnipeg) supporting important commercial fisheries. For the protection of the public the (Federal) Department of Fisheries immediately detained all stocks of fish believed to come from this river system, and an inspection scheme was set up. At first, until June 1970, this was at the Freshwater Institute in Winnipeg. Analytical methods were developed there and a programme of research initiated.

The Food and Drug Directorate of the (Federal) Department of National Health and Welfare set a limit of 0.5 ppm (mg Hg/Kg) which is enforced under a section of the Food and Drug Act and regulations. This limit is also in use in the United States. It is subject to revision and is considered to have a safety factor of 10-100 against the development of signs of neurological disease. It is one half of the limit in use in Sweden and in Germany. Fish consumption in Canada is estimated to be about 18 g per capita per day, which is considerably less than in many European countries. The 0.5 ppm limit is applied to fish exported from Canada.

Fish above the limit have been destroyed by burning, to ensure that they could not be eaten by humans, domestic animals or wildlife. In the first 3-4 months of operation of the inspection scheme more than 500,000 Kg of fish had to be destroyed. Later, smaller amounts needed to be condemned, since contaminated lakes were closed to fishing.

Contaminated lakes were discovered in a national survey which was started in cooperation with various Federal and Provincial Government departments (Figs. 1 & 2). In the light of the Swedish experience chlorine-alkali plants were suspect. So also were pulp mills which at one time used organic mercury compounds for control of slime organisms, though this use had been almost discontinued for some years. In fact, most of the mercury contamination of fish in Canadian inland waters can be related to all but one of the 14 chlorine-alkali plants in the country. These plants are stated to have consumed some 100,000 Kg of mercury in 1969, out of the total Canadian consumption of about 140,000 Kg. Discharges from these plants are now strictly regulated.

Where contamination has been found, commercial fisheries are closed, and there are schemes of compensation to the fishermen affected. In Lake Winnipeg whitefish have low mercury content, though other species of fish are unsafe. The important fishery for whitefish is therefore permitted. Before leaving this mention of mercury pollution in freshwater systems, it may be mentioned that there are lakes with no pollution in which fish are found with mercury above the 0.5 ppm level. In some cases there is evidence of mercury in deposits of metallic ores in the neighbourhood.

Quite early in our investigations attention was directed to Howe Sound in British Columbia, where a chlorine-alkali plant had been discharging wastes into an arm of the sea for some years. Mercury was found in bottom living animals close to the plant, but not in inshore waters a few miles along the coast. Part of this area has been closed to fishing for shellfish and groundfish (see Table 2).

Elevated mercury levels have also been found in shellfish near outlets of a chlorine-alkali plant on the Atlantic Coast at Dalhousie, New Brunswick, but there is no commercial fishery here and no closure is necessary.

A third chemical plant discharging to the sea in Nova Scotia came into operation in 1970, with mercury discharges controlled at low level.

However, analysis of organisms from the open sea shows that many species of fish, and marine mammals contain significant amounts of mercury. It is difficult to believe that this is due to pollution of the ocean. In fact it is estimated that discharges of mercury from industrial use and from the combustion of coal would take some centuries to double the present level of mercury in the ocean. This level is far from negligible though it is not known with great certainty, being probably between 0.01 and 0.03 microgram per litre. Somewhat higher levels in a polluted lake which has been studied at Winnipeg by Dr. A.L. Hamilton have given direct evidence of accumulation and increase of mercury concentration in organisms as the length of the food chain increases.

In the sea it is in fact found that, just as in fresh water, mercury concentrations are highest in the larger and most predaceous fish, as is shown in Tables 2,3,4,5, and 6. It is seen in fact that there are unacceptable levels, ie. above the Canadian limit of 0.5 ppm, in the larger Atlantic halibut, in swordfish, in some tuna and in Pacific dogfish. These findings have resulted in the closure of the swordfish industry worth $4 million in 1969, and involving about 70 boats. Considerable quantities of already processed tuna have had to be destroyed, and an industry for Pacific dogfish which had been planned has had to be abandoned.

It is not surprising that seals and whales should also be found to contain high levels of mercury, as is shown in Tables 7, 8 and 9.

