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ALASKA HARBOR SEAL (*Phoca vitulina*) CONTAMINANTS

A Review with Annotated Bibliography

Rebecca S. Papa
Paul R. Becker

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
NIST Charleston Laboratory
Charleston, SC 29412

NIST

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology
Gaithersburg, MD 20899-0001

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U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary
TECHNOLOGY ADMINISTRATION
Gary Bachula, Acting Under Secretary for Technology
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Raymond G. Kammer, Director

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PREFACE

The numbers of harbor seals (*Phoca vitulina*) have declined steadily and substantially over the last 2 decades in the Central and Western Gulf of Alaska, including Prince William Sound. Although the reasons for this decline have not been identified, hypotheses have included fishery interactions, changes in availability of food resources, human harvests, disease, increase in predation, increase in disturbance, and pollution. The decline of the harbor seals in this region of Alaska has coincided with the decline in the numbers of the Steller sea lion (*Eumatopias jubatus*), suggesting common reasons for the decrease in numbers of both pinniped species.

Although the presence of contaminants has been suggested as one possible causative factor in the decline of both the harbor seal and Steller sea lion, very little information is readily available on contaminant concentrations in these animals. As an initial step in the development of a database that can be used to define the types of studies needed to address the possible role of anthropogenic contaminants in the decline of harbor seals, existing data and information on levels of contaminants in the harbor seals of Alaska, the contiguous United States, and other areas of the world were reviewed. This report provides references and current scientific literature, as well as "gray" literature and unpublished databases.

Although the results of past research and monitoring in Alaska were emphasized, comparative information was available from Canada, other areas of the North Pacific, Northern Europe (particularly the Baltic Sea region), and the North Atlantic and is included in this report. Information on other marine mammal species is also included only as it lends to the interpretation of the harbor seal data.

This report is divided into three sections: (1) a synthesis of information based on the review, (2) tables that summarize the published data, and (2) an annotated bibliography. The annotated bibliography is provided as a hard copy in this report, as well as on PC disk (Pro-Cite 3.1 for Windows). The Pro-Cite program will allow for entering additional references to this bibliography as they are published. This bibliography is divided into two parts, a database for references containing vital information on harbor seals, both in Alaska and other parts of the world, and a second database that includes other supplemental information, such as research relating to contaminants and other marine mammals, including other pinniped species and cetaceans. Currently, 432 references are entered, each including an abstract and a keyword index. Many of the "gray literature" reports have no abstracts; therefore, abstracts have been written for inclusion in this bibliography. The great majority of the information on contaminants and their potential health effects on harbor seals in this volume (47%) is derived from European studies. Additional information is derived from studies of other pinniped species and, in some cases, small cetaceans.

Additional annotated bibliographies are planned and will include the following marine vertebrates: (1) additional marine mammal species, (2) sea turtles, and (3) colonial seabirds. These bibliographies will provide initial guides to the literature on contaminants in these organisms, and will be published in hard copy report form and on PC disks in Pro-cite 3.1 for Windows. PC disks containing the current bibliographies can be obtained by contacting:

Paul R. Becker, NIST- Charleston, 219 Fort Johnson Road, Charleston, SC 29412
Telephone: 803-762-8503; Fax: 803-762-8700; Email: paul.becker@nist.gov

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DISCLAIMER

Certain commercial equipment or instruments are identified in this paper to specify adequately the experimental procedures. Such identification does not imply recommendations or endorsement by the National Institute of Standards and Technology nor does it imply that the equipment or instruments are the best available for the purpose.

SECTION I

CONTAMINANTS IN ALASKA HARBOR SEALS: A SUMMARY OF THE AVAILABLE DATA

BACKGROUND

Harbor seal (*Phoca vitulina*) distribution includes temperate and subarctic coastal waters of the North Pacific, North Atlantic, and contiguous seas. In Alaska, harbor seals inhabit the coastal areas and offshore islands from Dixon Entrance to Kuskokwim Bay and Nunivak Island (Fig. 1). They are distributed in small groups (25-250 animals) along the shorelines of southeast Alaska, the south side of the Alaska Peninsula, the Aleutian Islands, and northern Bristol Bay; and in larger groups (>500 animals) in fjords with tidewater glaciers in southeast and southcentral Alaska, and in major estuaries (Hoover-Miller, 1994). These animals occur primarily in coastal waters within 20 km of shore, often aggregate in estuaries and protected waters, and are thought to have strong affinity to specific haulout areas. Haulout sites include sand beaches, tidal mud flats, offshore rocks and reefs, and man-made objects. Harbor seals are sedentary animals that feed, reproduce, and rest near or on shore and are top-level trophic consumers. Because harbor seals feed at high trophic levels (fish, octopi, etc.), they have the potential for relatively high organochlorine contaminant concentrations in their tissues and are good indicators of bioaccumulation.

Anthropogenic contaminants and their impacts on marine mammals have become a widespread concern among biologists over the last several decades. Organochlorine pollutants (e.g., dichlorodiphenyltirchloroethane (DDT), polychlorinated biphenyls (PCBs), chlordane, toxaphene, dieldrin, etc.) constitute a multitude of compounds that were not present in the natural environment before the first quarter of the 20th century. It wasn't until the 1960s that these contaminants were first detected in tissues of marine mammals (Holden and Marsden, 1967). Because organochlorine compounds are lipophilic, toxic, and easily stored in body fats of animals, most marine mammals, which feed at or near the top of the food web, are excellent monitoring tools for determining bioaccumulation of contaminants and long-term effects concerning global pollution associated with industrialization.

The presence of contaminants has been suggested as one possible cause for the decline of several marine mammals species, including the harbor seal (*Phoca vitulina*). The number of harbor seals has declined steadily and substantially over the last 2 decades in the Central and Western Gulf of Alaska, including Prince William Sound and the Aleutian Islands. The concern with the decline in this region of Alaska has been magnified because it has coincided with the decline in the Stellar sea lion (*Eumatopias jubatus*) population, suggesting common reasons for the decrease in numbers of both pinniped species. With the insufficient amount of information currently available on contaminant concentration loads in harbor seals in Alaska and the extensive increase in human industrial activities that this region has been experiencing, it is imperative that a database be established. This database can be used to define what studies need to be conducted to evaluate what role anthropogenic contaminants have on the decline of harbor seals. As an initial step in the development of this database, existing data and literature on contaminants in the harbor seals of Alaska, as well as other regions, have been compiled and reviewed. The amount of literature available on harbor seals is concentrated in areas of Northern Europe, particularly the Baltic Sea region, as well as Canada and the North Atlantic. From this, scientists can only suggest that organochlorines and other contaminants may play a role in toxicological and physiological effects, such as reproductive dysfunctions and immunosuppression, and could be a causative factor in the decline of these animals in Alaska.

