AWASH IN A SEA OF HEAVY METALS

Mercury Pollution and Marine Animals

By

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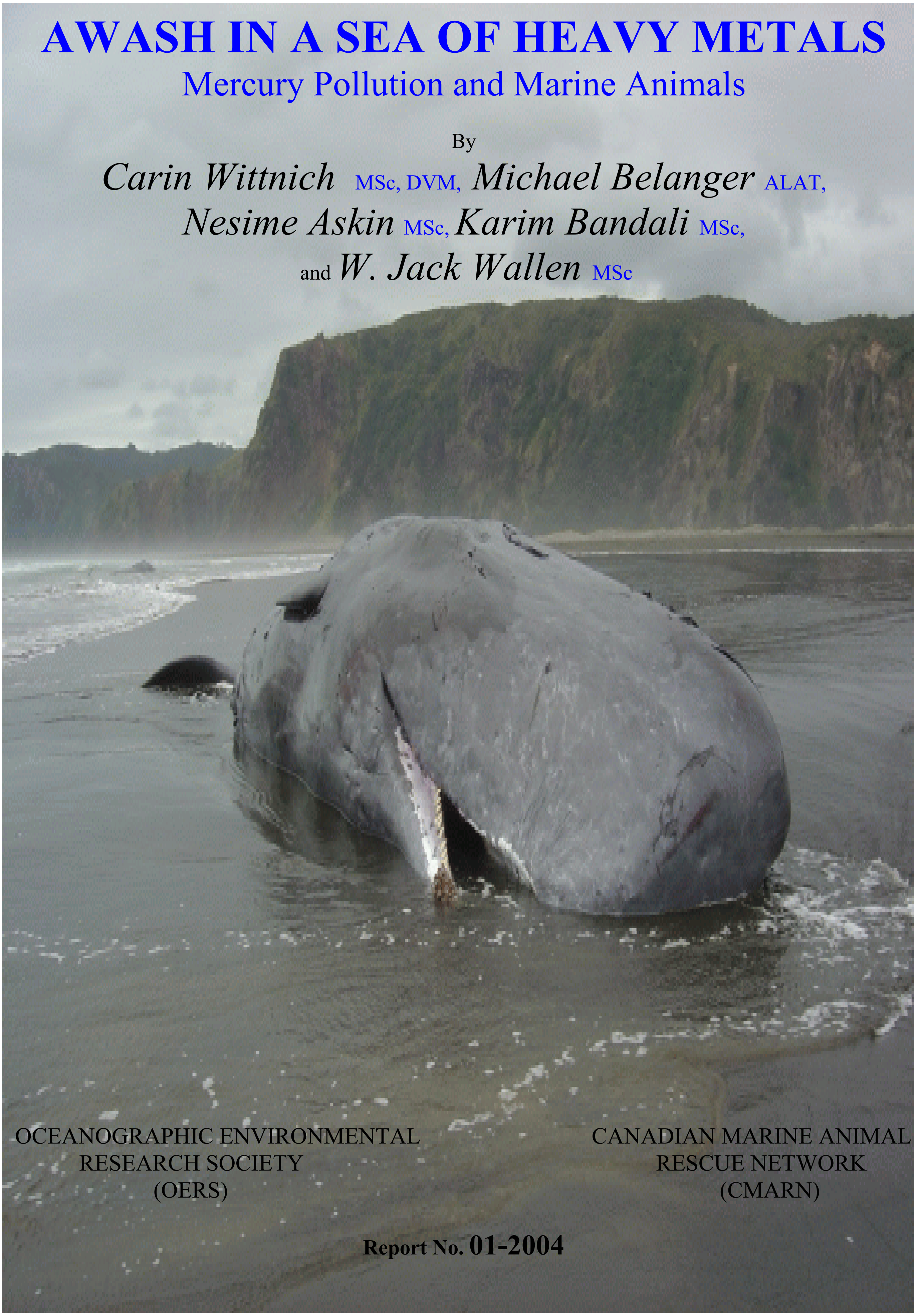

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CANADIAN MARINE ANIMAL
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It would be reasonable to assume that pollutants in the marine environment have decreased following decades of world wide regulations and standards. However, recent reports have shown that pollution is still a lingering problem despite numerous decades of attempting to control what is being released into the various rivers, watersheds, lakes and oceans. Pollutants such as heavy metals can linger for many decades and even centuries causing serious problems for future generations of animals and humans. In fact, within the heavy metals, mercury is the **second leading cause of death** after lead.

Using data from the scientific literature, this report shows that mercury, a naturally occurring and man made heavy metal, has not decreased or at best has remained constant after decades of regulations. Studies on livers of dolphins from the British Isles show a **6 fold increase** of mercury from 1989 to 1998 (from ~20 to 130 µg/g wet weight respectively). Studies examining seal livers from across the Canadian Arctic reveal that mercury levels have **not decreased** from 29 µg/g wet weight in 1972 to 31 µg/g wet weight in 1996. World wide, seal livers from 1972 to 1994 show that mercury levels **have doubled** from ~12 µg/g wet weight to ~ 25 µg/g wet weight. As decades of mercury emissions work their way up the food chain and are augmented by mercury still being discharged by today's coal burning plants, human populations around the world are in danger- those who eat several meals of fish per week (Canada or United States) or eat marine mammals (Inuit, Faroe Islands, Japanese) or live near polluted waterways (Amazon River). This could result in the worldwide birth of thousands of newborns with neurological diseases or developmentally challenged young children. A 1999-2000 study showed that pregnant women and children are high risk individuals with "more than 300,000 newborns each year in the U.S. may be exposed to *in utero* methylmercury levels" that increase chances to adverse neurodevelopmental effects.

More studies are required to study long term effects of pollutants such as heavy metals to prevent needless human deaths and tragic debilitating diseases as well as to prevent the extinction of numerous species of animals.

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The Oceanographic Environmental Research Society (OERS)

Founded in 1995, the Oceanographic Environmental Research Society's mission is to rescue, treat, and rehabilitate marine animals who are injured due to natural or man made accidents and once healthy, release them back into their natural habitat.

The Canadian Marine Animal Rescue Network (CMARN)

Founded in 2000, the Canadian Marine Animal Rescue Network strives to cooperate with other interested groups or individuals to establish a network of groups or organizations to help stranded/sick marine animals, build rehabilitation facilities across Canada and amass teams of trained marine animal volunteers.

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Mercury Pollution and Marine Animals

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1) It is believed by many individuals that the marine environment is cleaner and safer now than it was 40 years ago, that environmental groups are grossly exaggerating environmental conditions and that “the oceans are so incredibly big that our impact on them has been astoundingly insignificant.”.(1)

2) The number of animal species being placed on the ‘threatened’ or ‘at risk’ list are increasing. In 1978, Canada had 17 species listed as ‘threatened/at risk’. By 2002, there was a **25 fold increase** in the number of ‘threatened/at risk’ Canadian species to 431.(2,3)

3) There are numerous conflicting reports as to the state of our environment, however there are few reports that have looked at the effects of pollution (especially the heavy metals such as mercury) in numerous species on a global scale over many decades.(4,5)

4) Of all the heavy metals being disposed of in the environment, mercury is the second leading cause of death in people after lead.(6)

Heavy metal pollution tends to be persistent, have long lasting effects in the environment, and bioaccumulates up the food chain to affect the top predators. Recent reports have shown that power plants using fossil fuels still generate large amounts of mercury emissions into the atmosphere which eventually fall into the oceans or seas.(7) This report will analyze four decades of scientific studies and reports to compare the levels of mercury in the liver tissue of different marine animals to see if the amount of mercury released into the environment has actually decreased, remained unchanged or

increased in the various marine species.

This report demonstrates that the long lasting effects of heavy metals such as mercury lingers within the environment for many decades which affects many generations of animals that live within it. High levels of mercury in expectant mothers can produce offspring that are neurologically impaired or produce developmentally challenged young who cannot survive under natural conditions which can lead to the unsuccessful reintroduction of many threatened species and lead to the extinction of many populations of various marine animals.

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Introduction

The oceans, rivers, lakes and streams around the world have always been used by humans for various purposes: as a means of travel, a source of food and as a gigantic reservoir to dispose of their wastes. It has always been assumed that the world's oceans and waterways were so large and vast that they were capable of removing, absorbing or accumulating vast amounts of pollution. In fact it is still believed by certain individuals that we can safely dispose of a certain amount of pollution every year in our various marine environments without damaging the habitat or poisoning our water sources.(1) However, studies looking at the effects of pollution over long periods of time suffer from some serious limitations. In general, these studies have been done on a single species of animals, in small geographical areas or over narrow periods of time. As well, the cost of long term studies is very high, performed in extremely difficult environments, or deal with animals that are extremely difficult to work with or locate.(4,8,9)

Mercury: A Natural and Man-Made Metal

Mercury occurs naturally in various forms including water and fat soluble variants. It is produced in an inorganic form from naturally occurring events such as volcanic activity, the weathering of natural deposits in the ground or evaporation from the oceans. The principal introduction into the water ecosystem is through the exchange of mercury from the air into the water.(10,11) These naturally occurring amounts of mercury can then be converted by microorganisms into **methylmercury** which is one of mercury's most poisonous forms. This deadly form of mercury enters the food chain by being absorbed by plants or eaten by small animals such as snails who are then eaten by larger animals and so on up the food chain where it bioaccumulates or collects in the bodies of the top predators. As a result, all animals and humans carry a 'basal amount' of methylmercury within their bodies.

Mercury, as it moves up the food chain, is stored in various organs of the body depending on the species. For instance, fish store mercury mostly as methylmercury in their skeletal muscles, so marine animals that eat fish are prone to having higher mercury levels than marine animals that eat algae, vegetation or small animals such as krill. In marine animals mercury is usually reported from liver samples as total mercury due to the fact that methylmercury has several methylated forms and is expensive to measure which makes comparisons between studies hard to equate.(12) **However, almost all measured mercury (~99%) in the tissues of aquatic animals appears in the form of methylmercury**.(13) Cetaceans (whales, dolphins) and pinnipeds (seals, walrus) have developed a complicated biochemical process in conjunction with selenium that ‘neutralizes’ mercury, which allows mercury to be stored in a less dangerous form. At low mercury levels, the ratio of mercury to selenium is in a 1:1 ratio in the liver but this ratio does not always seem to be evident.(14) In studies that looked at chronic high doses of mercury fed to seals, it was found that renal failure, toxic hepatitis and death occurred. Other studies, found gonadal and adrenal steroid synthesis alterations in seals who were fed methylmercury. Beluga whale cells (spleen and lymphs), that were cultured with the same high levels of mercury as found in contaminated belugas found in the St Lawrence River, showed decreases in viability and proliferation responses.(15) So it would seem that mercury poisoning may have different responses and effects in various species of marine animals.

Man-made processes create the majority of mercury now being produced and the introduction of mercury into the environment through these processes **has increased 3-fold since 1900**.(11) A recent report from the United Nations Environment Program (UNEP) has shown that power stations and waste incinerators produce 1,500 tons or 70 percent of new, man-made air bourne emissions annually. Developing countries are producing the majority of these emissions with the highest producer being Asia at 860 tons per year.(16) Once in the atmosphere, mercury can travel hundreds and thousands of miles to be released far from the original point of contamination.(16)

Mercury Poisoning

As societies grew and industrialization developed, greater amounts of heavy metals were disposed in lakes, rivers and oceans with the earliest known instances of heavy metal pollution being traced back to Greek/Roman times.(17) The first report of high levels of mercury in wild animals occurred in Sweden in 1950 and by the mid 1950's mercury poisoning was widespread in Swedish wildlife.(18) Then in the

1950's and 60's there were a number of environmental disasters involving humans which brought an increased awareness of how deadly and catastrophic mercury poisoning can be. People in Japan, Sweden, and Iraq all suffered serious disasters involving mercury that killed thousands of people and left a legacy of misery that is still being felt today.(19,20) In 1976, it was reported that an estimated 8,500 people had been poisoned by mercury, including 700 deaths, over the last 2 centuries.(21) One of the most famous incidents involving mercury comes from Minamata Bay, Japan.(22) Since the 1950's, 2,264 Japanese individuals have been officially diagnosed as having suffered from mercury poisoning and of those 1,435 have died from this poison.(23) Reports as recently as 2001, have shown that as many as 2 million more people, from the same area, may be suffering from this poison.(24) In 1960, over 1,000 people in Iraq were struck with mercury poisoning from eating flour made from seeds treated with an antifungal methylmercury compound- 30 to 40 % of these people died and most of the rest suffered from permanent injuries.(25) In 1972, Iraq again suffered from the effects of mercury poisoning where 6,530 people were hospitalized from eating bread made with flour contaminated with methylmercury- 500 of those patients died. In Brazil, the mining of gold in the Amazonian river basin has caused the release of mercury from 2 sources: the mining of gold and the burning of the jungle for farmland.(26) It has been estimated that Amazon River gold mining industry releases over 130 tons of mercury per year- most of it as air emissions and the rest into the local rivers as runoff.(27) Mercury's deadly potential to cause death and misery has led to an increase in environmental awareness which instigated many regulations, standards and international declarations for the proper disposal and use of mercury.

Physiological Effects of Mercury

Mercury has no vital function in living organisms and therefore it is said that any amount absorbed by the organism, beyond the 'normal' basal level, must be deemed as detrimental.(28) Mercury poisoning may be acute or chronic depending upon how quickly the mercury enters the organism. With acute poisoning the symptoms usually appear quickly and severely. However, chronic poisoning usually takes time to develop and any damage done is typically irreversible.(21) When an organism is affected by acute mercury poisoning, the principal symptoms are loss of coordination, mental deterioration and loss of sight and hearing.(29) Chronic symptoms usually include neurological disabilities and reproductive disorders. (29) Table #1 shows the toxicological effects of methylmercury in various organs or physiological systems within species in which these are quantified. However, in marine mammals it is hard to document the same physiological and toxicological effects of mercury as they are difficult to confirm and observe in the wild.

In marine animals, it is thought that mercury affects primarily the liver, where it is broken down, but it may also affect the renal and neural systems. Fetal and neonatal young of marine animals normally have low concentrations of mercury in their livers due to the fact that only methylmercury is capable of being transferred across the placenta from their mother.(29) Also, it would seem that most mature marine animals are capable of demethylating mercury in their bodies and storing it in a less deadly form.(30) In certain species such as seals, whales, and humans, the females are capable of passing on mercury in the milk that they feed their young with.(29) This results in females showing lower levels of mercury within their bodies but more importantly it passes on a poison to the young which affects them at a very important stage of their lives-during development and maturation. In Harp seals fed a diet high in methylmercury, there was observed failure of the liver and kidneys and anomalies in the liver were also observed in dolphins with high levels of mercury.(31) It is interesting to note that sick or stressed animals seem to be unable to detoxify methylmercury as efficiently as healthy animals. This suggests that mercury could become a factor in animals who are undergoing a stress and may be one reason why rescued animals have poorer rehabilitation outcomes.(32)

The end result of all of this mercury evaporating into the atmosphere and flowing through the various water systems is the contamination of various food sources which depending upon culture and preferences could include plants, clams, mussels, various species of fish, and even dolphins and whales. (33-37) A diverse group of people from around the world have been affected by eating mercury contaminated food- from the Inuit eating seal meat in the Canadian Arctic, small children from the

Seychelles Islands eating fish, from the child bearing women of the St. Lawrence River area eating fish or adults and children from Japan and the Faroe Islands eating dolphin and whale meat. All of these foods are sources of mercury which can accumulate within the human body and can affect the unborn, the very young and the mature in various ways. As well, there is still a certain amount of mercury retained in the sediments of mangrove ecosystems, river beds and lagoons that is a constant source of mercury- acting as a reservoir for this poison for many decades to come.