There are some remarkably high values in livers of grey seals, and indeed there was one animal in this series at 387 ppm. This animal's age was estimated at 25 years. There seems to be a clear relationship between mercury in liver of seals and age as shown by Figure 3. It has been pointed out by our colleague in the Fisheries Research Board, Dr. D.E. Sergeant, that differences between mercury contents in the different species of seals can be explained by diet. Grey seals with high mercury content eat benthic fish and cephalopods, whilst harp seals eat a variety of pelagic fish and pelagic crustacea and are thus eating at one stage lower in the food chain.

This relationship between mercury contamination and position in the food chain is receiving attention in our laboratories. Levels in a freshwater system are shown in Table 10. This is part of a larger study at Winnipeg by Dr. A.L. Hamilton.

READING LIST

BLIGH, E.G. 1970. Mercury in Canadian Fish. Manuscript Report Series No. 1088, Fisheries Research Board of Canada.

BLIGH, E.G. 1971. Environmental Factors Affecting the Utilization of Great Lakes Fish as Human Food. Limnos 4: 13-18.

BLIGH, E.G. 1971. Mercury Levels in Canadian Fish. Proceedings, Special Symposium on Mercury in Man's Environment, 15 and 16 February 1971 Ottawa, Canada. Royal Society of Canada, Ottawa Ontario, Canada.

FIMREITE, N. 1970. Mercury Uses in Canada and their Possible Hazards as Sources of Mercury Contamination. Environmental Pollution 1: 119-131.

UTHE, J.F., F.A.J. ARMSTRONG AND M.P. STAINTON. 1970. Mercury Determination in Fish Samples by Wet Digestion and Flameless Atomic Absorption Spectrophotometry. J. Fish. Res. Bd. Canada 27: 805-811.

WOBESER, G., N.O. NIELSON, R.H. DUNLOP AND F.M. ATTON. 1970. Mercury Concentrations in Tissues of Fish from the Saskatchewan River. J. Fish. Res. Bd. Canada 27: 830-834.

TABLE 1

Mercury Content of N. Pike from the Saskatchewan R. System

Location	No. of Samples	Ave. ppm Hg.
Downstream of Edmonton	3	1.34
Downstream of Prince Albert	3	1.07
Upstream of Saskatoon	10	0.46
Downstream of Saskatoon	17	5.96
Cedar Lake	44	0.67
Cedar Lake	(Meal)	1.98
Moose Lake*	4	0.19
Lake Winnipeg	75	0.52
Lake Winnipegosis*	10	0.16

* Control

TABLE 2

Mercury in B.C. Fish

Species	Location	Ave. ppm Hg.
Crabs	Squamish	1.55-(13.4)
"	Fraser River Flats	0.19
"	West Vancouver	0.14
"	Tofino	0.02
Dolly Varden	Carpenter Lake	0.41 - 1.94
Dogfish	English Bay	1.08
Flounder	Squamish	1.00-(1.42)
"	Fraser River Flats	0.23
"	Hecate Strait	0.11
Herring	Squamish	0.14-(0.30)
"	Prince Rupert	0.07
Lake Trout	Pinchi Lake	2.86
Rainbow Trout	Tezzeron Lake	0.04

TABLE 3

Mercury Levels in Atlantic Coast Fish

Species	Ave. ppm Hg.
Cod	0.02 - 0.23
Clam	0.02 - 0.11
Crab	0.06 - 0.15
Flounder	0.07 - 0.17
Haddock	0.07 - 0.10
Herring	0.02 - 0.09
Herring Meal	0.02 - 0.14
Lobster	0.08 - 0.20
Oyster	0.02 - 0.14
Swordfish	0.82 - 1.00
Tuna	0.33 - 0.86

TABLE 4

Mercury Levels in Commercial Marine Species - Groundfish

Species & Sizes		Landings (1969) in 1000 lbs	Landed Value (1969) in $1000	Mercury Levels No. of Tests	Mercury Levels Average ppm.
Cod		555,018	22,891	163	0.12
Haddock		81,282	6,780	67	0.06
Redfish		215,884	5,883	67	0.08
Flatfishes		282,904	11,605	152	0.09
Greenland Turbot		41,255	968	4	0.08
Pollock		29,529	984	8	0.11
Hake		13,119	454	8	0.09
Cusk		6,336	259	9	0.12
Catfish		7,574	260	9	0.13
Lingcod	- under 9 lbs	4,596	750	25	0.10
	- 9-15 lbs			35	0.18
	- over 15 lbs			50	0.43
Pacific Halibut	- under 100 lbs	28,080	11,952	210	0.18
	- over 100 lbs	5,756	2,448	59	0.42
Atlantic Halibut	- under 100 lbs	3,250	1,324	205	0.39
	- over 100 lbs	362	147	300	0.80
Total Groundfish		1,278,059	66,067		

Inspection Branch,
Department of Fisheries & Forestry
Ottawa,
April 30, 1971.