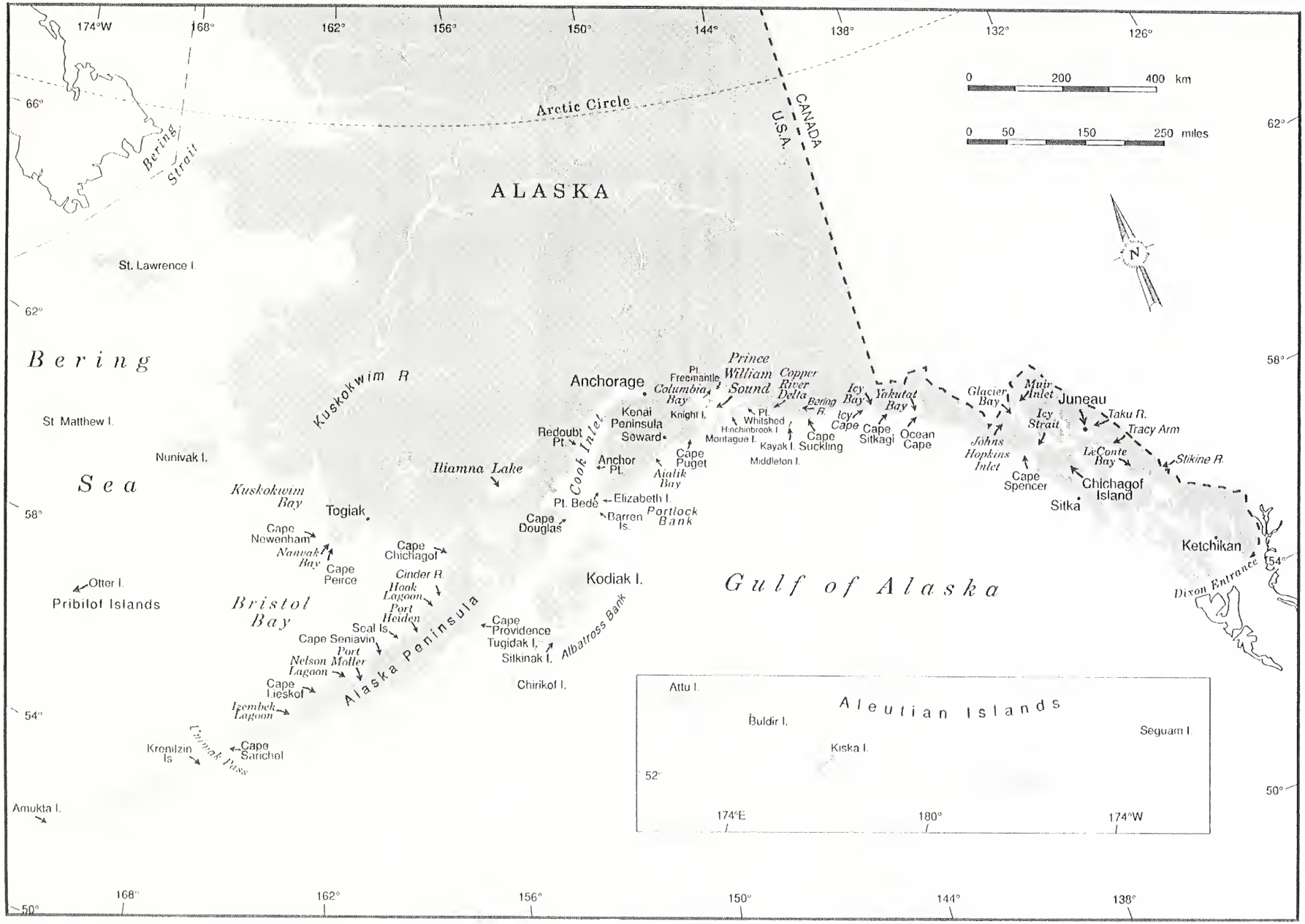

Figure 1. Harbor seal (*Phoca vitulina*) distribution in Alaska (taken from Hoover-Miller, 1994).

Currently, 152 references have been entered into the bibliography (Section III) that pertain to vital information on harbor seals worldwide and approximately 20 percent of those include data for Alaskan harbor seals. The literature that is available from Alaska is limited and almost all previous research has concentrated on harbor seals from Prince William Sound, Southeast Alaska, and Kodiak Island. Earlier reports focused primarily on persistent organic pollutants, such as DDT and PCBs, but more recently heavy metals, particularly mercury, and radionuclides have also become a concern as well as recent oil spills, including the 1989 *Exxon Valdez* spill. Because of the natural occurrence of heavy metals and some petroleum hydrocarbons, specifically those compounds found in crude oil, it is even more difficult to assess the effects they have on harbor seals. With the insufficient amount of data available, the contaminant concentration loads in Alaska harbor seals are not well understood, which makes it essential that a database be compiled that can help scientists to evaluate the information that is available to determine the impact these compounds do have on the health of harbor seals in Alaska.

HEAVY METALS

Heavy metal concentrations in marine mammals are usually reported for liver and kidney, with some data published for muscle, blood, skin, and hair. For many of the trace elements in marine mammal tissues (including heavy metals), little is known of what concentrations are within the normal ranges for a particular species. Concentrations of essential trace elements, such as copper and zinc, are generally characterized by relatively narrow ranges of values within a species and, for many elements, the ranges are similar from one species to another. The concentrations of selenium in marine mammals vary much more widely than most other essential elements; however, this is probably due to its relationship to the accumulation of mercury and the positive correlation between the two metals in the livers of animals that accumulate mercury. The nonessential, potentially toxic elements, such as arsenic, cadmium, mercury, and lead, show the greatest variability with concentration ranges often spanning several orders of magnitude.

A summary of data published on heavy metal concentrations in the tissues of harbor seals, worldwide, are presented in Section II, Tables 2.1 - 2.3. Only two papers were found that report the concentrations of heavy metals (i.e., cadmium, lead, arsenic, mercury, and selenium) in Alaska harbor seals (Anas, 1974; Miles, et al., 1992) but these data were for animals that were sampled 20 to 30 years ago in Kodiak Island (Gulf of Alaska) and the Pribilof Islands in the southern Bering Sea. The geometric means and value ranges for these data are presented in Table 2.1 (Note that one paper was published in 1992, but the data were based on samples collected in 1976 through 1978).

The available information for the contiguous United States is not much better (Table 2.2). The most recent data are for cadmium, copper, lead, nickel, mercury, and selenium concentrations in blood collected 7 to 9 years ago from harbor seals from southern Puget Sound, San Nicolas Island, San Francisco Bay, and on the Monterey, California coast (Kopec and Harvey, 1995). The liver concentration values for these heavy metals have been published for harbor seals from Puget Sound (Calambokidis et al., 1984), but these animals were sampled 16 to 26 years ago. Although it appears that European studies have concentrated on chlorinated hydrocarbon contaminants in harbor seals, some relatively recent (10 years old) heavy metal data (i.e., mercury, selenium, cadmium, and lead) are available for this species from Norway (Skaare et al., 1994), the coast of Germany (Wenzel et

al., 1993), and the coast of Sweden (Frank et al., 1992) (Table 2.3). The best comparative data for Alaska harbor seals are the mercury and selenium concentrations reported in liver and kidney from this species sampled in the Sea of Okhotsk in 1989 (Himeno et al., 1989).

Cadmium. Cadmium is a nonessential element, with limited metabolic regulation by mammals. Highest concentrations occur in kidney and liver of mammals and birds, with most of the body burden occurring in the kidney. Cadmium has an extremely long half-life (30 years in humans) and unlike other metals, including mercury, little or no cadmium is transferred from female to newborn via lactation. As in the case of mercury, cadmium is incorporated in a metallothionein complex in the liver and kidney and may combine with selenium to form an insoluble cadmium selenide complex, thereby reducing the toxicity of the metal (Martoja and Viale, 1977). Cadmium concentration levels reported for harbor seal tissues are shown in Figure 2.

Miles et al. (1992) reported kidney concentrations of this metal in harbor seals sampled near Kodiak Island in 1976 to 1978 ranging from 0.3 mg/kg to 44 mg/kg wet mass for both male and female animals (Table 2.1) which lies within the range reported for northern fur seals (Zeisler et al., 1993) and bowhead whales (Bratton et al., 1997). This range was substantially narrower than has been found for walrus (Taylor et al., 1989; Warburton and Seagars, 1993). No cadmium data were found for harbor seal kidney tissue from the contiguous United States or for areas outside the United States.