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Table1- Methylmercury's Toxicological Effects in the Various Organs/Systems of Numerous Species*

System	Species	Toxicological Effects
Central Nervous System	Human-children	- severe neurological dysfunction & developmental abnormalities i.e. mental retardation, disturbed physical growth, limb deformities, cerebral palsy, poor coordination
	Monkey/Rat/ Mouse	- similar to human children
	Human-adults	- peripheral impairment, tremors, auditory impairment, gait disturbance, vertigo, fainting
	Monkey/Rat/ Mouse/Rabbit	- similar to human adult
Reproductive	Human	- increased incidence of spontaneous abortions & congenital anomalies, decreased fertility and conception
	Monkey	- abnormal sperm, lowered conception rate
	Rat	- reduced litter sizes
	Rat/Mouse	- decreased fetal survival
	Mouse	- malformation of embryos, lowered sperm counts
	Guinea Pig	- fetal abortions
Cardiovascular	Human	- increased blood pressure and tachycardia in children, irregular heart beats, cardiac arrest, decreased heart rate, higher cardiovascular death rates
	Monkey	- cerebrovascular changes, hypertension, intimal thickening
	Rat	- calcification of arterial wall, increased blood pressure in SHR females, hypertension, decreased heart rate
Hematological	Rat	- decrease in hematocrit, hemoglobin, and clotting times
Renal	Human	- necrosis of renal tubules, albuminuria, proteinuria, fatal acute renal failure, impaired renal function, in females an increase in deaths due to nephritic disease
	Rat	- fibrosis, inflammation, increased renal weights, decreased renal enzymes, renal hypertrophy, reduced function
	Mouse	- degeneration of tubules, chronic nephropathy, increased serum creatine, swollen tubuler epithelium

* Modified From: Toxicological Effects of Methylmercury, National Research Council, National Academy Press, Washington, DC, 2000.

Results

This section will present decades of data on mercury concentrations in the livers of various marine mammals such as polar bears, whales, narwhals, seals and dolphins from different geographical locations around the world. Wherever possible, the data are organized by geographical areas within each species from the most recent to the oldest data, allowing for the comparison of mercury values within the same region. Due to the fact that mercury can be broken down and stored as various 'species', studies have presented liver mercury levels by reporting total and methyl mercury levels. This report will represent the data as **total** amount of mercury in the livers to allow for proper comparison between all studies. The values of the liver mercury levels are all expressed as a **mean ± standard deviation** and are converted to reflect the same concentration values of: **$\mu g\ g^{-1}$ wet weight**. Dry weight values were converted using the wet weight to dry weight ratio of 70% moisture content in the liver.(38) As previous studies used different values (i.e. ppm or parts per million) to express their results, those values have also been converted using the following equation: **1 mg/kg= 1 part per million**.(39) Please note that the data compiled within the tables or used to make the graphs have **not been statistically compared**. The 'Years Taken' column in the tables represents the actual date that the samples were taken - **not** the date of publication of the study. To assist the reader, a representative map is included for every figure showing **the general vicinity** of where each study or studies were performed.

The result section is organized to show a figure or figures followed by a data table from which the figure(s) were made. The figures will be used to show the data over time for quick comparison within geographical areas and the tables will contain all available data for the various species. The references used to create the tables have been given their own section at the end of this report to make it easier for the reader to acquire the original data.

Marine Animals

This section will show the mean amounts of mercury in a figure and table format of the various species over different geographical locations. Depending on the geographical location, species, age or sex, mercury levels vary from very low (ranging from 0.05 µg/g wet weight in Greenland seals) to very high values (700 µg/g wet weight in Mediterranean dolphins). However, in whatever geographical area we examined, the mercury levels within each species has shown an increase or at best a stabilization of the mean levels of mercury over 30 to 40 years. For example, in Greenland seals, mercury went from 0.05 µg/g wet weight in 1978-87 to 7 µg/g wet weight in 1994-95 (Figure A-3) and dolphins from the United Kingdom went from 19 µg/g wet weight in 1989-91 to 130 µg/g wet weight in 1996-98 (Figure C-1). In addition to a geographic story over time for a specific species, our report provides a world wide perspective regarding the amount of mercury over time. For example, Figure A-4 looks at seals over time from 1972 to 1994 which reveals that mercury levels rose from approximately 12 µg/g wet weight to approximately 25 µg/g wet weight.

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Figure A-1. Mercury Levels in Seal Livers From the Canadian Arctic-1972 to 1996.

The data for Arctic seals reveal that the mean concentration of mercury had decreased over the mid 70's and early 90's but by 1996, the values had returned back to the early 1970's levels. The data show **no change** over a 24 year period.

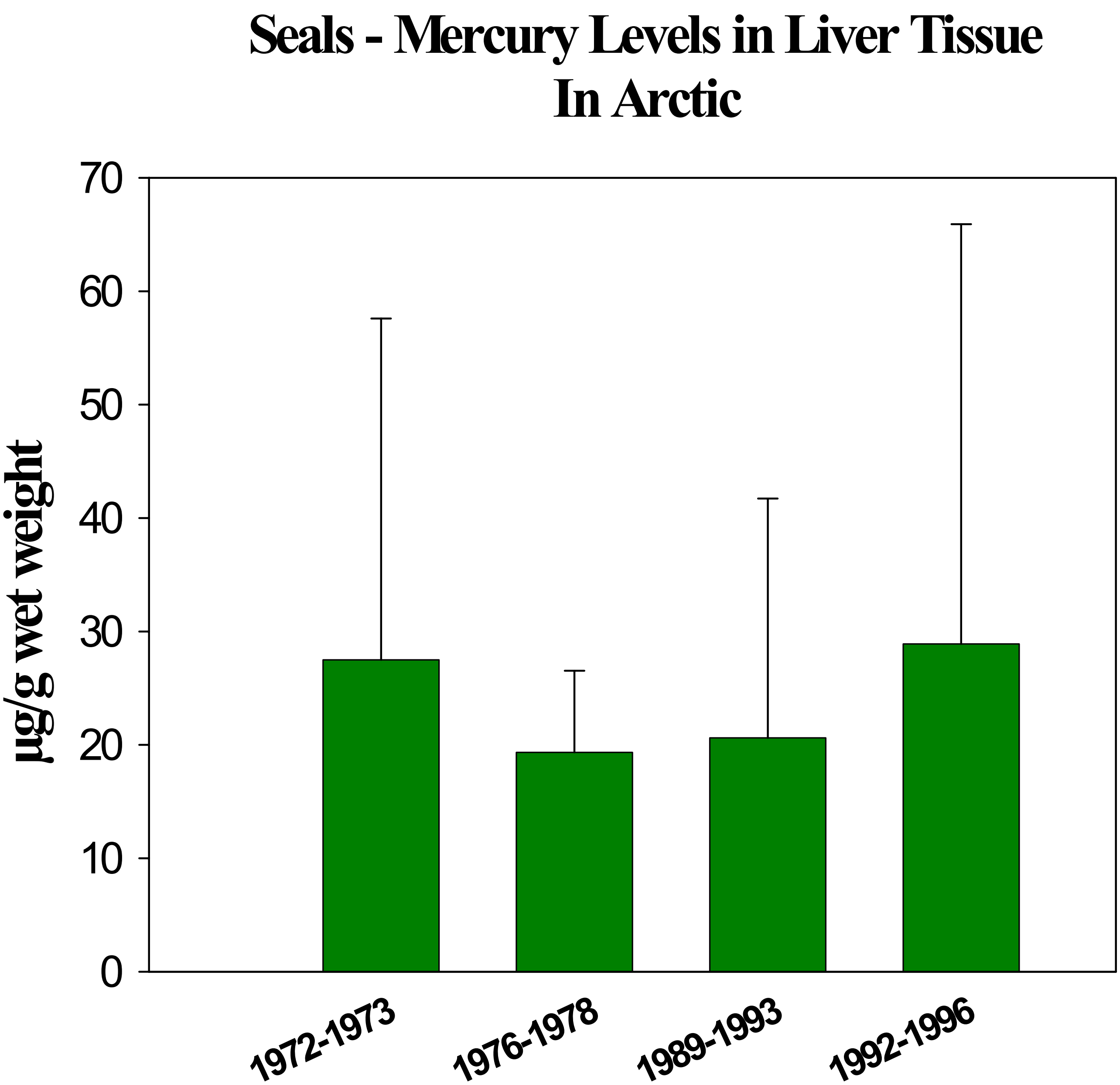


Figure A-2. Mercury Levels in Seal Pup Livers from the East Coast of Canada-1972 to 1978.

Even though seal pups have very low levels of mercury, this graph shows **a tripling** of mercury over a 6 year period.

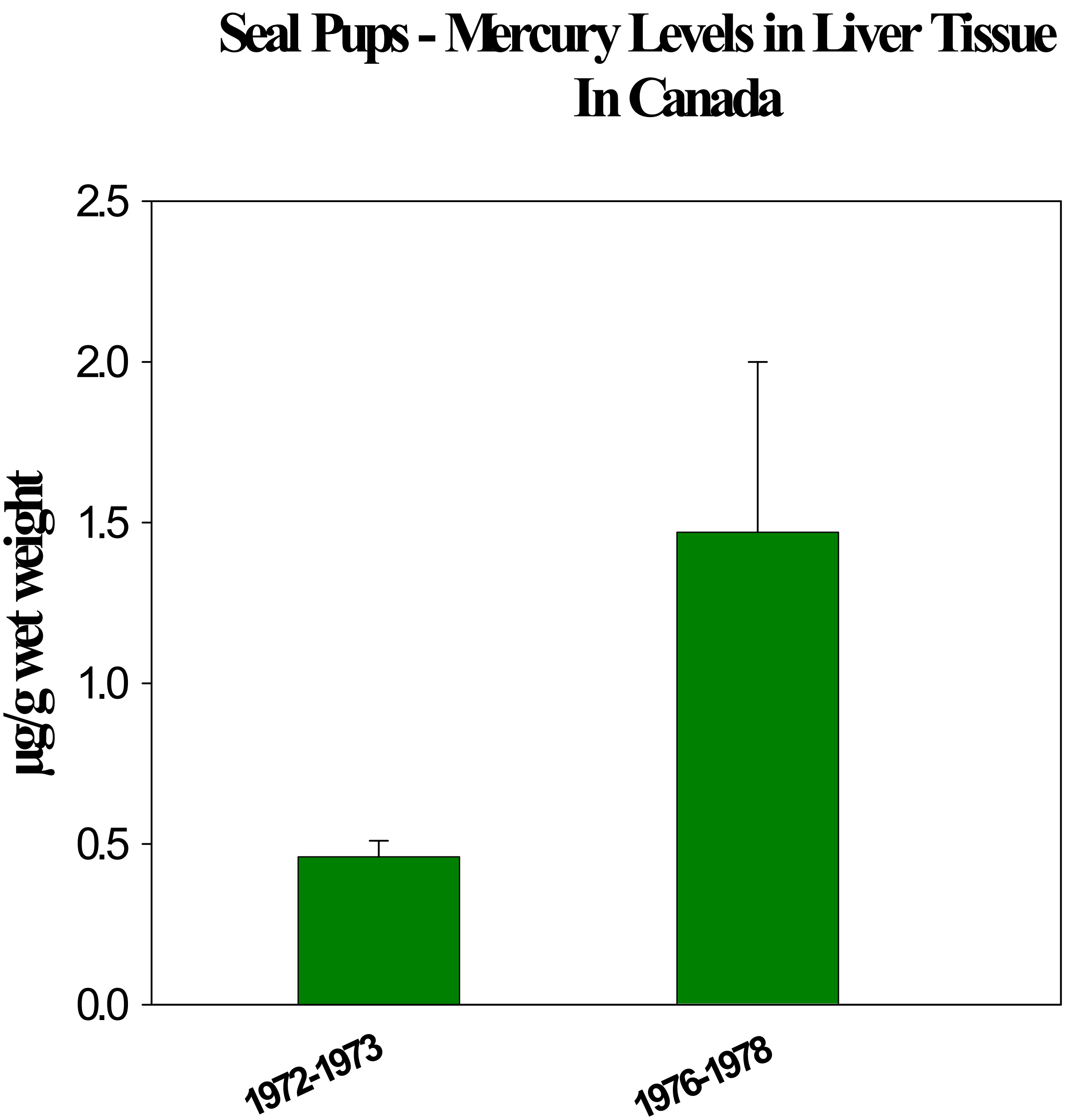


Figure A-3. Mercury Levels in Seal Livers from Greenland-1978 to 1995.

Mean levels of mercury in Greenland seals in 1985-91 **rose eight times above** the levels of 1978-87 with a slight decrease in 1994-95.