TABLE 5

Mercury Levels in Commercial Marine Species - Pelagic & Estuarial

Species & Sizes		Landings (1969) in 1000 lbs	Landed Value (1969) in $1000	Mercury Levels: No. of Tests	Mercury Levels: Average ppm.
Herring		1,077,818	11,420	118	0.06
Mackerel		29,268	1,099	62	0.07
Salmon, Atlantic		4,314	2,282	8	0.07
Salmon, Pacific		79,037	27,827	40	0.04
Smelt		4,399	380	37	0.09
Capelin		7,942	65	10	0.02
Swordfish	- under 50 lbs	7,131	4,112	104	0.55
	- 50-100 lbs			78	0.86
	- over 100 lbs			42	1.08
Tuna					
Bluefin	- under 10 lbs	5,484	984	7	0.37
	- 10-30 lbs			29	0.51
	- over 30 lbs			36	0.89
Yellowfin	- under 70 lbs			147	0.21
	- over 70 lbs			28	0.62
Skipjack	- under 9 lbs			124	0.17
	- over 9 lbs			53	0.21
Dogfish, Atlantic		No Commercial Landings		15	0.41
Dogfish, Pacific		No Commercial Landings		58	0.70
Total of Pelagic and Estuarial Fishes		1,230,577	49,012		

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TABLE 6

Mercury Levels in Commercial Marine Species

Species	Landing or Production (1969) in 1000 lbs	Value (1969) in $1000	Mercury Levels Number of Analysis	Average ppm.
MOLLUSCS & CRUSTACEANS				
Clams	8,613	648	64	0.06
Oysters	11,965	1,237	15	0.08
Scallops	13,647	12,058	43	0.03
Lobsters	40,064	29,443	51	0.13
Queen Crabs	19,046	1,704	39	0.09
Dungeness Crabs	3,710	682	17	0.12
Shrimps	4,633	1,068	28	0.09
Total Molluscs and Crustaceans	103,007	46,921		
MEALS & OILS				
Fish Meal	94,936	6,784	55	0.17
Herring Meal	184,346	15,312	49	0.20
Fish Oil	7,496	466	5	0.09
Herring Oil	69,781	4,039	4	0.05

HARP SEALS	Average Weight	Number of Specimens	Average Mercury Levels in P.P.M. Meat	Flippers	Heart	Liver
Adults	600 lbs	10	0.34	0.35	0.20	5.12
Pups	20 lbs	10	0.29	0.29	0.18	0.73

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TABLE 7

Mercury in Hudson Bay Beluga Whale

Tissue	Ave. ppm Hg
Meat	0.97
Meal	2.87
Muktuk	0.18
Liver	8.87
Kidney	2.44
Heart	1.35
Lung	0.64
Intestine	0.61
Atlantic Fin Whale Meat	0.06
Atlantic Humpback Whale Meat	0.24
Atlantic Pothead Whale Meat	1.74

TABLE 8

Mercury Levels PPM in Seals

/	N	Blubber	Hair	Muscle	Liver
Grey Seal *Halichoerus grypus*	11	0.08	-	1.13	99
Harbour Seal *Phoca vitulina*	8	0.04	1.56	0.71	8.9
Hood Seal *Cystophora cristata*	1	[0.38]	-	0.62	27
Harp Seal *Pagophilus groenlandicus*	25	0.03	-	0.38	3.5
Fur Seal *Callorhinus ursinus*	49	-	2.69	0.49	29.6

TABLE 9

Mercury Content (PPM) of Arctic Whale

Species	N	Muscle
White Whale *Delphinapterus leucas*	43	0.53
Narwhal *Monodon monoceros*	2	0.64