Mercury. Mercury is a non-essential, toxic trace element that tends to concentrate to its highest level in liver tissue. The relatively high concentration values for this element in marine mammal tissues are well known. The database on mercury in marine mammals is probably the largest of all the heavy metals. Concentration values of mercury among species, within species, and among geographical areas vary widely. Since it is not easily regulated internally by vertebrates, this element tends to bioaccumulate. The organic form, methylmercury, has a relatively long half-life and is relatively toxic. There is evidence to support the idea that both seabirds and marine mammals have the metabolic ability to de-methylate the methyl mercury, converting it to inorganic mercury, which is less toxic, can be stored in relatively high levels within a metallothionein complex or selenium complex, and is eventually excreted. This ability to de-methylate organic mercury appears to be an adaptive means of maintaining high body burdens derived from fish prey high in mercury content. The de-methylation ability may not be present in newborn and young animals; at least this appears to be the case for some pinnipeds. Mercury concentration levels reported for harbor seal tissues are shown in Figure 3.

Anas (1974) reported total mercury concentrations in livers collected in 1971 from Pribilof Island harbor seals as ranging from 0.6 mg/kg to 8.9 mg/kg wet mass. These values are comparable with concentrations reported recently by Mackey et al. (1996) of ringed seals from Norton Sound (0.45 mg/kg to 5.2 mg/kg wet mass), and for northern fur seals from the Pribilof Islands (Zeisler et al., 1993), and are substantially less than those reported by Miles et al. (1992) for the harbor seals sampled in the Kodiak Island area in the late 1970s (0.4 mg/kg to 72 mg/kg wet mass). As a comparison, ranges of total mercury reported for this species in the contiguous United States have been 3.3 mg/kg to 78 mg/kg wet mass for Puget Sound (Calambokidis et al., 1984), and 16 mg/kg to 138 mg/kg wet mass for the Northeast United States (Lake et al., 1995). No methylmercury values have been reported for harbor seals in the United States.

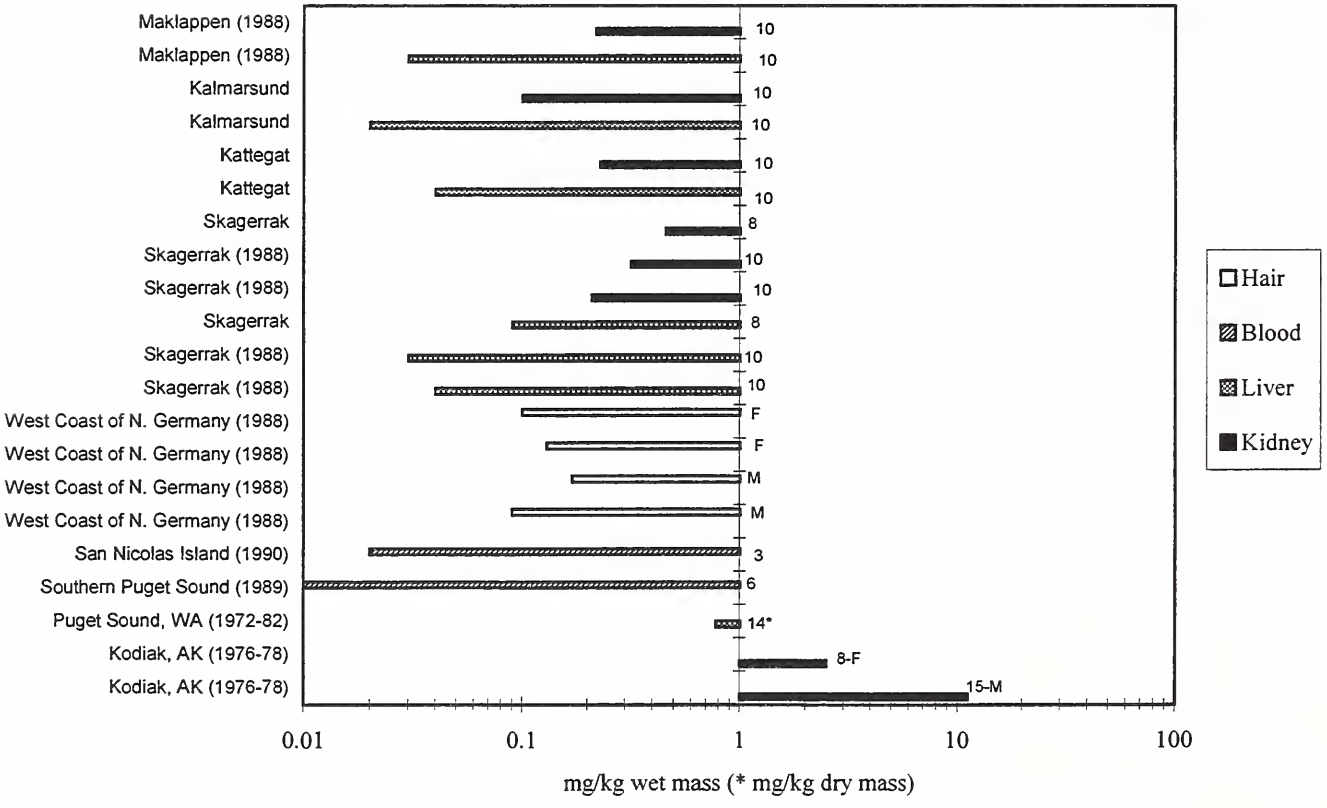

Figure 2. Concentration values (mean, n to the right of mean) of cadmium in tissues of harbor seals (M = male, F = female).