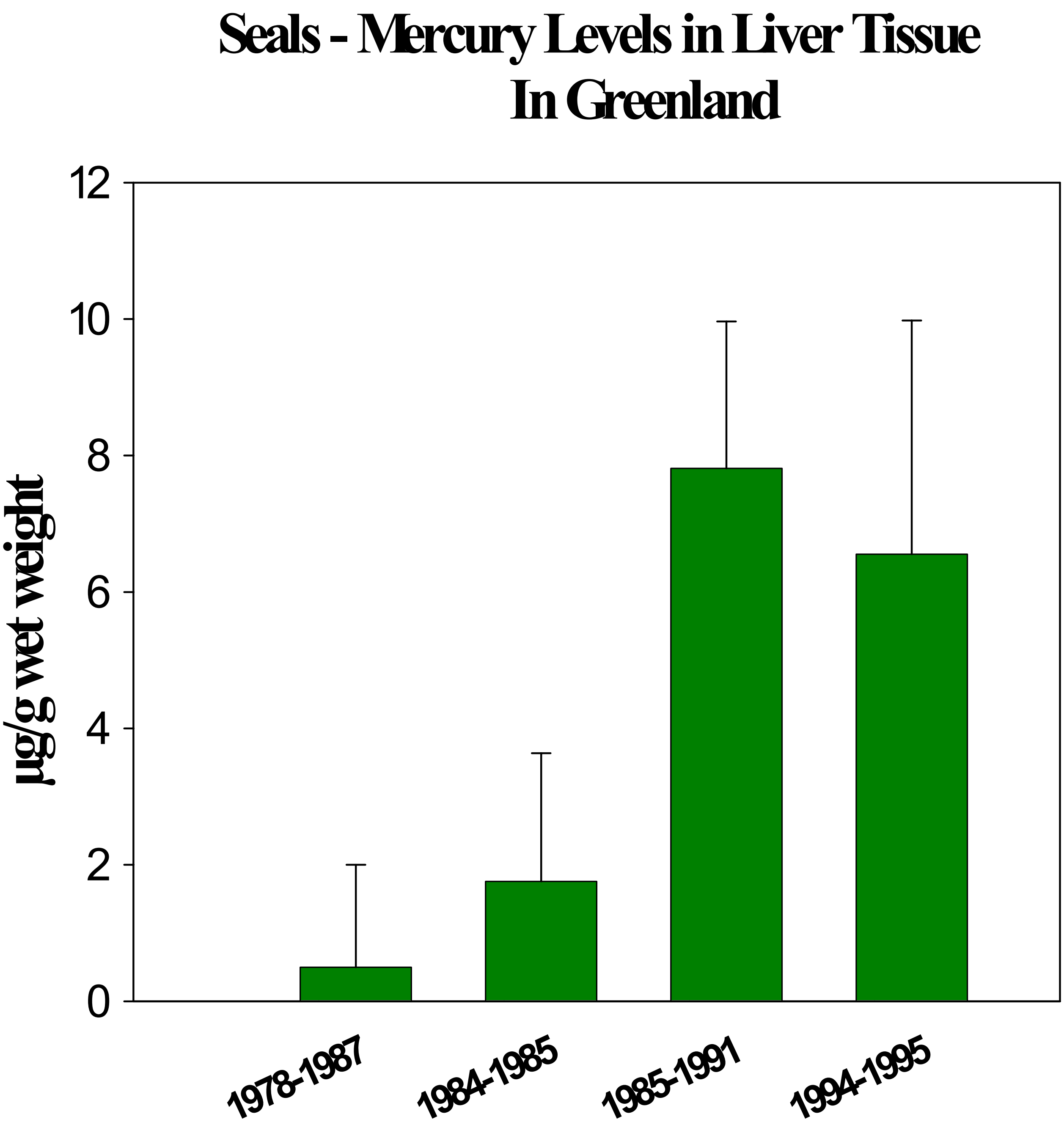


Figure A-4. Mercury Levels in Seal Livers Worldwide-1972 to 1994.

Mean levels of mercury in seals from around the world showed **a gradual decrease** until 1991. However, there was **a dramatic increase** in mercury between 1988-1994.

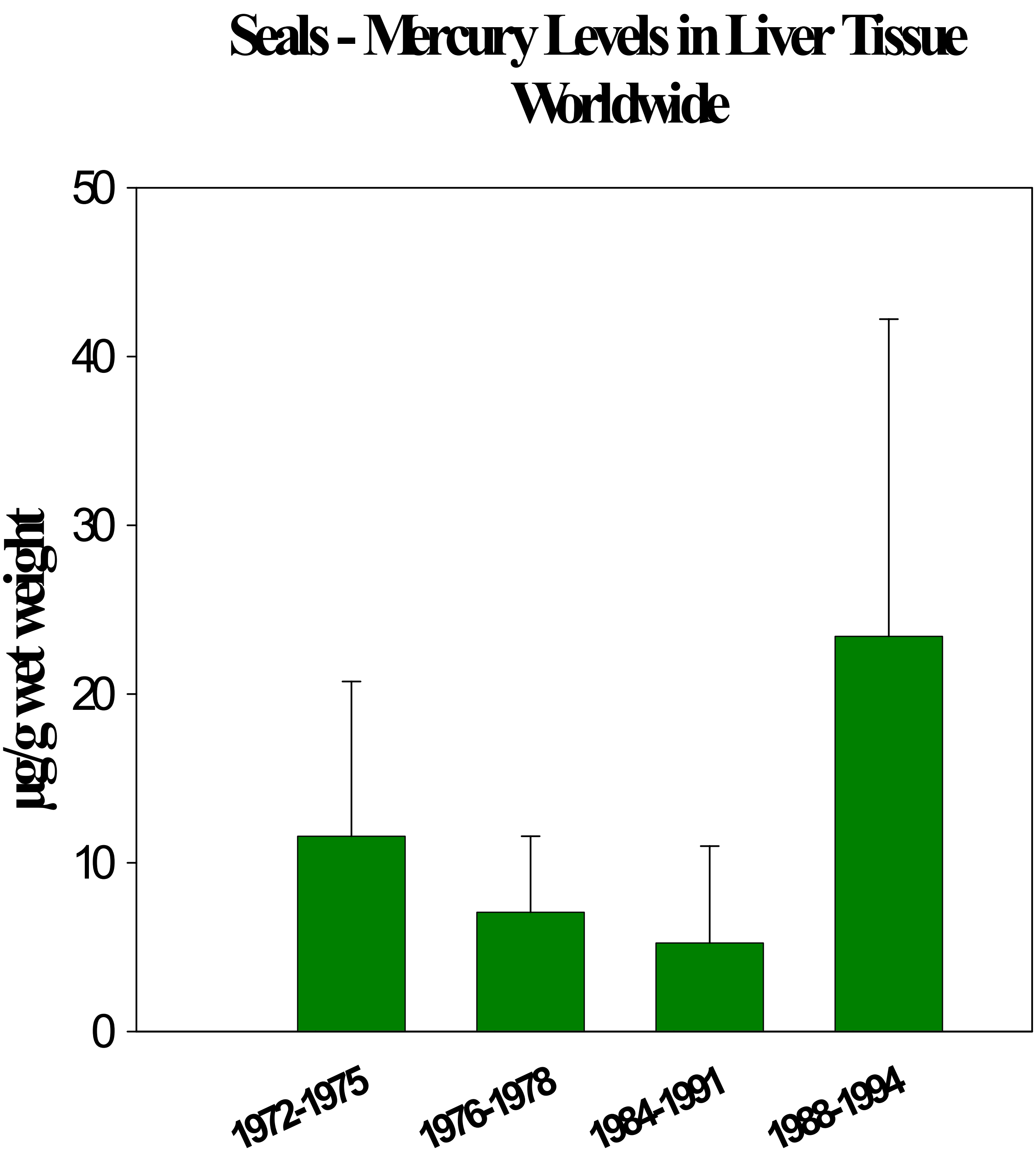


Table A. Mercury Levels in Liver Tissue in Seals

Value (mean±SD)	Year(s) Taken	Location	Ref
7±3	1994-95	Greenland	1
7±4	1994-95	Greenland	1
1±1	1986	Greenland	3
8±1	1986	Greenland	3
3±2	1985-91	Greenland	3
8±2	1985-91	Greenland	3
20±4	1985-91	Greenland	3
85-2146	1984-87	Greenland	13
1±2	1984-85	Greenland	3
3±2	1984-85	Greenland	3
2±1	1984-85	Greenland	3
1±2	1978-87	Greenland	3
27±37	1994	Arctic	2
31±37	1992 & 96	Arctic	4
33±35	1987-93	Arctic	2
8±7	1989-93	Arctic	2
28±30	1972-73	Arctic	2
3 (pup)	1976-78	Arctic/Greenland	11
3±2 (pups)	1976-78	Arctic/Greenland	11
4±3	1976-78	Arctic/Greenland	11
6±3	1976-78	Arctic/Greenland	11
12±9	1976-78	Arctic/Greenland	11
13±13	1976-78	Arctic/Greenland	11
86±112	1988-91	Irish Sea	6

62±93	1988-89	British Isles	5
1±1 (pups)	1976-78	Gulf of St Lawrence	11
1±1 (pups)	1976-78	Gulf of St Lawrence	11
2±2	1976-78	Gulf of St Lawrence	11
3±2	1976-78	Gulf of St Lawrence	11
13±8	1976-78	Gulf of St Lawrence	11
13±16	1976-78	Gulf of St Lawrence	11
2±1 (pups)	1976-78	Newfoundland-Labrador	11
2±0 (pups)	1976-78	Newfoundland-Labrador	11
2±1	1976-78	Newfoundland-Labrador	11
3±2	1976-78	Newfoundland-Labrador	11
12±9	1976-78	Newfoundland-Labrador	11
9	1976-78	Newfoundland-Labrador	11
14±11	1972	Nova Scotia, Canada	8
5±1 (female)	1972	Eastern Canada	8
1±1 (pups)	1972	Eastern Canada	8
1	1972	Nova Scotia, Canada	8
1-5	1988-93	Chukchi/Bering Sea ,Alaska	10
1-9	1989-93	Bering Sea, Alaska	10
19±8	1980-85	Bering Sea	14
11±7	1975	Pribilof Islands, Alaska	9
62±8	1987	S Georgia, Antarctica	12
3±3	1984	Okhotsk Sea, Japan	7

Figure B-1. Mercury Levels in Pilot Whale Livers from around the Atlantic Ocean-1977 to 1991.

Mean levels of mercury in Pilot whales from the Atlantic Region from 1977-91 which shows a **3.5 decrease** from the 1977 to1991.

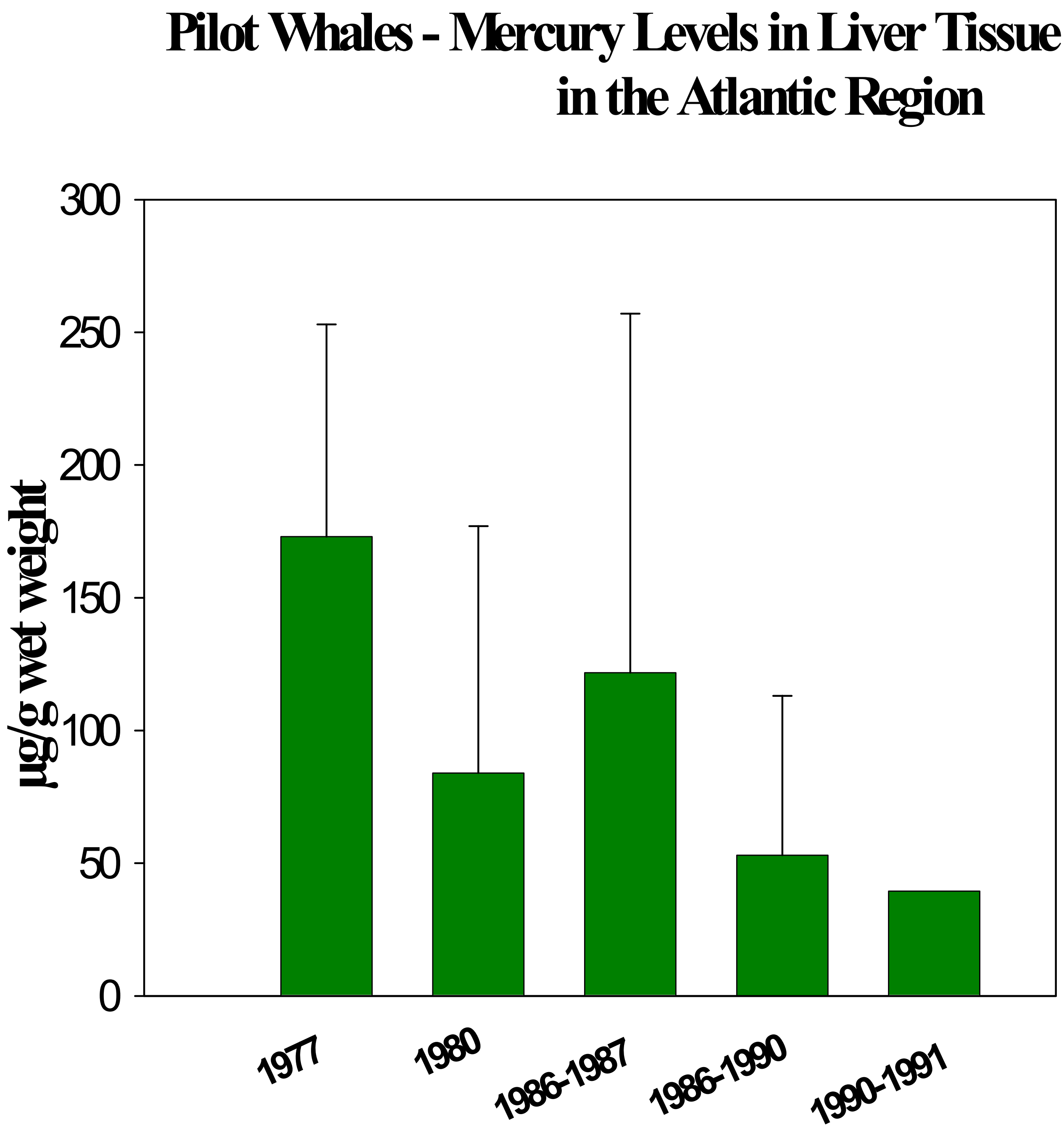


Table B. Mercury Levels in Liver Tissue in Pilot Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
40±39	1990-91	Northwest Atlantic Ocean	3
128± 175	1987	Faroe Islands	5
133±104	1987	Faroe Islands	1
128±175	1987	Faroe Islands	1
98±87	1986	Faroe Islands	1
1411±24	1997	New Caledonia(Fiji)	2
1452±79	1997	New Caledonia(Fiji)	2
1	1997	Northeast England	7
39±37	1990-91	Massachusetts, USA	7
53±60	1986-90	Massachusetts, USA	6
105±98	1980	Newfoundland, Canada	4
63±88	1980	Newfoundland, Canada	4
289±156 (female)	1977	Cumberland Island, USA	3
57±4 (male)	1977	Cumberland Island, USA	3
89±68	unknown	Caribbean Sea	2

Figure C-1. Mercury Levels in Dolphin Livers from the United Kingdom-1989 to 1998.

Mean levels of mercury in dolphins from around the United Kingdom remained constant except for **two dramatic increases** in mercury in 1991-1993 and 1996-1998. Mercury levels **have risen almost 7 times** since 1989 to 1998.