TABLE 10

Mercury in the Aquatic Food Chain

	Number of Samples	Range of Values	Arithmetic Mean	More Numerous Organisms
Algae Eaters	39	0.01 - 0.18	0.05	Zooplankton; Snails; Mayfly Nymphs.
Zooplankton Eaters	9	0.01 - 0.07	0.04	Insect Larvae; Minnows.
Omnivores	9	0.14 - 1.16	0.45	Insect Larvae and Adults; Scuds.
Detritus Eaters	12	0.13 - 0.89	0.54	Worms; Clams; Insect Larvae.
Predators	25	0.01 - 5.82	0.73	Insect Larvae and Adults; Frogs.

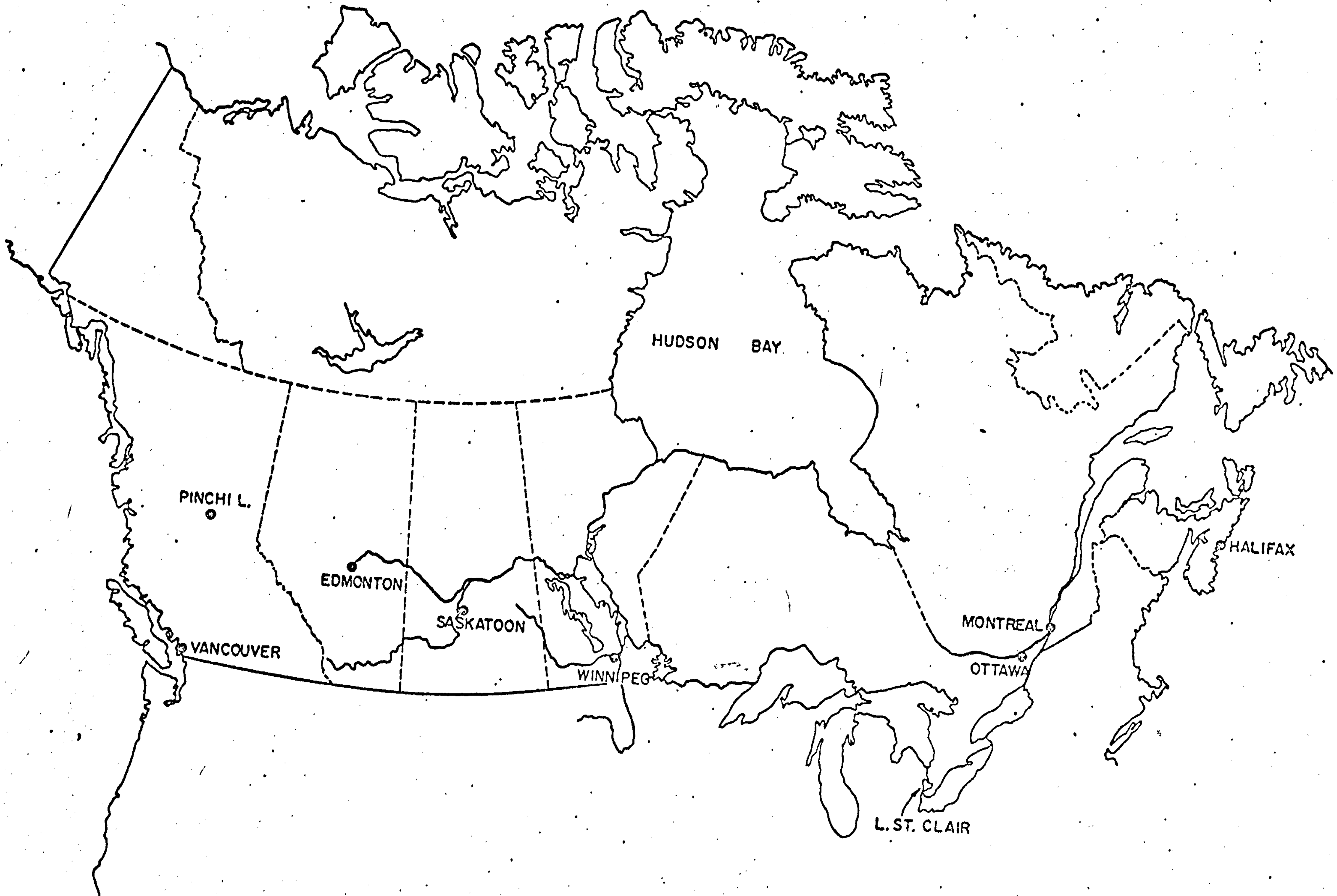

Fig. 1 Map of Canada noting key locations.