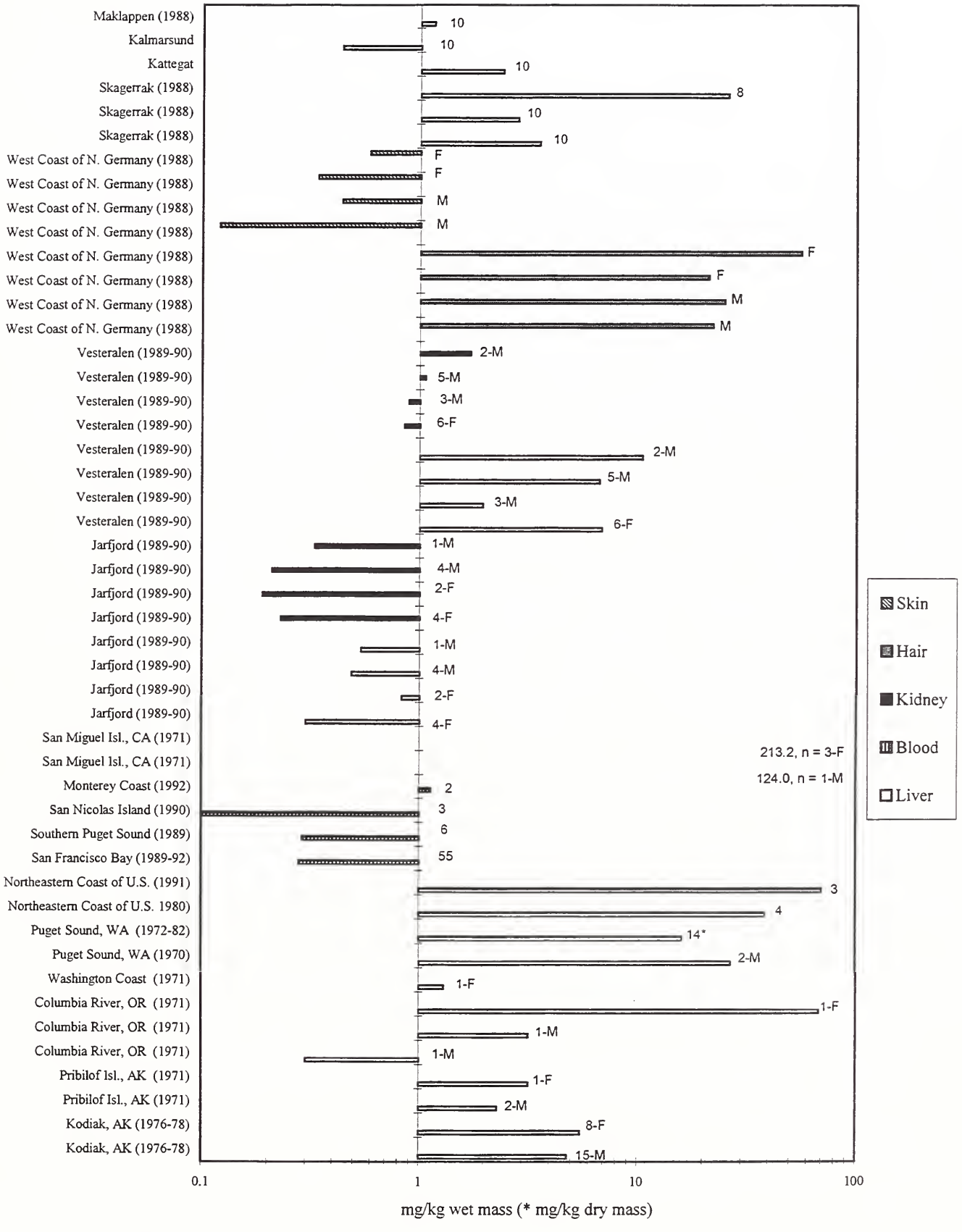

Figure 3. Concentration values (mean, n to the right of mean) of mercury in tissues of harbor seals (M = male, F = female).

Selenium. Selenium is an essential element believed to have an antidotal action on the toxic effects of mercury, cadmium, arsenic, copper, and thallium. Although the mechanism for this action is not clear, two possibilities are that the selenium stimulates the formation of metallothioneins or that heavy metals are incorporated in insoluble selenide compounds. Concentrations of silver and selenium also may be related. The case of silver differs from other selenium-metal interactions in that silver can cause the symptoms of selenium deficiency in vitamin E-deficient animals by the formation of a silver-selenium complex that may reduce the available selenium required for normal cellular processes (Ridlington and Whanger, 1981).

Within physiologic limits, mammals appear to have a homeostatic mechanism for retaining trace amounts of selenium and excreting the excess material. Toxic effects can occur when the rate of intake exceeds the excretory capacity. The most consistent positive correlation of selenium with any other element in liver tissue has been with mercury; therefore, animals with relatively high mercury levels also will have high selenium levels. The selenium concentrations in harbor seal livers reported by Miles et al. (1992) for animals from Kodiak Island tend to support this assumption (Table 2.1). Selenium concentration levels reported for harbor seal tissues are shown in Figure 4.

Lead. Lead is a nonessential element that has increased markedly in the environment over the last century due to anthropogenic sources. Although most of the environmental exposure is probably of lead in its inorganic form, the organic alkyl lead, which is lipid soluble, results in a more severe toxic response. Although tetraethyl- and tetramethyllead degrade rapidly, triethyllead is relatively stable and once absorbed by mammals, it becomes rapidly distributed among brain, liver, kidney, and blood. Lead particles are readily absorbed in mammals via the respiratory system. Gastrointestinal absorption is age dependent in humans and is probably age dependent for most mammals: 5 to 10 percent in adults and 30 to 40 percent in young. The principal route of excretion is urinary.

Few lead values have been reported for harbor seals in general (Fig. 5). Miles et al. (1992) reported Kodiak Island animals having liver concentrations ranging 0.2 mg/kg to 2.1 mg/kg wet mass. This is higher than levels reported by Calambokidis et al. (1984) for Puget Sound harbor seals (0.23 mg/kg to 0.85 mg/kg wet mass). Caution is required when using reported lead values (particularly older data) since this trace element is easily introduced into a sample during sample collections, handling, and analytical determinations.

Copper. Copper is an essential element and is regulated metabolically in vertebrates. As has been reported for other mammals, the highest values occur in the liver, followed by kidney and muscle. Most marine mammal liver values reported are below 20 mg/kg. No copper concentrations have been reported for Alaska harbor seals. Calambokidis et al. (1984) reported copper levels in the livers and blood of harbor seals from Puget Sound ranging 14 mg/kg to 63 mg/kg wet mass. Reported liver concentrations for other pinnipeds in Alaska range 6.47 mg/kg to 45.17 mg/kg wet mass for ringed seal to 9.64 mg/kg to 33.3 mg/kg wet mass for bearded seal (Becker et al., 1997). Copper concentrations tend to vary among and within species and attempts to correlate copper concentration in marine mammal tissues with areas of pollution have not been successful (Thompson, 1990). Diet appears to be important in determining copper levels.

Arsenic. Marine organisms generally have higher concentrations of arsenic than terrestrial or

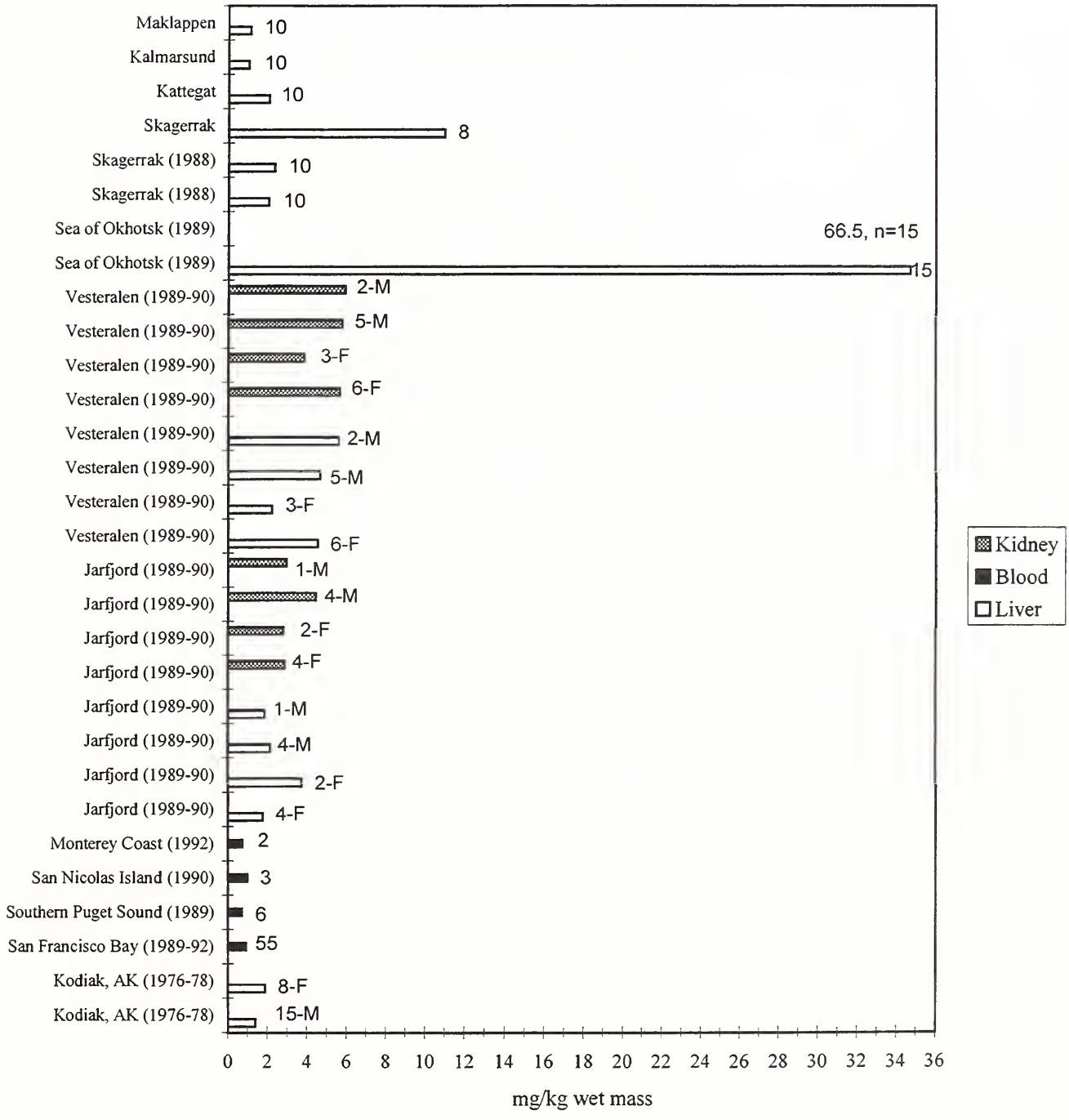

Figure 4. Concentration values (mean, n to the right of mean) of selenium in tissues of harbor seals (M = male, F = female).