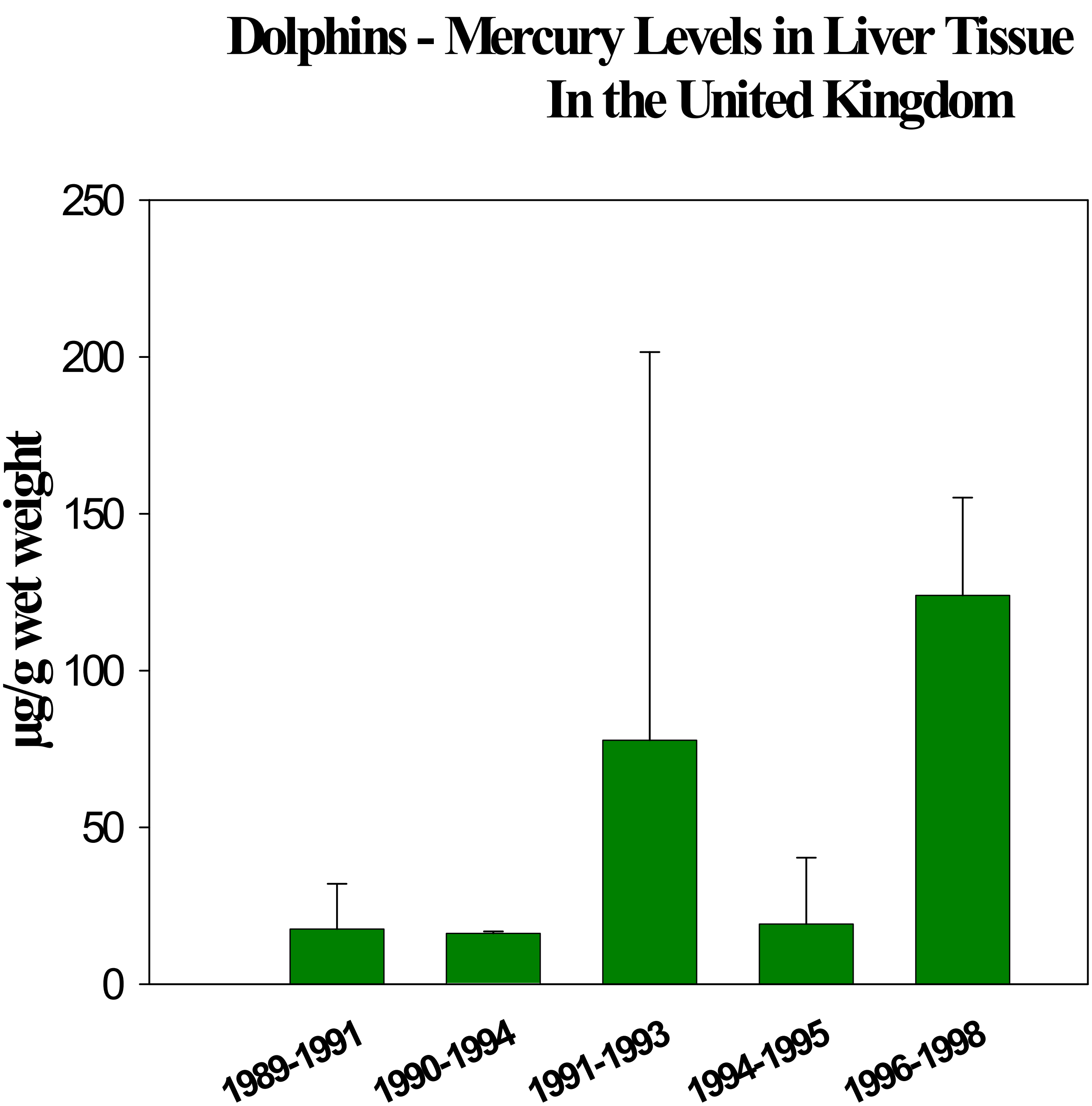


Figure C-2. Mercury Levels in Dolphin Livers from the Mediterranean Sea-1972 to 1996.

Mean levels of mercury in dolphins around the Mediterranean area from 1972 to 1996 have **doubled** in value.

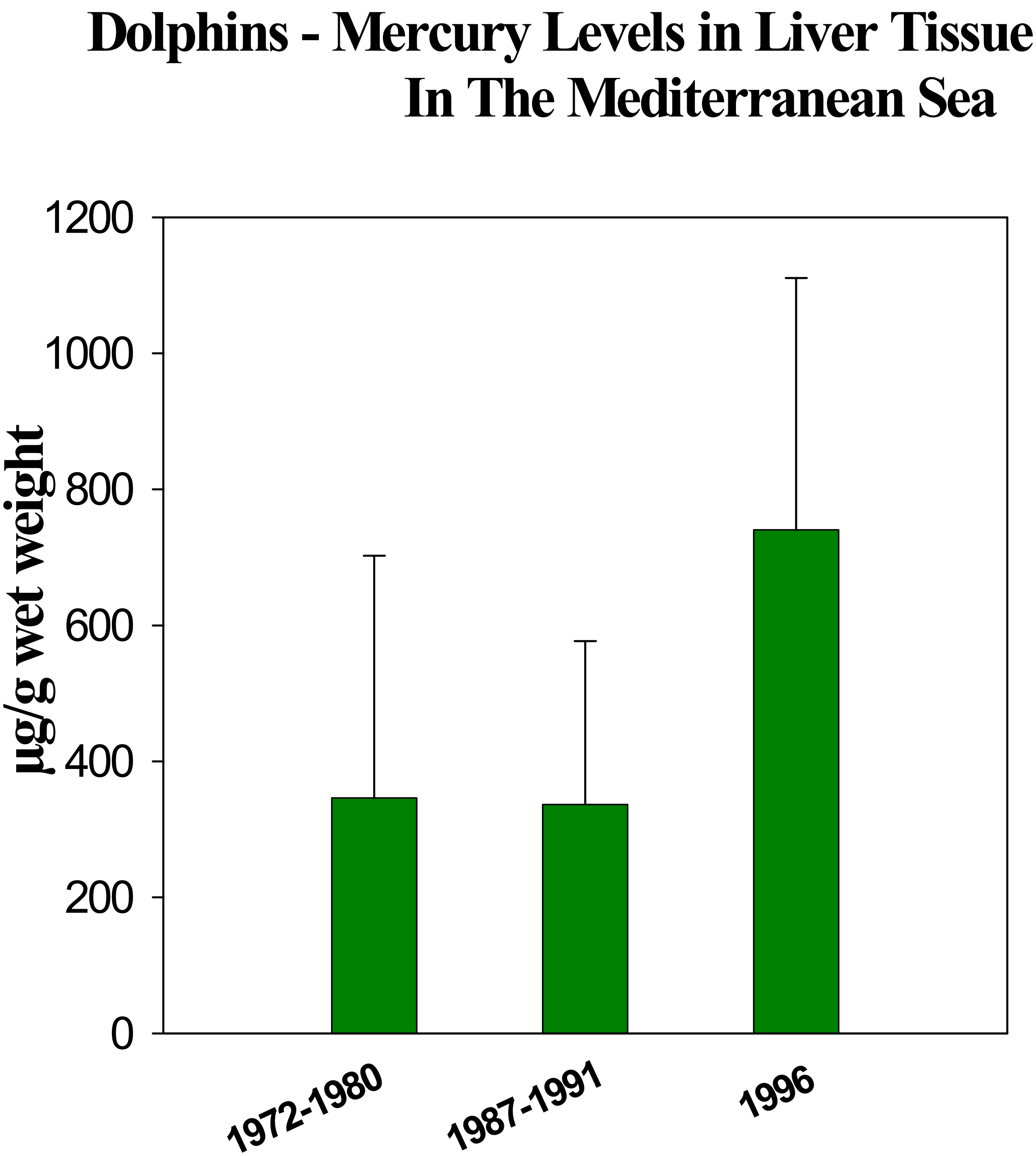


Figure C-3. Mercury Levels in Dolphin Livers from the U.S. Atlantic Area-1980 to 1994.

Mean levels of mercury in dolphins around the U.S. Atlantic Sea area from 1980 to 1994 have **doubled** in value.

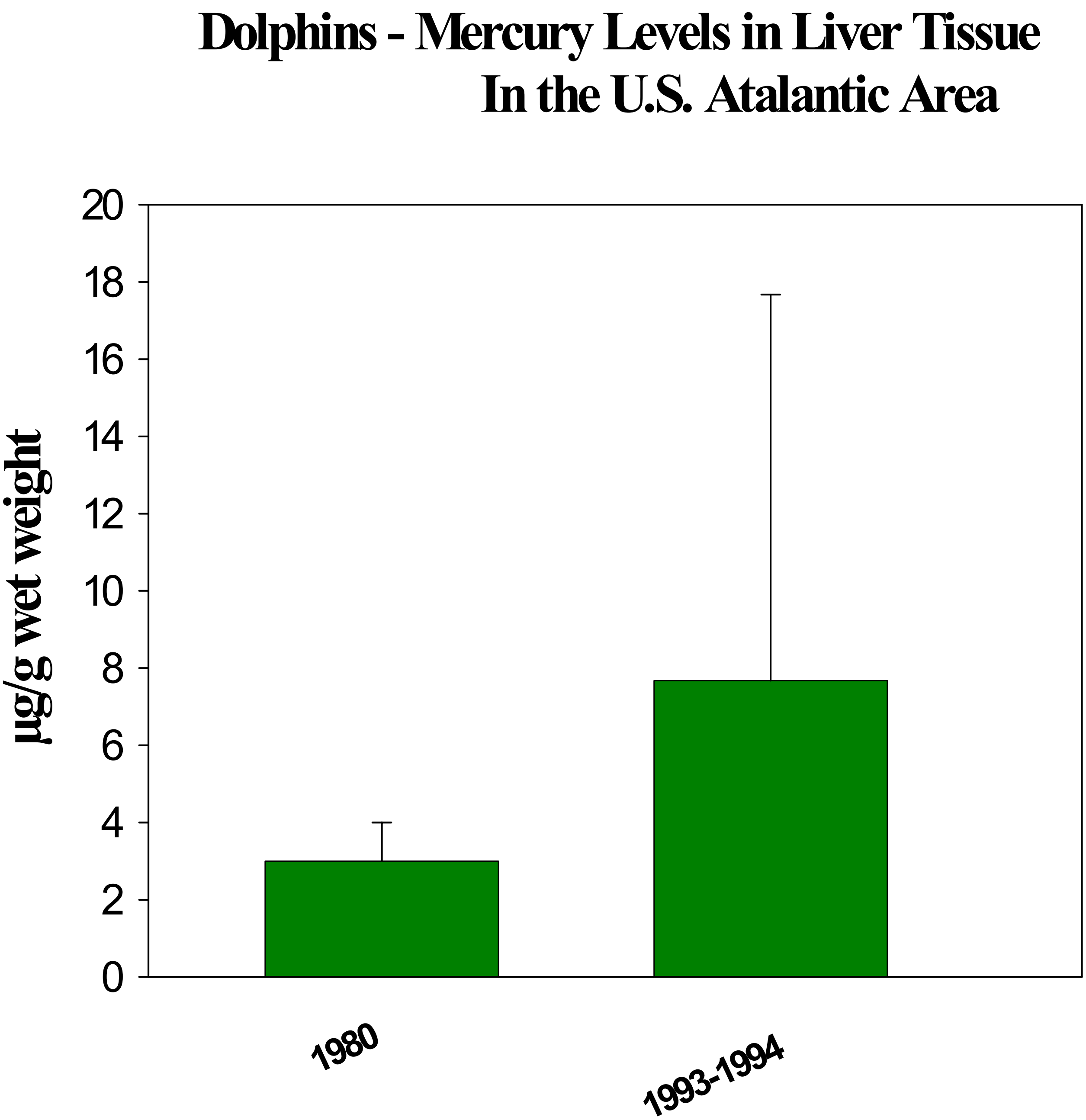


Table C. Mercury Levels in Liver Tissue in Dolphins

Value (mean±SD)	Year(s) Taken	Location	Ref
50±61	1995-96	Australia	1
102	1998	Wales	3
146	1996	Wales	3
12	1995	England	3
43	1994	Wales	3
2.6	1994	England	3
78±124	1991-93	North Sea	14
20±6 SE	1990-94	British Isles	12
12±3 SE	1990-94	British Isles	12
15±17	1989-91	Irish Sea	15
21±12	1989-90	British Isles	16
0-11	1974	Scotland	11
3	1994	NW Atlantic	17
10±10	1993	NW Atlantic	17
10±10	1993	Massachusetts, USA	5
3±1	1980	Newfoundland, Canada	18
15.5	1997	Mediterranean Sea	4
1002	1996	Adriatic Sea	2
478	1996	Adriatic Sea	2
642±609	1988-90	Mediterranean Sea	7
189±29	1987	Adriatic Sea	6
180±84	1987 & 1991	Adriatic Sea	8
68±43	1972-80	French Atlantic	10
346±356	1972-80	Mediterranean Sea	10

205±102	1977-80	Kii Penn, Japan	9
7±2 (males)	1977-80	Kii Penn, Japan	9
20.8	1991	California, USA	13

Figure D-1. Mercury Levels in Beluga Livers from the Arctic-1981 to 1994.

Mean levels of mercury in belugas from around the Arctic region from 1981 to 1994 shows a **gradual decrease** in mercury levels to roughly **half** of 1981 levels.

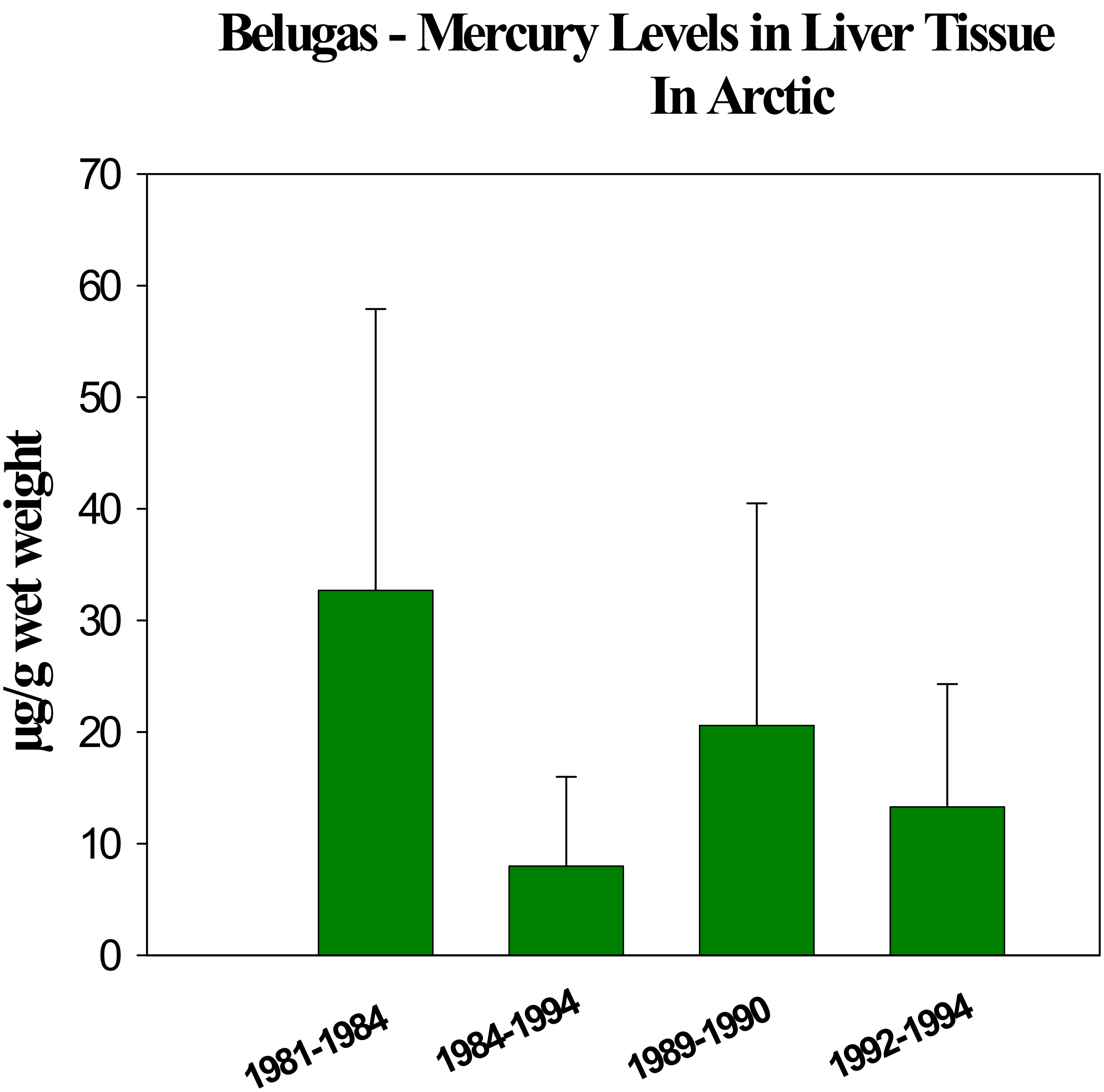


Table D. Mercury Levels in Liver Tissue in Beluga Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
27±25	1993-94	Arctic	1
10±8	1992-94	Arctic	1
36.5±35.9	1990	Point Lay, Alaska	2
4.7±3.8	1989	Point Hope, Alaska	2
2.8±0.1	1992	Cook Inlet, Alaska	2
8±8	1984-94	Arctic	1
62±8	1984	Arctic	1
8.3±7.7	1984	Grise Fiord, Canada	3
18.7±16.8	1984	Pangnirtung, Canada	3
24.9±25.2	1984	Eskimo Point, Canada	3
38.4±48.0	1984	Hudson Bay, Canada	3
44.1±45.5	1981-84	Mackenzie Delta, Canada	3
34±43	1982-87	St-Lawrence River, Canada	1
126±161	1982-87	St Lawrence River, Canada	3

Figure E-1. Mercury Levels in Narwhal Livers from the Arctic-1983 to 1994.