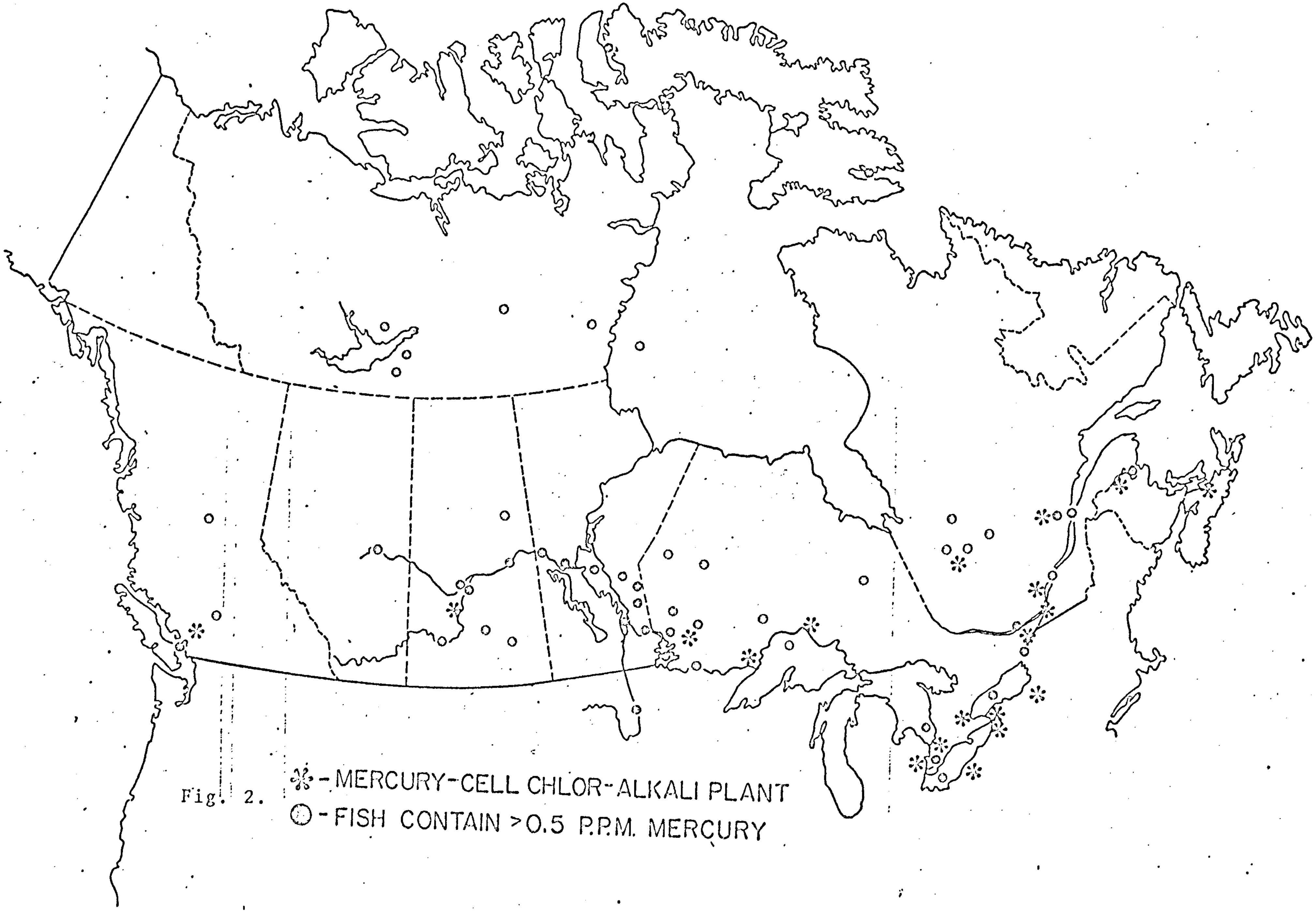

Fig. 2. ✻ - MERCURY-CELL CHLOR-ALKALI PLANT
○ - FISH CONTAIN >0.5 P.P.M. MERCURY