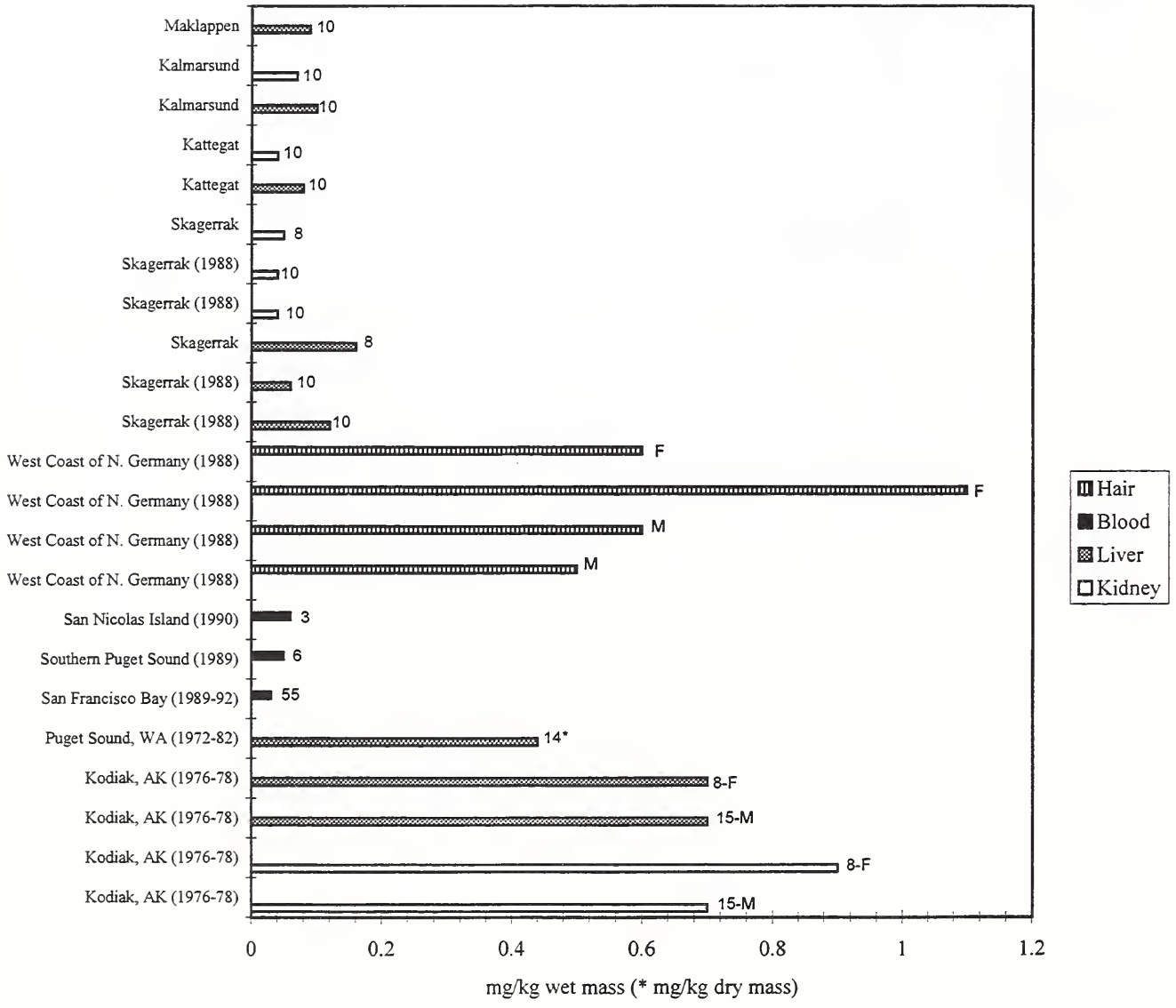

Figure 5. Concentration values (mean, n to the right of mean) of lead in tissues of harbor seals (M = male, F = female).

freshwater organisms. Miles et al. (1992) reported the geometric mean arsenic concentrations in the livers of 15 harbor seals from Kodiak as being 0.08 mg/kg wet weight. Although no arsenic concentration values in liver have been reported for this species in the contiguous United States, Becker et al. (1997) reported arsenic levels in bearded seals and ringed seals from Norton Sound ranging 0.17 mg/kg to 0.56 mg/kg wet mass and 0.165 mg/kg to 2.42 mg/kg wet mass, respectively.

In marine fish, crustaceans, and molluscs arsenic occurs mainly as the non toxic pentavalent organic compound, arsenobetaine. A recent study by Goessler et al. (1998) identified arsenobetaine as the predominant arsenic compound in Alaska ringed seal, bearded seal, and beluga whale liver tissue. Additional organoarsenic compounds identified in this study were arsenocholine, tetramethylarsonium cation, dimethylarsinic acid, and an unknown arsenic compound. The physiological significance of these compounds in marine mammals is unknown.

Tin. Organotin compounds can be toxic and can bioaccumulate. Butyltin compounds have been used worldwide since the 1960s as antifouling agents (tributyltin) for boats and aquaculture nets, as stabilizers for chlorinated polymers, and as catalysts for silicones and polyurethane foams (monobutyltin and dibutyltin). Degradation products of tributyltin (TBT) are dibutyltin (DBT) and monobutyltin (MBT). Both TBT and DBT can cause immunosuppression in mammals (Kannan et al., 1997; 1998). Because of their use, one would expect butyltin (BT) compounds to occur in higher concentrations in coastal waters than in offshore waters.

Because of their tendency to occur in near shore coastal waters and congregate in discrete haulout areas, one would expect harbor seals to be a prime candidate marine mammal species for the investigation of BT compounds in Alaska waters. No data have been published on these compounds in this species. However, studies by Tanabe et al. (1998) also suggest that pinnipeds may have greater capacity for metabolizing BT compounds than cetaceans. Spotted seals (*Phoca largha*) and ribbon seals (*Histriophoca faciata*) from the coast of Japan had mean liver concentrations of total BT of 50 ng/g and 75 ng/g wet mass, respectively. Mean levels in cetaceans from the Japanese coast were one and two orders of magnitude higher. Northern fur seals from the Sanriku Coast had mean BT concentrations of 320 ng/g wet mass, while Dall's porpoise (*Phocaenoides dalli*) from the same area had mean levels of 760 ng/g wet mass.

PERSISTENT ORGANIC POLLUTANTS (POPs)

Persistent organic pollutants include organic compounds, such as PCBs, dioxins, furans, chlorinated pesticides (i.e., DDT, dieldrin, chlordane, endrin, toxaphene, mirex, kepone, etc.), and polycyclic aromatic hydrocarbons (PAHs). Although technically PAHs are considered to be persistent in the environment, they are readily metabolized in mammals and, therefore, do not accumulate in the mammal tissues. Rather than looking for these compounds in marine mammal tissues, a relative measure of recent exposure to PAHs can be derived by the measurement of PAH metabolites in excretory fluid (e.g., bile) (Krahn et al., 1993).