Mean levels of mercury in narwhals around the Arctic region from 1983 to1994 have almost **doubled**.

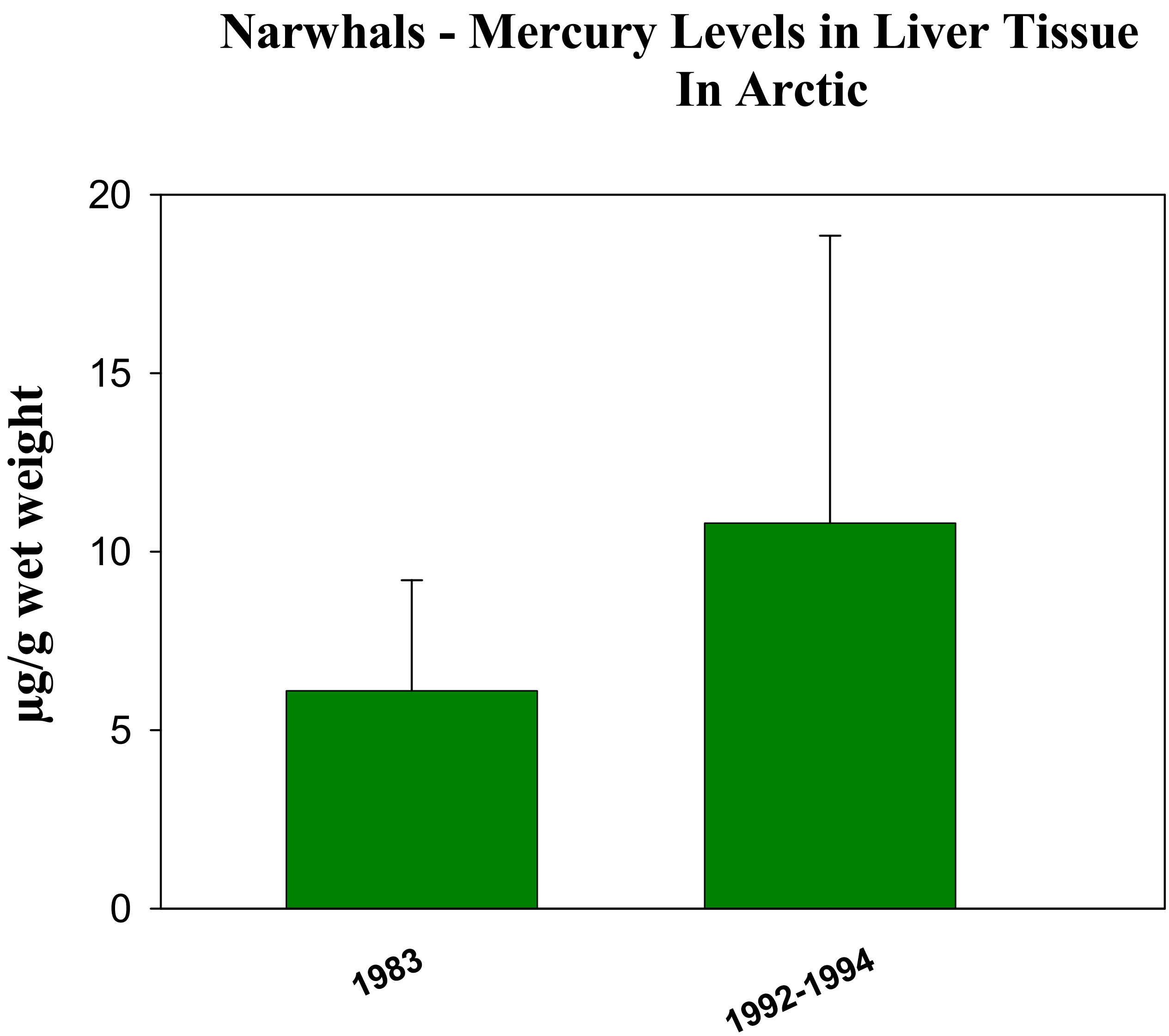


Table E. Mercury Levels in Liver Tissue in Narwhals

Value (mean±SD)	Year(s) Taken	Location	Ref
11±8	1992-94	Arctic	2
6±3	1983	Arctic	1

Figure F-1. Mercury Levels in Beaked Whale Livers from around the World-1993 to 1998.

Mean levels of mercury in single Beaked whales from around various regions of the world from 1993 to 1998 have shown a gradual moderate **increase.**

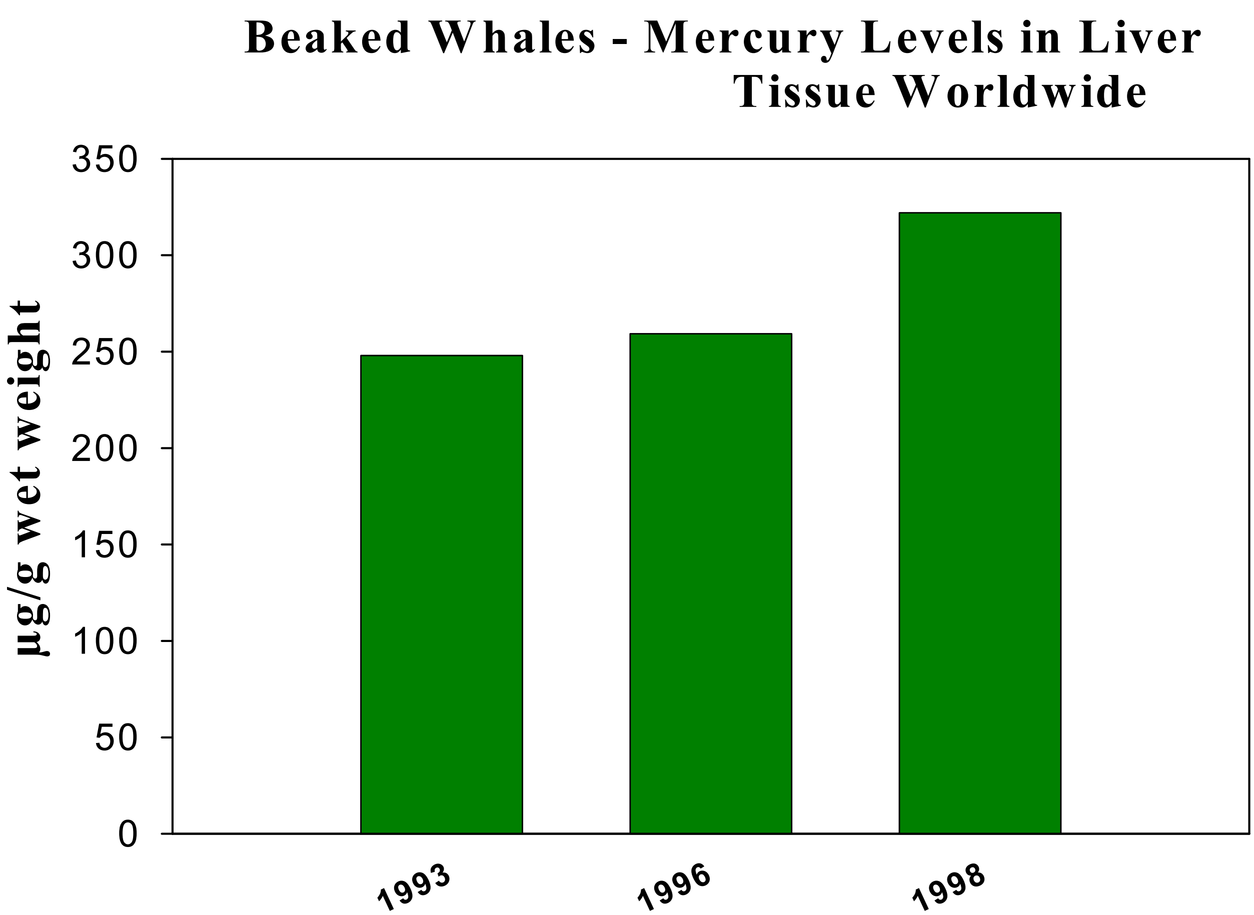


Table F. Mercury Levels in Liver Tissue in Beaked Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
322	1998	England	2
259	1996	Adriatic Sea	1
248	1993	NW Atlantic	3

Figure G-1. Mercury Levels in Minke Whale Livers from around the World-1991 to 1996.

Mean levels of mercury in single Minke whales from around the world from 1991 to 1996 have **increased 250 times.**

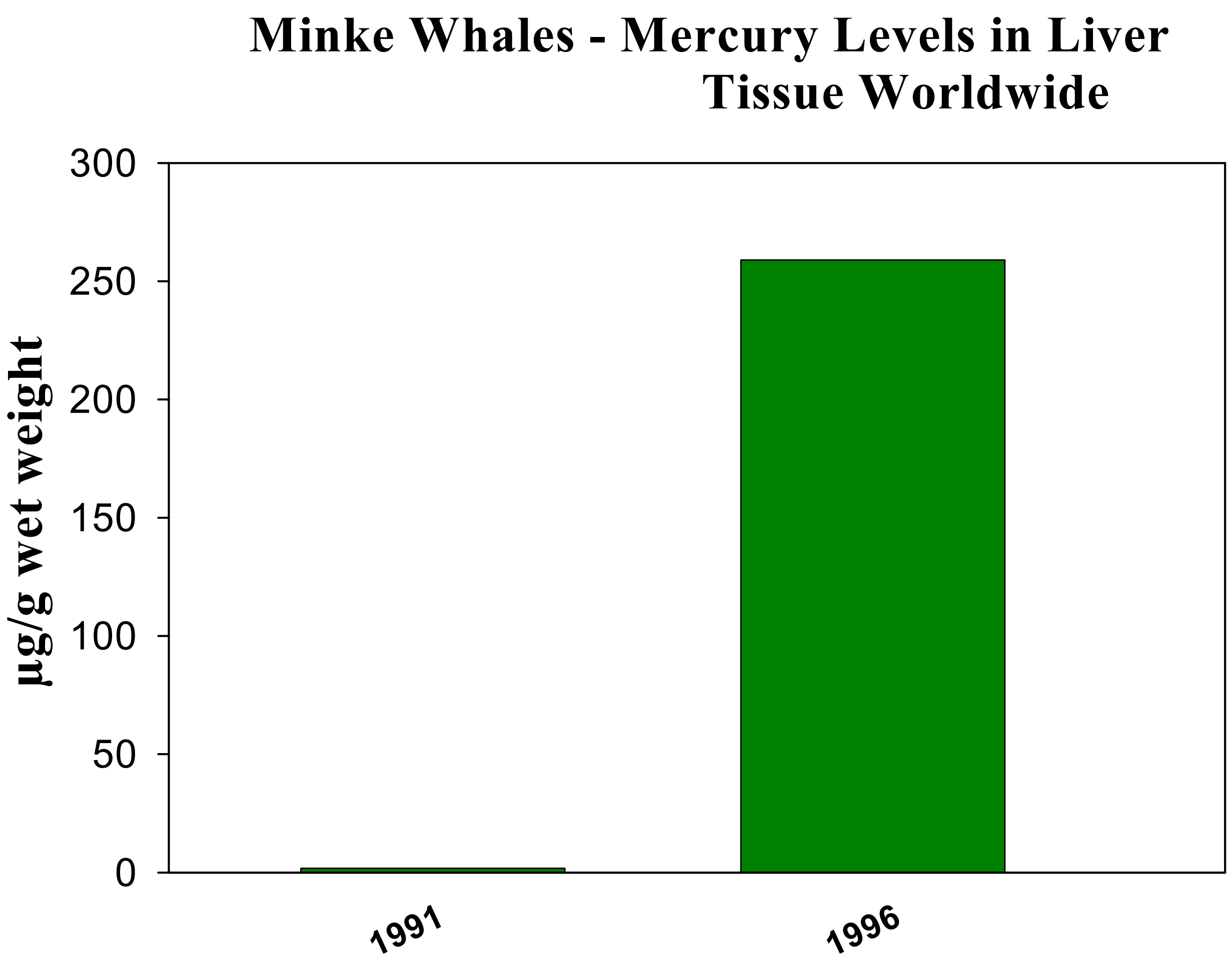


Table G. Mercury Levels in Liver Tissue in Minke Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
259	1996	England	1
2	1991	Irish Sea	2

Figure H-1. Mercury Levels in Polar Bear Livers from Greenland-1983 to 1990.

Mean levels of mercury in Polar Bears from Greenland have **gradually risen** 2.5 times since 1983.