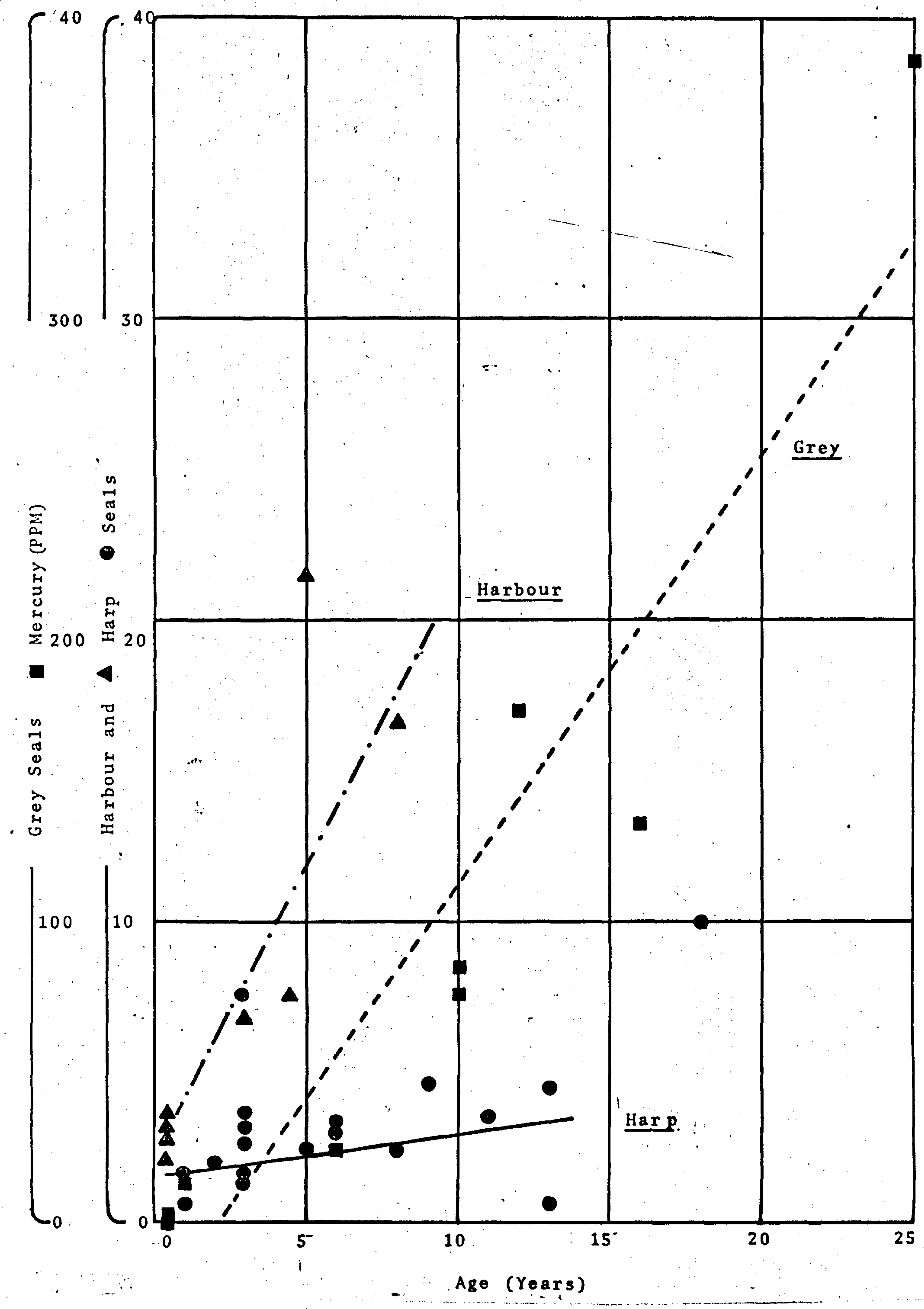

Fig. 3. Relationship between age and mercury content in seal liver.