The following persistent organic pollutants have been measured in the blubber and livers of harbor seals from Alaska (Table 2.4): PCBs (expressed as total, or sum of congeners, and as congener-specific values), DDT (expressed as total and as isomers of DDT, DDD, and DDE), chlordane

compounds, hexachlorobenzene (HCB), endrin, dieldrin, and isomers of hexachlorocylohexane (α-, β-, and γ-HCH). These have been commonly reported in tissues of harbor seals from Prince William Sound, Kodiak, and Southeast Alaska (Krahn et al., 1997; Lewis 1995; Varanasi et al., 1993). In addition, endosulfan, a current use pesticide that is considered to be non persistent, has been reported by Lewis (1995) at very low levels in the blubber of harbor seals from Southeast Alaska (Fig. 6). Data on the concentrations of persistent organic pollutants in tissues (i.e., blubber, liver, kidney, muscle, and brain) of harbor seals from Alaska, the contiguous United States, and northern Europe are presented in Tables 2.4 - 2.6.

Polychlorinated biphenyls (PCBs). Much of the past data on PCBs in environmental samples are presented as "total" PCBs or represented as the amount of technical mixtures (Arochlors, Clophens, etc.). Expressing the data in terms of technical mixtures has come about through the use of commercial technical mixtures as reference materials. With the development of high resolution gas chromatography with electron capture detection (GC-ECD), the individual PCBs congeners are now routinely separated, identified, and quantified. Rather than using technical mixtures as reference materials, the individual congeners of interest can then be used for comparison.

The value of congener-specific analysis is apparent when one considers that, although technical mixtures are the original source of PCBs in the environment, the composition of various commercial mixtures with different overall chlorine contents differs from those of environmental mixtures (Duinker, et al. 1988). Although the sum of PCBs may be appropriate for identifying hot spots and trend monitoring, a real understanding of the "trends" and the ability to interpret the meaning of the data requires identification and quantification of individual congeners. This requirement is emphasized by the fact that, although PCBs are metabolized by a wide variety of organisms, not all congeners are metabolized at the same rate, nor are all congeners labile (Kannan, et al. 1989). In addition, some congeners are apparently more toxic than others. For example, based on toxicity that is similar to that of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), the PCBs with the molecules in planar configuration (i.e., PCB-77, -126, and -169) and mono-ortho substituted derivatives of the planar compounds (i.e., PCB-105 and -118) have higher toxicities than other PCB congeners. The few data on planar PCBs in marine mammals suggest that they contribute a minor fraction to the total PCB congener concentrations in marine mammal tissues. The ortho substituted PCB congeners that have lower toxicities compared to the planar compounds have much higher concentrations in marine mammal tissues and may actually contribute more to the toxicity of these compounds (Tanabe et al. 1989; 1997).

The more recent congener specific data are not directly comparable with older PCB data reported on the basis of Aroclors or Clophens. The majority of early PCB data were reported as equivalents of commercial Aroclors, particularly Aroclor 1254, which has been found to be an overestimate of as much as a factor of 2 when compared to more recent reporting of the sum of PCB congeners (Norstrom et al., 1988). In addition, if all the congeners present in a sample were analyzed, their sum would be equal to the total PCBs. However, not all congeners can be completely separated nor are there reference compounds available for all congeners. In most cases this sum does not equal the total, but something less; how much less is usually unknown.

PCB congeners commonly reported in marine mammal tissues include: PCB-18, -28, -44, -49, -52, -95/66, -87, -99, -101, -105, -132, -110, -118, -128, -146, -149, -151, -153, -138, -163, -156, -183,

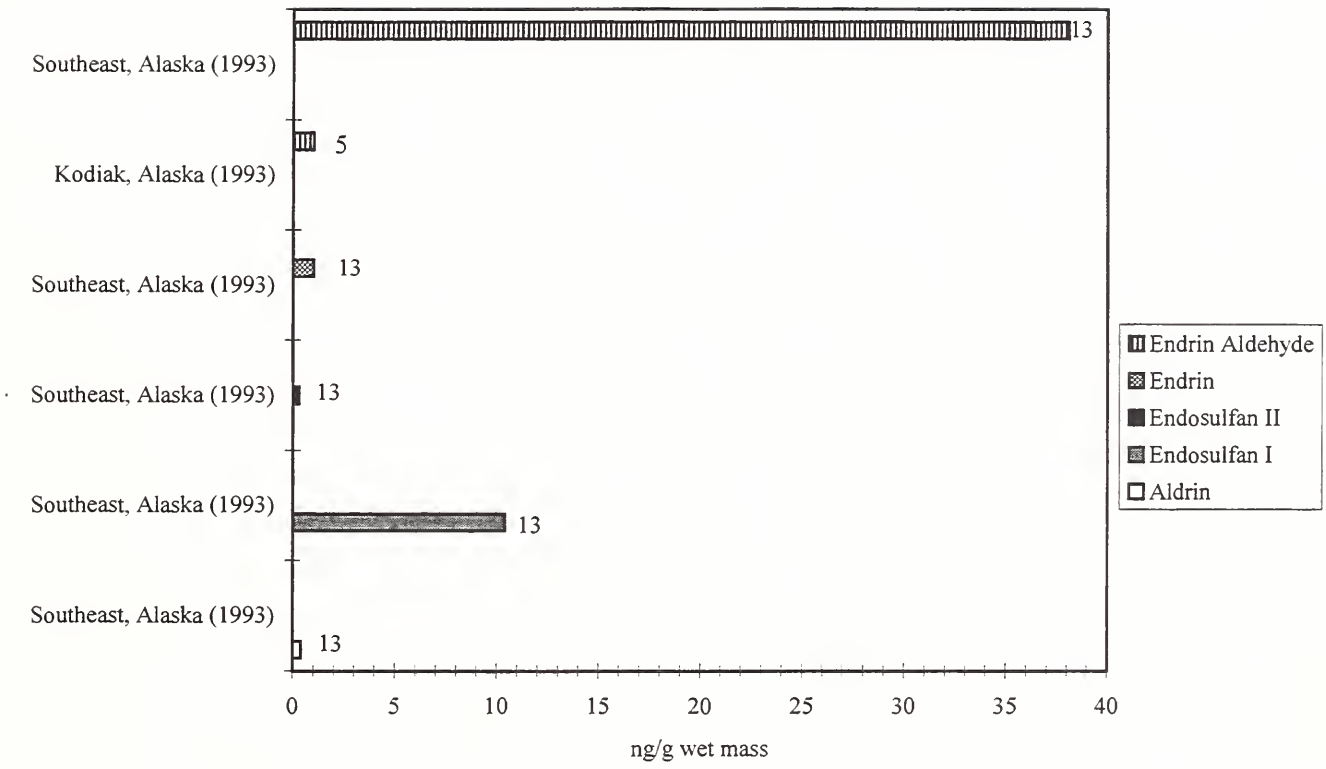

Figure 6. Concentration values (mean, n to the right of mean) of organochlorine compounds in blubber of harbor seals in Alaska.

-187, -170, 201/157, -180, -187, -194, -195, -206, and -209. Because of different extraction and analytical techniques used in measuring PCBs in marine mammal tissues, the number and kinds of congeners reported are not consistent between laboratories. PCB-153, however, is routinely reported by all laboratories. This relatively non toxic congener is highly resistant to metabolic breakdown and almost always dominates the concentration of PCBs in marine mammal tissues. PCB-153 is, therefore, a good congener for comparing relative differences in PCB concentrations among different populations of animals and among different laboratories and data sets. Figure 7 presents PCB-153 concentration data for the blubber of harbor seals from Prince William Sound Alaska, the northeast and northwest coasts of the United States, northern Europe, and the British Isles. The Prince William Sound harbor seals had PCB-153 concentrations an order of magnitude lower than were reported for this species from the northwest and northeast coasts of the United States and from northern Europe.