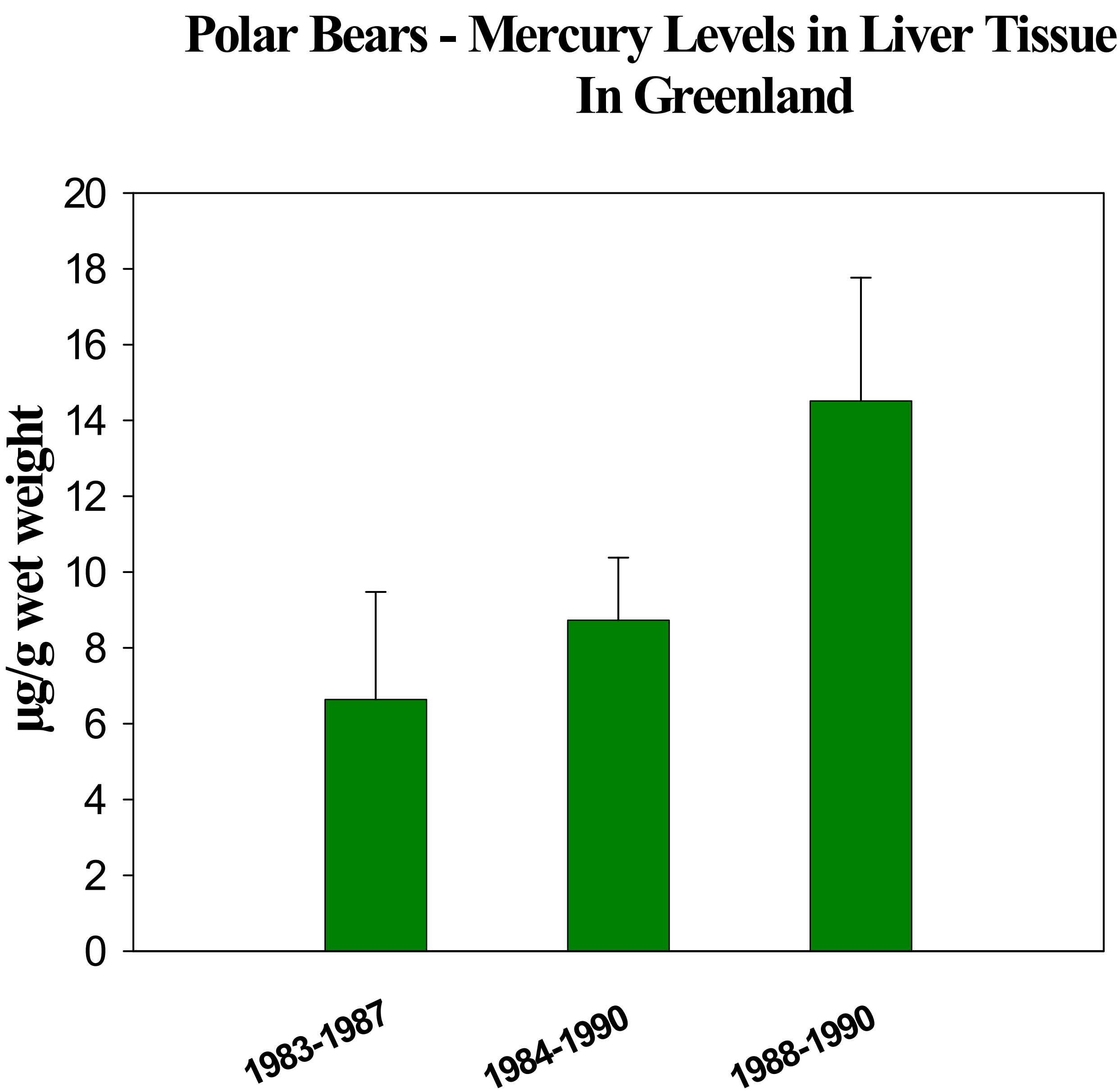


Table H. Mercury Levels in Liver Tissue in Polar Bears

Value (mean±SD)	Year(s) Taken	Location	Ref
12.4±11.1	1988-90	Greenland	1
21.0±1.1	1988-90	Greenland	1
4.3±1.5	1988-90	Greenland	1
12.9±1.2	1988-90	Greenland	1
22.0±1.1	1988-90	Greenland	1
7.16±1.2	1984-90	Greenland	4
10.3±2.1	1984-90	Greenland	4
403-590	1984-87	Greenland	2
3.0±0.0	1983-87	Greenland	1
7.1±1.1	1983-87	Greenland	1
6.7±1.3	1983-87	Greenland	1
2.1±1.3	1983-87	Greenland	1
7.5±1.1	1983-87	Greenland	1
13.4±1.2	1983-87	Greenland	1
30.1	1982	Canadian Arctic	2
44.2±14.2	1982	Alaskan-Beaufort Sea	3

Figure I-1. Mercury Levels in Porpoises from the Northwest Atlantic-1969 to 1992.

Mean levels of mercury in Porpoises from the Northwest Atlantic region from 1969 to 1992 show **no change over time.**

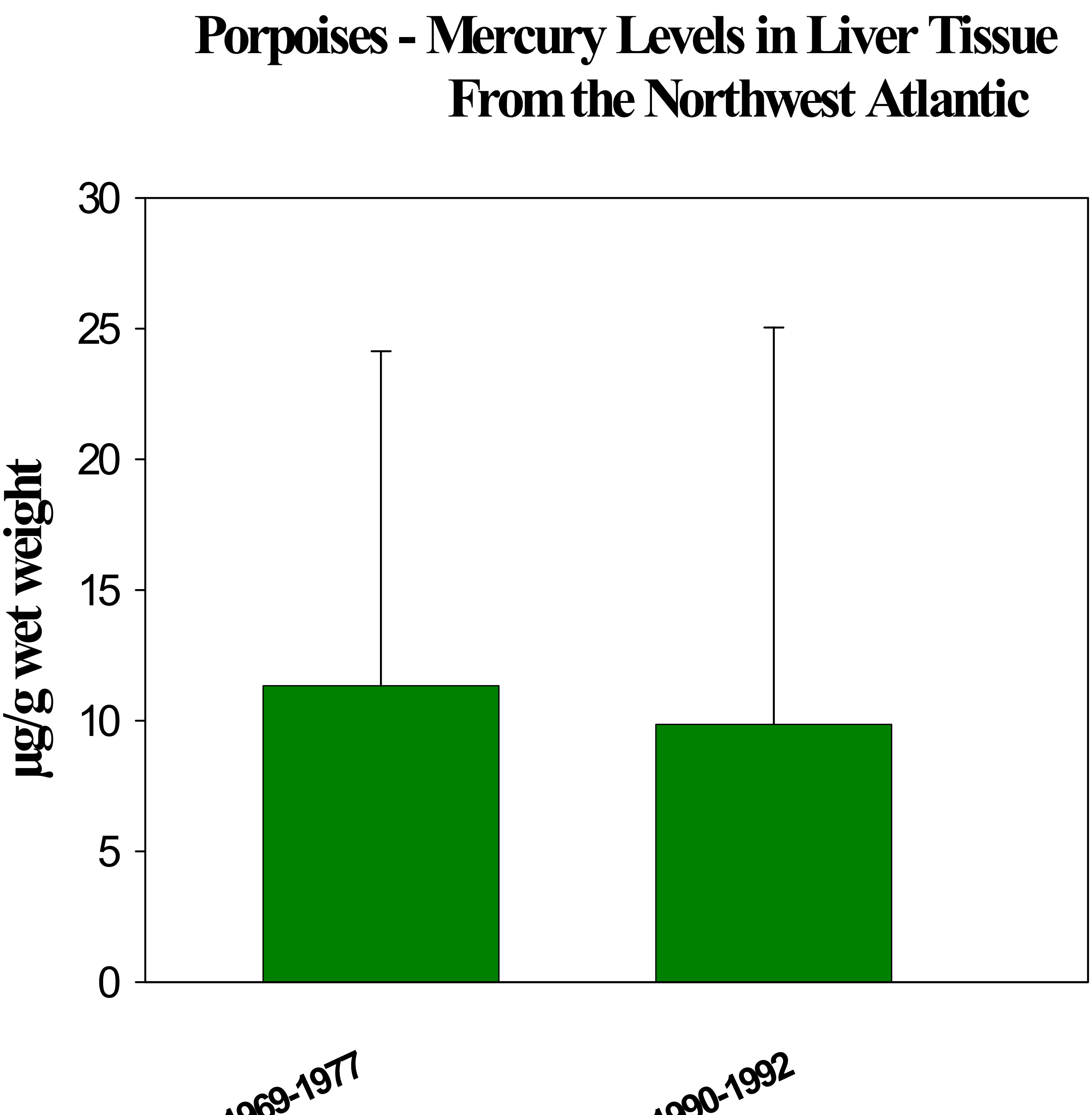
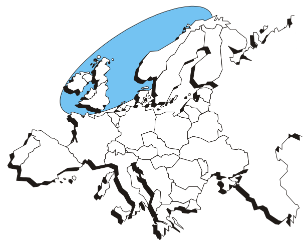


Figure I-2. Mercury Levels in Porpoises from the North Sea-1974 to 1993.

Mean levels of mercury in Porpoises from the North Sea region from 1974 to 1993 showing variable levels depending upon the area being examined. The levels of mercury have **increased** 15 times since 1974.



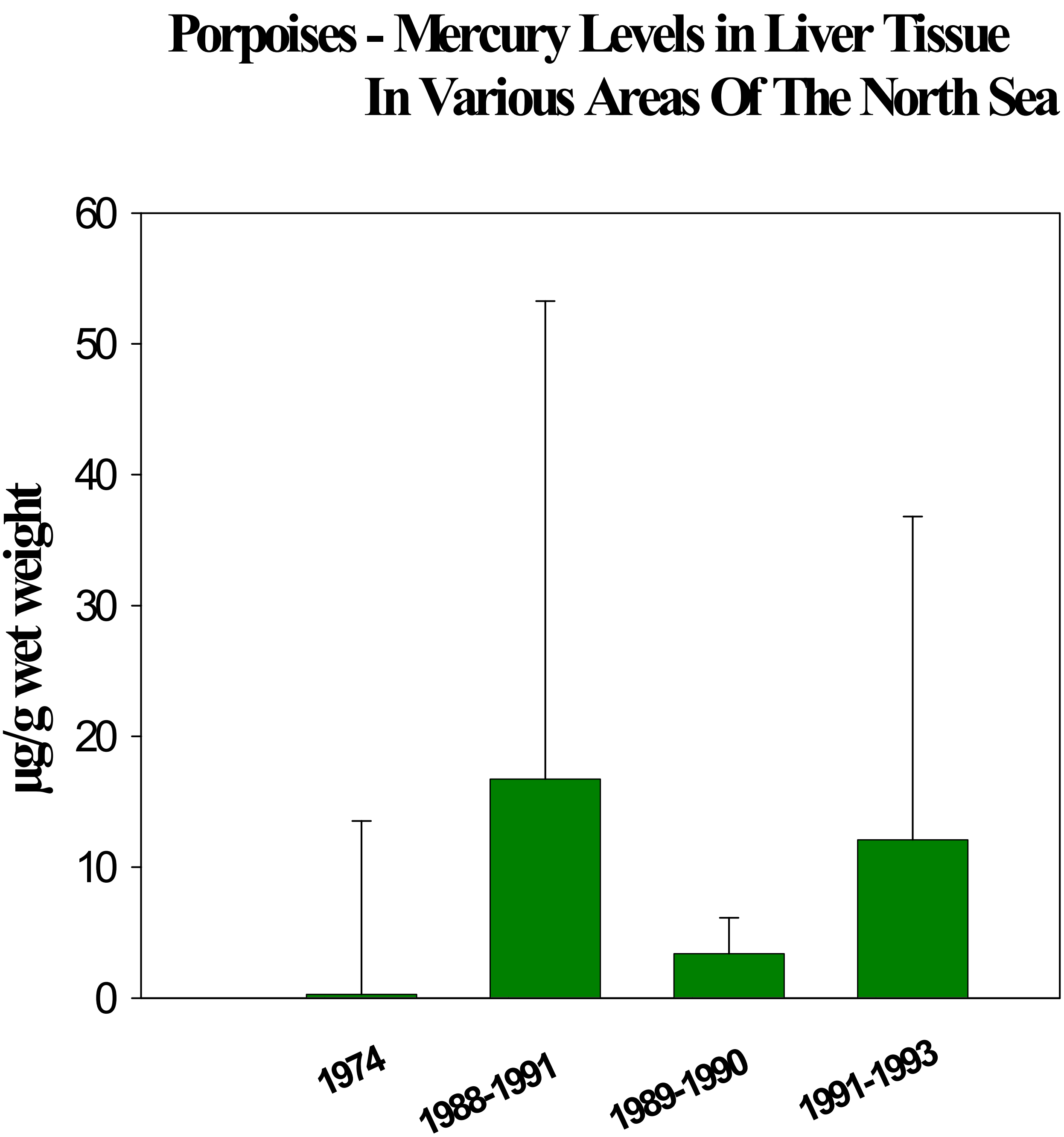


Table I. Mercury Levels in Liver Tissue in Porpoises

Value (mean±SD)	Year(s) Taken	Location	Ref
10±15	1990-92	NW USA	5
26±15	1977	Bay of Fundy, Canada	3
30 (female)	1977	Bay of Fundy, Canada	3
8 (female)	1976	Bay of Fundy, Canada	3
14±9	1976	Bay of Fundy, Canada	3
5±5 (females)	1975	Bay of Fundy, Canada	3
8±6 (males)	1975	Bay of Fundy, Canada	3
3±1 (males)	1974	Bay of Fundy, Canada	3
4 (females)	1973	Bay of Fundy, Canada	3
1±0 (males)	1973	Bay of Fundy, Canada	3
11±9 (females)	1972-73	New Brunswick, Canada	3
10±18 (females)	1972	Bay of Fundy, Canada	3
5±5 (males)	1972	Bay of Fundy, Canada	3
3±3 (males)	1971-73	New Brunswick, Canada	3
1 (female)	1971	Maine, USA	3
3 (female)	1971-72	Rhode Island, USA	3
40±62 (females)	1971	Bay of Fundy, Canada	3
4±5 (males)	1970-73	Nova Scotia, Canada	3
31±26 (females)	1970-73	Nova Scotia, Canada	3
20±2	1970-72	Nova Scotia, Canada	3
10±10 (males)	1969	Bay of Fundy, Canada	3
15±31 (females)	1969	Bay of Fundy, Canada	3
12±25	1991-93	North & Baltic Seas	1
4 (female)	1989-90	Norway	4
1±1 (male)	1989-90	Norway	4
2±2 (male)	1989-90	Norway	4
3±3 (male)	1989-90	Norway	4

5±3 (male)	1989-90	Norway	4
5±5 (male)	1989-90	Norway	4
1±1 (female)	1989-90	Norway	4
2±1 (female)	1989-90	Norway	4
5±6 (female)	1989-90	Norway	4
5±3 (female)	1989-90	Norway	4
14±33	1988-90	British Isles	6
20±40	1988-91	Irish Sea	6
0-11 (males)	1974	Scotland	2
0- 16 (females)	1974	Scotland	2

Table J. Mercury Levels in Liver Tissue in Pygmy Sperm Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
8±0	1997	New Caledonia	1
77±1	1997	New Caledonia	1
14	1997	England	2
12	<1990	Argentina	1
1±1	unknown	South Africa	1
6±6	unknown	South Africa	1

Table K. Mercury Levels in Liver Tissue in Fin Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
2	1992	England	1