Concentrations of the sum of PCB congeners (a total of 17 congeners) in the blubber of Prince William Sound harbor seals are compared with those measured in four other species of pinnipeds in Table1.1. Concentration levels in the animals from Prince William Sound Arctic (452 ng/g ± 236 ng/g wet mass) were of the same order of magnitude as measured in ringed seals (*Phoca hispida*) from the Alaska, but less than levels found in northern fur seals (*Callorhinus ursinus*) from the Pribilof Islands (1,343 ng/g ± 522 ng/g wet mass) and harbor seals from the coasts of Washington and Oregon (3,116 ng/g ± 1,517 ng/g wet mass), and substantially less than Steller sea lions (*Eumatopias jubatus*) from the Gulf of Alaska (23,000 ng/g ± 37,000 ng/g wet mass).

DDT and Metabolites. Although many different compounds have been identified in various organisms as metabolic products of DDT, the predominant ones in mammals are DDD (dichlorodiphenyldichloroethane), DDE (dichlorodiphenyldichloroethylene), and DDA (dichlorodiphenyl acetic acid). DDD is rarely stored as a metabolite. It is unstable and readily degrades through a series of intermediates to DDA, which is water soluble and excreted in urine. DDE is a degradation product of DDT through the loss of one molecule of HCL (dehydrohalogenation). Metabolism of DDT to either DDE or DDD is considered to be quite fast on the order of years. Although DDE further degrades to DDA by the loss of two more molecules of HCL, this reaction is very slow. DDE is relatively stable and tends to persist. This persistence of DDE results in a portion of the parent compound (DDT) accumulating in the tissues as DDE.

The individual isomers of DDT and its metabolites also vary in the rates of degradation depending on the molecular arrangement of chlorine atoms. The ratio of 2,4'-DDT to 4,4'-DDT in the technical mixture is 1:4. The missing 1,4- disubstitution in one of the phenyl rings of 2,4'-DDT facilitates its degradation. The metabolites 2,4'-DDD and 2,4'-DDE are rarely found to be enhanced to the same extent as are the 4,4'-derivatives.

The degradation of DDT begins in the soil through the activity of microorganisms. DDE has a greater volatility than DDT; therefore, it is probably more easily transported through the atmosphere into areas where application has not taken place, such as the Arctic. Also one would expect the ratio, DDE/DDT, to be generally higher in the open-ocean environment and the organisms inhabiting this environment than in the coastal environment. As the DDT is metabolized and passed along the food chain, one would also expect the ratio to be higher at the upper trophic levels. This pattern

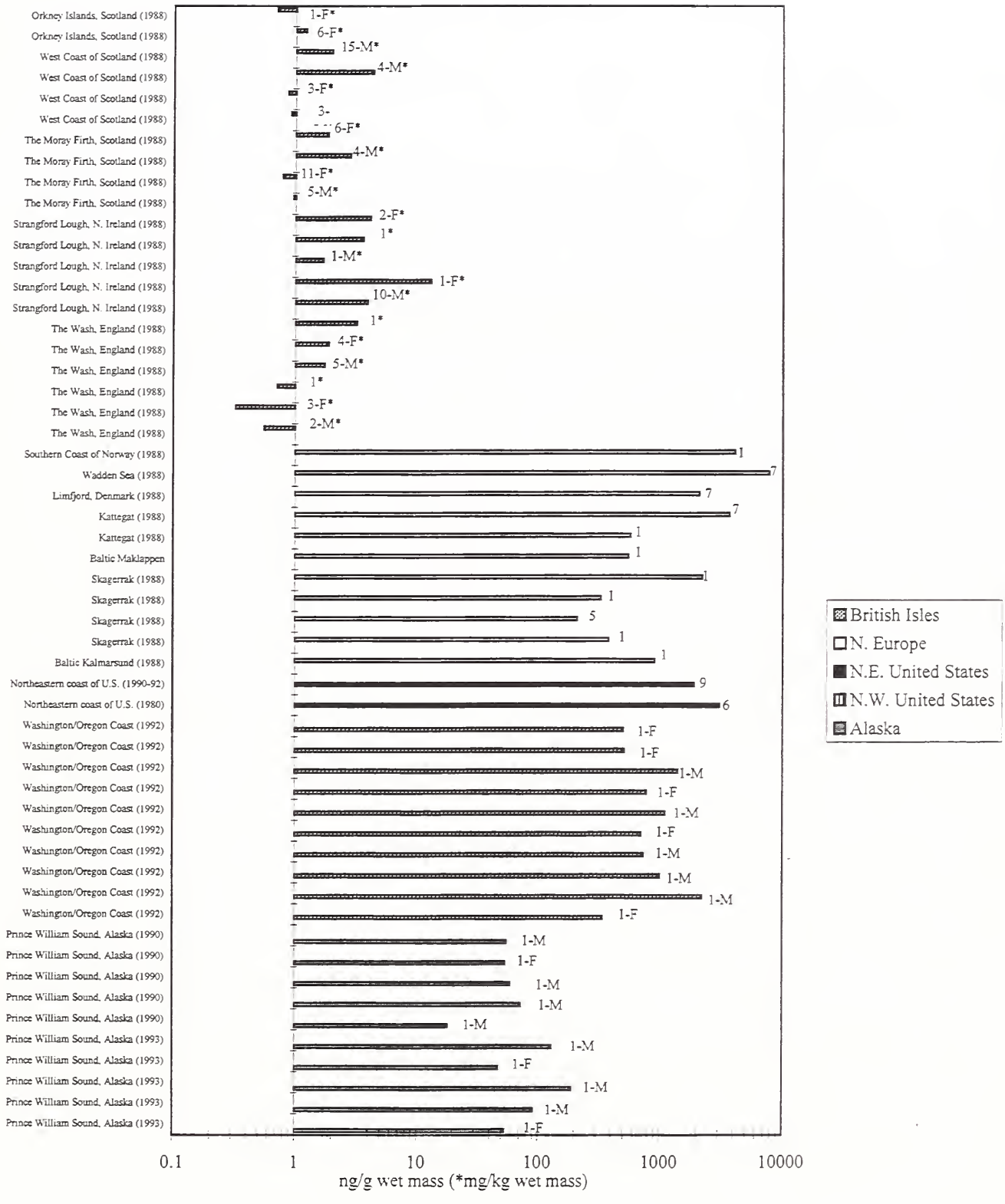

Figure 7. Concentration values (mean, n to the right of mean) of PCB 153 in blubber samples of harbor seals (M = male, F = female).

Table. 1.1. Comparison of concentration ranges and means ± 1 standard deviation (ng/g wet mass) of chlorinated hydrocarbons measured in the blubber of harbor seals from Alaska with other Alaska pinnipeds and with harbor seals from the Washington and Oregon coast

Location	s-PCBs	s-DDT	s-Chlordane	HCB	Dieldrin	Source
Harbor Seal:						
Prince William S.	225 - 798	130 - 523	80 - 331	8 - 16	3 - 9	1
n = 5	452 ± 236	314 ± 170	205 ± 110	12 ± 4	5 ± 2	
WA/OR coast	2,204 - 6,846	961 - 8,545	211 - 1,250	7 - 20	5 - 24	1
n = 10	3,116 ± 1,517	3,756 ± 2,139	657 ± 310	13 ± 4	12 ± 6	
Northern Fur Seal:						
Pribilof Is.	550 - 2,054	946 - 5,602	298 - 1,230	nd - 2	4 - 260	1
n = 7	1,343 ± 522	2,711 ± 1,470	792 ± 361	0.6 ± 0.7	52 ± 85	
Pribilof Is.	275 - 590	1,090 - 1,480	79 - 342	nd	1.2 - 26	2
n = 2	432	1,285	210	-	14	
Steller Sea Lion:						3
n = 8	23,000 ± 37,000	20,000 ± 35,000				
Ringed Seal:						
Norton Sound	89 - 363	69 - 255	90 - 295	7 - 50	4 - 31	1
n = 8	273 ± 83	190 ± 60	182 ± 80	22 ± 13	18 ± 8	
Norton Sound	334 - 1,425	372 - 1,922	124 - 154	24 - 122		2
n = 2	420	590	1,147	139	73	
Barrow, AK		35 - 378	77 - 164	2 - 56	0.6 - 24	2
n = 2	640	225	120	29	12	
Bearded Seal:						
Norton Sound	66 - 356	8 - 366	12 - 451	0.76 - 7	nd - 8.5	1
n = 6	162 ± 112	103 ± 133	155 ± 159	4 ± 3	4 ± 3	

1 - Krahn et al. (1997); 2 - Schantz et al. (1993); 3 - Varanasi et al. (1993)

appears to be consistent among tissue types, which is illustrated by the comparison of p,p'DDE to total DDT shown in Figures 8-12 for liver, blubber, brain, and muscle tissue from harbor seals sampled in the United States, Canada, and Europe.