Table L. Mercury Levels in Liver Tissue in Sperm Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
15±9	unknown	North Sea	2
72±46	1994-95	North Sea	1

Table M. Mercury Levels in Liver Tissue in Killer Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
88	1995	England	1

Table N. Mercury Levels in Liver Tissue in Bowhead Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
>1, n=3	1992	Chukchi Sea, Alaska	1

Table O. Mercury Levels in Liver Tissue in Walrus

Value (mean±SD)	Year(s) Taken	Location	Ref
0.13	1990	E Hudson Bay	1
0.17	1990	E Hudson Bay	1
0.07	1989	Foxe Basin, Arctic	1
1.1 wet wt	1986-89	NW Alaska	1
0.19	1986-89	Diomede, Gambell, Savoonga, Arctic	1
0.08	1982-88	Foxe Basin, Arctic	1
0.02	1981-84	Gambell, Arctic	1
0.05	1981-84	Savoonga, Arctic	1
0.04	1981-84	Diomede, Arctic	1
0.00	1981-84	Nome, Arctic	1
0.20	1981-84	Wales	1
0.07	1981-84	Bering Sea	1

Table P. Mercury Levels in Liver Tissue in Gray Whales

Value (mean±SD)	Year(s) Taken	Location	Ref
30	1991	San Francisco Bay	1
120	1990	Strait of Juan de Fuca	1
25±16	1989	Kodiak & Tugidak Islands, Alaska	1
63±19	1988-1991	Puget Sound, USA	1
55±25	1988-1991	Washington, USA	1
Undetectable	1984	Port Angeles	1

Table Q. Mercury Levels in Liver Tissue in River Otters

Value (mean±SD)	Year(s) Taken	Location	Ref
4 to 18, n=5	1982-83	Iberian Penn, Spain	1
5±1	1982-84	British Isles	2
2923±2230	1979	Ontario, Canada	3
2 (male)	1979-81	Manitoba, Canada	5
2±1 (male)	1979-81	Manitoba, Canada	5
3±2 (males)	1979-81	Manitoba, Canada	5
5±2 (males)	1979-81	Manitoba, Canada	5
3 (female)	1979-81	Manitoba, Canada	5
2±1 (females)	1979-81	Manitoba, Canada	5
2±1	1979-81	Manitoba, Canada	5
2±1	1979-81	Manitoba, Canada	5
96	1979	N W Ontario, Canada	6
9	<1980	Wisconsin, USA	4

Discussion

"The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) which results in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities"

-The definition of marine pollution by the Food and Agriculture Organization of the United Nations 1986.
(GESAMP report # 30)

In a recent 2001 report, from the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (an advisory group to the United Nations, World Health Organization, World Meteorological Organization, International Maritime Organization and others), listed 14 factors that were "global concerns regarding the deterioration of the marine environment".(40) The same report also states that "increased risks to human health resulting from the **chemical contamination** (author's emphasis) of the oceans remains a major concern".(41) Another 2001 study by GESAMP states that: "The state of the world's seas and oceans is deteriorating. Most of the problems identified decades ago have not been resolved, and many are worsening. New threats are emerging".(42)

It would seem that pollution of the oceans and seas is still a serious problem and it is generally accepted in the research field that the long term effects of pollution are largely unknown, little understood and varies from species to species.(5,9) Collectively, the detrimental effects from 50,000 to 100,000 substances now in daily use- with 1,000 new substances being introduced every year- on the various physiological systems of these species and how this may affect the future of many of these species around the world remains largely unidentified.(43) Consequently baseline values from the data found in this report over large time periods and from various geographical locations throughout the world will help conservation efforts to monitor any presently threatened or at risk species of marine animals and those of the future. These reported data establishes a uniform, standardized biological collection of information on numerous species which fills a large void in the scientific literature.

Long Term Mercury Concentrations

Existing long term data for world wide environmental pollution and its effects on marine animals is extremely limited and is based on either small sample sizes, a limited time scale or small geographical locations.(44) Studies that have looked at various environmental stresses or pollution over long periods of time have shown conflicting or misleading data. For example, a study performed from 1984 to 1999 of oiled seabirds washing up on the shores of Newfoundland showed 62% of the birds had oil on their feathers and that this number hid risen to74% of the animals in the last 5 years of the study.(45) However a study done in the southern part of the North Sea (Netherlands) using birds found from 1977-97 showed a significant decline of oil pollution (46% oiled birds).(46) Another shorter study using birds found in the Netherlands, Germany and Denmark from 1990-92 showed that oil pollution is a chronic problem as oppose to the large, dramatic oil spills that occur periodically.(47) It can be seen that using one study to indicate that there has been a 'decline in chronic oil pollution in the North Sea' should be examined more closely and has to be used in conjunction with other world wide studies to examine the total amount of oil being spilled into our environment.(46) The same could be said for studies looking at any pollutant especially those that can accumulate up the food chain such as mercury.

Even though it is accepted that marine animals seem to have a tolerance to mercury poisoning- due to the protective effect of selenium to allow them to store mercury as a 'neutral' species- increasing the amount of mercury in an ecosystem over time will eventually have a negative impact on various species and eventually humans. The International Workshop on Heavy Metals in the Arctic published in November, 1999 stated that the principle target of mercury is the central nervous system and that the earliest effects are most likely to be behavioral.(48) Though difficult to observe and study, these behavioral effects can 'have significant adverse effects on individuals and alter the maintenance of viable animal populations' such as the decline of the freshwater population of Ringed seals in Finland during the 1960's and 70's.(48) The same Workshop on Heavy Metals also stated that 'information on sub-lethal biological effects on Arctic organisms is limited for a number of reasons', that 'observed levels of Cd (cadmium) and Hg (mercury) in some Arctic marine birds and mammals are high enough to be a concern' and that 'observable effects in wild animal populations have been a challenge to find'.(48)

It is possible that these observable effects in wild animals have been difficult to find due to numerous reasons- the state of decomposition of the bodies, the lack of sufficient numbers, feeding habits and environmental conditions.(49,50) As well, the initial cause of mass strandings or death of large numbers of marine animals can often be hard to conclude. For instance, if mercury poisoning affects the hunting capabilities of the animal(s) through the loss of coordination or loss of vision or renders them susceptible to disease or to organ failure (liver, kidney), this could lead to emaciation, a disorientated state, and disease.(13,51-53) Autopsies performed on animals from mass strandings often described their bodies in the above mentioned terms yet the cause of death is often attributed to a virus or bacteria. However, the underlying cause of the stranding may have been mercury poisoning. Bennett et al. reported in 2001 that Harbor porpoises who had died from infectious diseases had statistically higher mercury levels than animals that died from physical trauma and Siebert et al. reported a similar finding where an association was found between liver mercury, methylmercury levels and severity of disease in porpoises in the Baltic and North Seas.(52,53) Also it has been shown that during times of stress, safe storage sites of mercury such as fat can release its mercury which can affect other organs such as the kidneys.(54) When mercury was fed to 4 Harp seals, the high dose animals (liver total mercury levels of 134 & 142 μg/g) died of renal failure with signs of toxic hepatitis and uremia.(55) It has also been shown that mercury, cadmium, chromium, and selenium have been reported to have effects such as immunosuppression, neuro-toxicity, renal dysfunction, and influence the health and survival of the animals.(56,57) As such, various marine animal species have been used as biomonitoring objects to follow the progress of mercury up through the food chain.

Seals, dolphins and whales are of special interest since these species are consumed by humans in various geographical locations. Looking at mercury levels over time in specific geographical regions, some interesting data concerning mercury accumulation is revealed. As reported in this retrospective analysis, the amount of mercury in the livers of seals found in the Canadian Arctic, east coast of Canada and from Greenland, since 1972, has either remained stable or has dramatically increased.(Figures A-1,A-2,A-3) Narwhals, another northern food source in the Canadian Arctic, have doubled the amount of mercury in their livers.(Figure E-1) Likewise, Polar bears from Greenland have shown a doubling of mercury in their livers since 1983.(Figure H-1) However, Beluga whales, a staple food source for some Inuit people in the Canadian Arctic, have had a decrease in mercury levels since 1981.(Figure D-1) Since 1989 and 1972 dolphins from the British Isles and the Mediterranean Sea have had a six fold and two fold increase in mercury levels respectively.(Figures C-1,C-2) Porpoises from the Northwest Atlantic ocean have had no change in mercury levels from 1969 to 1992.(Figure I-1)

Clearly, it can be seen that despite worldwide regulations and widespread concern for the marine environment, mercury levels in numerous species of animals have increased since the 1960's and 70's. Whether these levels have an effect on individual animals or large population numbers within a species has yet to be proven. However mercury, unlike other chemicals, is essentially persistent- in other words it does not degrade into a harmless substance.(58) Thus whatever mercury is being produced by man-made processes only serves to add to the total overall pool of mercury circulating in an ecosystem.(58) This increasing amount of mercury, combined with hundreds of other pollutants being introduced into the environment, will over time reach a point where there will be ecological problems for all species including humans. A publication from the Conservation of Migratory Species (Bonn Convention) in 2002 reported that 21% of all reported threats to small cetaceans came from pollution.(59) Recent work with dolphins in Sarasota Bay, Florida, has found that newborn bottlenose dolphins are dying in unusual numbers. Although the exact cause has not been pinpointed yet, pollutants in their environment may play a huge role. This may also be true for the deaths of the young of the Northern Fur seals and Killer whales in Alaska.(60)

The amount of mercury in the environment may have reached the point where it has become a danger to humans. The U.S. Environmental Protection agency in a 1997 report to Congress concluded that some adults and populations of wild animals that consume large amounts of mercury contaminated fish were at risk.(61) The U.S. National Research Council in 2000 estimated that more than 60,000 children born each year are at risk of adverse neurodevelopmental effects due to exposure to methylmercury.(61) In recent years, numerous warnings concerning mercury poisoning have been issued. The United States Food and Drug Administration issued a warning to women of childbearing age and young children to limit their intake of tuna, other fish and shellfish due to a high mercury concern.(62) There was an article published in the American Medical Association's journal, JAMA, which stated that 8% of women had higher amounts of mercury than the U.S. Environmental Protection Agency's recommended dose.(63) As well, in the journal, New Scientist, a small study was published that showed that adults were at risk of impaired brain function from levels of mercury that were once thought of as safe.(64)

Variations in Geographical Locations

Geographically, levels of pollutants may vary considerably depending upon several factors: animal species, feeding behaviours, and bioavailability.(65,66) For instance, Harp seals in the Northwest Atlantic are usually divided into two separate breeding groups: the Newfoundland/Labrador and the St. Lawrence Gulf areas. Certain pollutants such as PCBs have been found to be different between these two groups.(67) Our review has found this to be true when comparing mercury levels in seals from across the Canadian Arctic and seals from Greenland seals.(Figures A-1,A-3) Canadian seals had mercury levels of approximately 28 $\mu g\ g^{-1}$ wet weight in 1972/73 with 1992/96 levels of 29 $\mu g\ g^{-1}$ wet weight- basically no change over 20 years. However, the Greenland seals had mercury levels of 0.05 $\mu g\ g^{-1}$ wet weight in 1978/87 but reached levels of 6.5 $\mu g\ g^{-1}$ wet weight in 1994/95- a 13 fold increase. However, when comparing the two geographical areas, the Greenland seals showed almost 5.5 times **less** mercury than Canadian seals. In figure A-4, which looks at the worldwide mercury levels of seals over time, there is a 2.5 fold increase of mercury between 1972 to 1994. When comparing another species, such as dolphins from the British Isles and Mediterranean, the difference in geographical location shows that there is a difference in the amount of mercury between these two groups- with dolphins in the Mediterranean having 17 times more mercury than British dolphins (~350 versus ~20 respectively).(Figures C-1,C-2) These figures show that over time British dolphins had a 6 fold increase of mercury from 1989 to 1998 while Mediterranean dolphins had 2 fold increase between 1989 to 1996. Tissue taken from single Beaked whales between 1993 to 1998 from different areas around the world shows a gradual increase in mercury levels from 250 to 330 $\mu g\ g^{-1}$ wet weight.(Figure F-1) In Minke whales, based on 2 animals from different regions of the world, there is a dramatic increase (250%) of mercury.(Figure G-1) From 1974 to 1993, Porpoises from around the North Sea area, have shown an almost 15% increase in mercury.(Figure I-2) Surprisingly, Pilot whales from around the Atlantic region show a decrease in mercury, however, this may depend on what region the animals came from. It is well known that Pilot whales from the Faroe Island have high mercury levels that can cause neurological problems in the children.(68)

As it can be seen, the data from different geographic areas show a similar trend of increasing mercury levels in various marine mammals from around the world. The same can be said for other species of animals. Recent reports (2003) reveal that certain fish who travel huge distances such as tuna, shark, sailfish, which were once thought to be 'safe', must now be eaten in moderation or only a certain number of portions per month especially by pregnant women and young children.(62) As Third World countries have lower standards for mercury emissions and with the evolution of rapid transportation of foodstuffs around the world, geographical location is no barrier against mercury poisoning. A family in the United States suffered mercury poisoning where they had 7 to 11 times the normal amount of mercury in their blood from eating fresh seabass that was imported from a Third World country.(69) Mussels, from the southern coast of Brazil, contained mercury that ranged from 0.12 to 17 mg/kg dry weight in 1997 to 0.051 to 0.22 mg/kg dry weight of mercury in 2000. Though these levels are deemed safe, it shows that mercury levels have remained stable in that area.(70) In Canada, apart from hunting the seals for their pelts, seal oil is used as a health food supplement being rich in omega 3 fatty acids and is exported to China and Japan. New ways of marketing the seal meat include seal salami, sausages, stew, canned meat and as pet food.(71) Figures A-2 and A-3 in this report shows that mercury levels in Canadian seal pups have risen almost 3 times from 1972 to 1976 and that Greenland seals have increased their mercury levels 6 times between 1978 to 1998. If the seal meat is contaminated with mercury, it could prove to be high enough to affect various populations around the world who may already have borderline or higher levels of mercury in their bodies.

Mercury and Marine Animals

So is there a connection between the release of mercury into the natural environment and its effects on marine mammals? A study published in 1994 showed that 3 marine mammal mass mortality events from the European, United States and Mediterranean areas between 1987 to 1992, which caused the death of 27,500 dolphins and seals, had evidence of being associated with pollution.(51) A 1993 report in dolphins showed that liver disease and mercury levels were linked together and concentration levels in excess of 50 ppm or the equivalent to 50 µg/g wet weight was found to be toxic.(51,72) In another study from 1995, liver samples were taken from Bottlenose dolphins who had stranded in separate events from around the Gulf of Mexico in 1990. These dolphins had levels of mercury that ranged from 5.1 to 87.8 µg g^{-1} wet weight- some animals obviously had levels which were well above the toxic level of 50 µg/g wet weight. Figures C-1 and C-2 of this report confirms that dolphins in the Mediterranean Sea have had mercury levels of **over 200 µg/g wet weight** since 1972 and the most recent study from 1996 shows that these dolphins to have mercury levels of **almost 800 µg/g wet weight**. Dolphins from the British Isles have had relatively low levels of mercury until 1996 where it jumps to ~ **120 µg/g wet weight**.

Has mercury bioaccumulated to high enough levels to be toxic and cause death in marine mammals? The introduction of this report states that mercury causes developmental problems in human children and various renal problems in human adults (Table #1). Adult seals who had chronic high doses of mercury fed to them suffered from renal failure, toxic hepatitis (swelling of the liver), changes in gonadal and adrenal steroid synthesis and death. A study done on wild Grey seal pups in a breeding colony showed that 26% of their deaths were due to starvation and 11% of the pups had jaundice severe enough to be the cause of death or to be a secondary problem- **all symptoms similar to mercury poisoning**.(73) It is possible that these pups were affected by high mercury levels causing them to have severe neurological dysfunction (disturbed physical growth or poor coordination) or had liver dysfunction which caused severe jaundice- all leading to their deaths. Some whales and dolphins form very strong bonds, are very social and have a strong pod cohesiveness which can be extremely deadly in combination with mercury poisoning. In one stranding event in 1986, a pod of 30 Pilot whales stranded in the Florida Keys. To help coordinate the rescue, 5 young whales were placed in a shallow bay. They 'appeared confused' but active. When a larger male was brought in, he immediately beached himself on shore. The other 5 younger animals beached themselves beside the adult.(75) The pod or some key members of the pod could have been affected by high mercury levels and were demonstrated classical symptoms of mercury poisoning such as confusion, visual or peripheral impairment, and auditory impairment (very important in whales and dolphins).

Obviously, identifying mercury poisoning in wild animals is difficult. To scientifically prove that mercury plays a role in the death of a specific animal or in groups of animals is as equally challenging. However, the task of identifying mercury's role in the death of individuals or groups and its influence in the survival of many species including mankind, is further complicated by other stresses or factors that have been introduced into the marine environment.

Other Environmental Factors

The list of human abuse to the various marine ecosystems includes pollution, habitat destruction, over fishing, noise pollution, invasion of foreign species plus many others which, in the space of 50 years, have caused a significant decline of fish, birds, seals, sea otters, dolphins, and whales around the world.(76-78) The overall global effects on specific species or populations is largely unknown and there remains 'a dearth of information on trends at a global scale'.(79)

Pollution includes a huge number of chemicals (heavy metals, radioactive materials, halogenated organics) and substances (oil, sewage, dredging materials) which as stated earlier can amount to hundreds or even thousands of substances being dumped yearly into the various marine environments.

What effect a single or a combination of all of these chemicals can have on marine mammals remains largely unknown. The Oslo and Paris Commissions (OSPAR) in their 2000 Quality Status Report on the North Sea stated that the **limited knowledge** (author's emphasis) in the following areas were of particular importance: 1) of organic substances, there was "a general lack of data"; 2) that in chemicals, the "information on inputs, environmental concentrations and biological effects was not readily available'; and 3) that there was limited data on the "chronic and combined effects of hazardous substances on organisms, and effect concentrations and ecological impacts of substances affecting the hormone system".(80) As marine mammals around the world are constantly being exposed to numerous chemicals and substances, the following section will illustrate how deadly some pollutants are on their own.

Other Toxic Metals

The following metals are commonly analyzed and reported in the scientific literature- arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.(81) As each of these metals may accumulate to be stored in high amounts within individuals, it is extremely difficult to interpret their toxic effects.(82) Table 2 shows some of the various physiological effects that these metals can cause.

Table #2. Physiological Effects From Various Metals

System	Metal	Toxicological Effects
Gastrointestinal	Arsenic, Chromium, Copper, Lead, Zinc	Diarrhea, black feces, blue/green feces, vomiting, colic, loss of appetite, increase of liver enzymes
Neurological	Arsenic, Lead, Mercury, Selenium, Zinc	Depression, hyperactivity, convulsions, blindness, tremors, coordination loss, lower body paralysis
Circulatory & Excretory	Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, Zinc	Dehydration, anemia, loss of weight, unable to walk, renal failure

Modified from: CRC Handbook of Marine Mammal Medicine: Health, Disease and Rehabilitation. CRC Press, Boston. 1990.

As it can be seen, poisoning from metals such as arsenic can have effects on numerous systems of the body while others, such as cadmium, can cause damage to only one system. It is interesting to note that, selenium, as stated earlier in this report, can combine with mercury to change mercury into a 'safe' form in the livers of marine mammals. However, selenium can also cause serious problems in large amounts. Therefore selenuim's protective effect of neutralizing mercury's deadly effects must have a certain threshold before it too turns into a deadly poison. Combinations of numerous heavy metals can cause various damage. Two recent studies have reported that exposure to heavy metals (mercury, selenium and zinc) in Harbour porpoises played a significant role in their deaths and that in Ringed seals, the arsenic stored in their blubber could potentially cause cancer.(52,83)

Synthetic Organic Compounds

Polychlorinated biphenyls (PCB's) and dichlorodiphenyl-trichloro-ethane (DDT) are part of a large group of chemicals that are persistent and therefore can readily accumulate up the food chain.(84) Their ability to change hormones and cause reproductive, developmental, and skeletal problems means that they can have a strong influence on the survival of animal populations much like mercury.(84)(Table 3) In the 1988 deaths of 20,000 Harbour seals in Europe, it was concluded that a previously unidentified virus was the cause of death. However, it was also acknowledged that the immunotoxic effects of chemicals like PCBs, and DTT contributed to the epidemic.(84) These chemicals may also be playing a part in the extinction of other marine animals such as the Killer whales on the Pacific coast of North America.(85) These chemicals enter their bodies from eating seals, porpoises and other marine mammals or salmon depending on whether it is a Transient (free roaming group) or Resident (native to one area) pod. In 2002, a single dead female Killer whale washed up on the shore that had toxic PCB levels in her blubber **too high to measure.**(85) Presently, toxins pose the greatest threat that these Pacific Killer whales have faced since the 1960's and 70's when they were captured for aquariums.(85)

Table 3. Physiological Effects From Various Organic Substances

System	Substance	Toxicological Affects
Reproduction	PCBs	Alteration of menstrual cycle, embryo absorption, abortions, death of embryo/fetus, premature birth, still birth, lowers testosterone levels
Immune System	PCBs DDT	Suppression of immune system, tumor growth, skull lesions
Development	PCBs, DDT	Behavioural responses, impaired growth
Digestive	PCBs	Gastric ulcers

Modified from: Encyclopedia of Marine Mammals: W.F. Perrin, B. Wursig, J.G.M.Thewissen eds.: Academic Press, New York, 2002.

Other Threats

Around the world, ecosystems and the numerous species of animals living within them are showing signs that the environment is under stress. For example the Bering Sea/Gulf of Alaska ecosystem has been studied with respect to sea trends and the relative abundance of various species from 1940 to 2000.(86) Within that ecosystem, the Stellar Sea Lion population has dropped 20%, Bowhead whales have dropped 70%, Spectacled Eiders have dropped by 90%, and herring and crab dropped from 100% in 1960 to 5% in 1985.(86)

Another example of human threat to a marine mammal is the sudden increase of Sea Otter deaths along the California coastline where it has been found dead or sick in record numbers.(87) As of April, 2003, 92 otters have been found washed up on beaches which represents a 25% increase from the previous highest number of deaths set in 1998. Biologists estimate that the bodies found in that 4 month period alone represents ‘about 60% of the total number of California otters that die each year.’(87) In the Spring census of 2002, the sea otter population was 2,139- down 10% from 2,377 in 1995. The cause of these deaths were found to be intestinal infections caused by a microscopic parasite common in house cats. It is believed that this disease infected the Sea Otters from people flushing their cat litter down the toilet where the parasite found its way into the natural environment.(87)

There remains contradictory reports as to how much damage is being done to the environment- in fact some believe that the environment is cleaner now than it was 40 or 50 years ago. Bjorn Lomborg in his book, The Skeptical Environmentalist, insists that levels of persistent pollutants (DDE, Dieldrin, HCB- all found in pesticides) have dramatically decreased in U.S. freshwater fish and in Great Lakes Herring gull eggs between 1969 to 1995.(88) However, according to the United State Environmental Protection Agency, pesticide sales **have increased from $500 million in 1962 to $11.9 billion in 1997.**(89) All of this pesticide, which contains these persistent pollutants including mercury, is washed off of the land where it is sprayed into the creeks, rivers and lakes and eventually finds its way into the seas and oceans. As mentioned earlier, these pesticides become part of the thousands of chemicals being released into the oceans each year.

A November 2003 report from the Centre for Science and Environment reveals that in the past 7 years the total importation into India of mercury and mercury compounds rose from 285 tonnes to 1,858 tonnes.(90) Meanwhile, the importation of organomercury compounds such as pesticides has increased from 0.7 tonnes to 1,312 tonnes.(90) Without the proper storage and handling procedures, this amount of mercury will be a source of environmental pollution around the world for decades to come.

It is generally accepted that marine mammals have developed protective mechanisms to accumulate harmful substances in their bodies . However, no matter what species is studied, the over exposure of any kind of substance or chemical which causes it to accumulate near levels of poisoning must have a threshold. This threshold is different for each species, for each member of that species and within separate populations of that species. The same can be said for the numerous other factors and stresses that mankind has introduced.

“If an animal has a chronic level of metal in its system, the ingestion or absorption of even a minor amount of additional metal may overburden the animal’s ability to process the toxin and the animal may be pushed into a subacute or acute poisoning state. If the animal is subjected to stress, even something as normal as pregnancy, the increase in metabolic rate may cause activation and/or metabolism of stored metals and move the toxin from a relatively “safe” tissue storage site (fat) to a more sensitive one (liver, kidney, nervous system, etc.) and in so doing produce clinical symptoms of poisoning.”.(54)

It is obvious that many marine mammals have reached their chronic threshold from the annual exposure of thousands of metals or substances being released into their habitat. Unfortunately it may be too late to prevent the extinction of many species.

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Conclusion

"Sometimes when we change the ecosystem we create other problems that we do not anticipate.

I am always leery about trying to control the ecosystem."

The Honourable Herb Dhaliwal- Canadian Fisheries Minister,

Testimony to the Senate Standing Committee on Fisheries-15 February, 2000.

"But the oceans are incredibly big that our impact on them has been astoundingly insignificant..."

Bjorn Lomborg, The Skeptical Environmentalist-

Measuring the Real State of the World 2001, page 189.

The above quotes show the various points of view concerning mankind's influence on the marine environment which consists of a delicate weaving of many different ecologies and thousands of species living together. Based on the most recent data, the unprecedented growth in the human population (1.6 billion to over 6 billion in the last century alone) is expected to exceed 8 billion by 2020 and could be as high as 12 billion by 2050.(91) This has placed and will continue to place the world's biodiversity under considerable stress. Based on data from 2001, the marine ecosystems will be continually **over exploited** and will provide less protein for the human population in the future.(91) As a result, marine mammals will have to face 2 new threats: as the food resources continue to shrink in the oceans and seas, marine mammals will become major competitors for the dwindling marine food stocks; and as the food stocks continue to fall, they themselves will become a new source of protein.(91) This lack of food will only add to the stress that marine mammals already face from other threats such as pollution and will only hasten the extinction of many species in the coming decades.

There are different views on how severe an impact mankind has had on the environment and it is believed by some people that environmentalist are using scare tactics to get their points across. Steven Milloy, author of Junk Science Judo: Self Defense Against Health Scares and Scams, has stated that:

“Everyone’s exposed to substances and there’s no evidence that low levels people are exposed to are harming anybody. It’s a waste of time and money that only serves to scare people.”(92) In today’s world of politics and the power of media exposure, this may be true. However, there is plenty of evidence from the past and present to suggest that to ignore the scientific data and trends of what is presently happening within our environment can have deadly consequences. When looking at mercury, these consequences could also include hundreds of thousands of children being born with neurological and developmental handicaps, creating untold hardships on families and communities, and causing the extinction of certain populations such as the people living in the Arctic or on the Faroe and Seychelle Islands. Though it may not be conceivable to stop the production of mercury completely, it is only logical to try to recover as much as possible, thereby limiting the amount of damage to our oceans, marine animals and ourselves.

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Appendix I

Limitations of Scientific Data

There are serious limitations in the reporting of scientific data. As controversial as this may seem, the fact remains that scientific data are often presented in a manner that at times seems to be dissimilar and inconsistent. This inconsistent presentation of the data are not the fault of the authors but of the editorial policies of the journals in which the data are being published. For example, many journals will ask the authors to shorten their manuscripts to allow for only a certain number of published pages. As well, the editor and/or reviewers may ask for the removal of certain information that would make it possible to compare the data between other studies. There are numerous research studies that contain huge amounts of information that is interesting but can not be cross compared with other studies when looking at different geographical location or another time interval. Looking at a recent report published in 1999, several drawbacks can be found. Henry and Best published an excellent study on the concentration of metals in marine mammals from Southern Africa in the Journal of Cetacean Research and Management.(93) They published heavy metals values from the livers, brain, kidney, and muscle of 178 individual marine mammals from 23 different species of cetaceans (note: their abstract states from "323 different cetacean species"). These biopsies were taken between 1982 to 1990 except for 3 animals- no mention of the date for the three animals are given or what groups these three animals were placed in. The mercury liver data is presented in 6 species of cetaceans as mature versus immature with no age description be able to classify exactly the ages and when looking at mercury liver levels in mature animals, they used only 3 or more mature specimens only. There are numerous tables and graphs showing details of each animal or of each species, however there is no way to discern which animals were used to study mercury levels.

In addition, the presentation of the data is not consistent from one journal to another. For example, data may be presented as mean ± Standard Deviation (SD) or mean ± Standard Error (SE). If a person assessing the data is unfamiliar with the differences between an SD or SE, the information could be misinterpreted to appear to be artificially consistent. SE data grossly underestimates the variability of the data compared to SD data. For example, mercury levels of 181 ± 50 SD would show as 181 ± 10 SE if 25 animals had been studied. Obviously the SE data shows a tighter range than SD.

There are also no consistent rules for the units used to represent data. For example, mg/kg, $\mu g\ g^{-1}$, parts per million and mean concentrations are all used to express data depending on the policies of the journal or editors. The conversion of the data into say, $\mu g\ g^{-1}$, could result in the data looking larger than if it was as parts per million.

Another confounding inconsistency is which tissue or organ is studied or reported. Each organ or tissue stores a pollutant in various amounts depending on numerous factors such as solubility or how it is metabolized or broken down. Using mercury as an example, the liver would store mercury in high amounts, with blubber as the second highest organ for storage, and kidney and skeletal muscle storing the least. However, some data are presented in muscle or blubber only with no liver tissue being examined, thereby making it impossible to compare this information1.

A consensus of how data should be represented, all necessary information being given and all of the data using the same units should be mandatory throughout all of the scientific journals. This would lead to a conformity throughout the scientific literature that publishes data in an efficient, precise and detailed manner which would lend itself to long term, geographical studies and analysis.

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