Concentrations of the sum of DDT (DDE + DDD + DDT) in the blubber of Prince William Sound harbor seals are compared with those measured in four other species of pinnipeds in Table 1.1. Concentration levels in the animals from Prince William Sound (314 ng\g ± 170 ng\g wet mass) were of the same order of magnitude as measured in ringed seals from the Alaska Arctic, but an order of magnitude less than levels found in northern fur seals from the Pribilof Islands and harbor seals from the coasts of Washington and Oregon and two orders of magnitude less than reported for Steller sea lions from the Gulf of Alaska.

Hexachlorobenzene (HCB). Of the various chlorobenzene compounds, hexachlorobenzene (HCB) is the most toxic and most persistent. This is a very volatile compound that has the potential for long distance atmospheric transport to northern latitudes. Although persistent in lipids of mammals, HCB is gradually metabolized to a wide variety of metabolites that appear in the feces and urine. Levels of HCB in fat and blubber are usually much higher than those of liver.

In Table 1.1 and Figure 13, HCB concentration levels in blubber tissue of harbor seals from Prince William Sound (12 ng/g ± 4 ng/g wet mass) are compared with levels reported for this species in the contiguous United States and with other pinnipeds from Alaska. Except for bearded seals from Norton Sound, which have somewhat lower levels, the HCB concentrations reported for Alaska pinnipeds are all very similar. These levels are also similar to those reported for harbor seals from the northwest United States.

Hexachlorocyclohexane (*gamma*-HCH). Hexachlorocyclohexane (HCH) occurs as several isomers, α-HCH, β-HCH, and γ-HCH (lindane). The levels in fat are an order of magnitude higher than in the liver or other internal organs, i.e., kidney, spleen, heart, and brain (Figs. 14 and 15). γ-HCH is less stable than α-HCH and may be transformed to the latter during atmospheric transport. One might, therefore, expect a proportionately smaller amount of the former occurring in Arctic organisms than in animals from lower latitudes. Muir and his associates reported smaller proportion of γ-HCH to α-HCH in the blubber of belugas from the Arctic as compared to those from the Gulf of St. Lawrence which they attributed to continued use of lindane as a pesticide and its possible introduction into the St. Lawrence River (Muir, et al. 1990). Data from harbor seals from both southeast Alaska and Kodiak Island suggest that the subarctic marine mammals of Alaska may have proportionately higher levels of γ-HCH to the α-HCH concentrations (Fig. 16).

Dieldrin. Dieldrin, which accumulates in animal tissue and is eliminated slowly, is one of the most commonly reported pesticides in marine mammals. Dieldrin concentration in the blubber of harbor seals from Prince William Sound (5 ng/g ± 2 ng/g wet mass) has been reported to be lower than those reported for the same species from the Washington and Oregon coasts (12 ng/g ± 6 ng/g wet mass), but higher than have been reported for this species in the North American Atlantic (Fig. 17 and Table 1.1). Comparison of levels in the Prince William Sound harbor seals with other Alaska pinnipeds, indicate similar levels, except for the northern fur seals, which have levels ranging an order of magnitude higher (52 ng/g ± 86 ng/g wet mass).

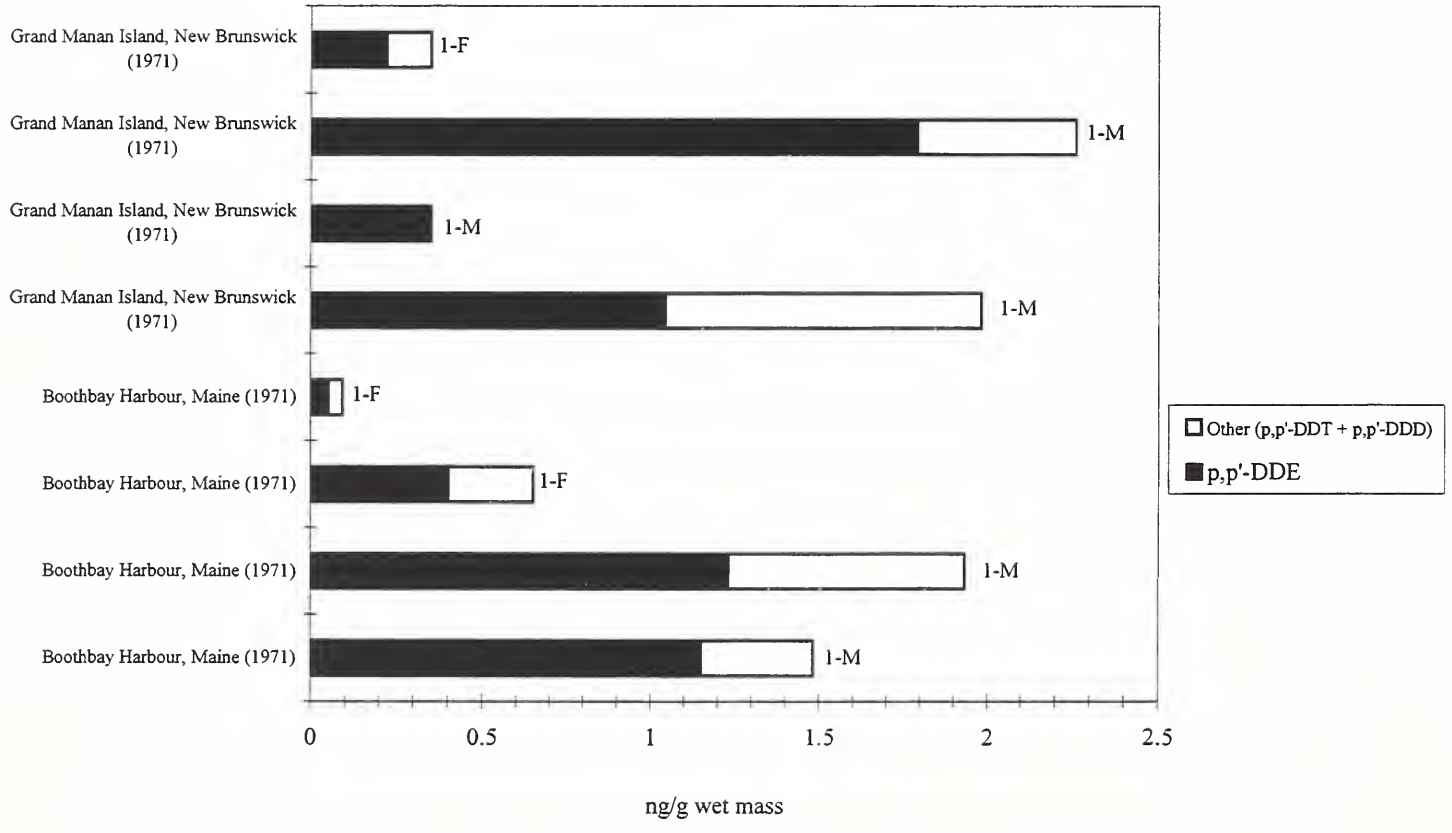

Figure 8. Concentration values of total DDT in liver samples of harbor seals in the United States (M = male, F = female).

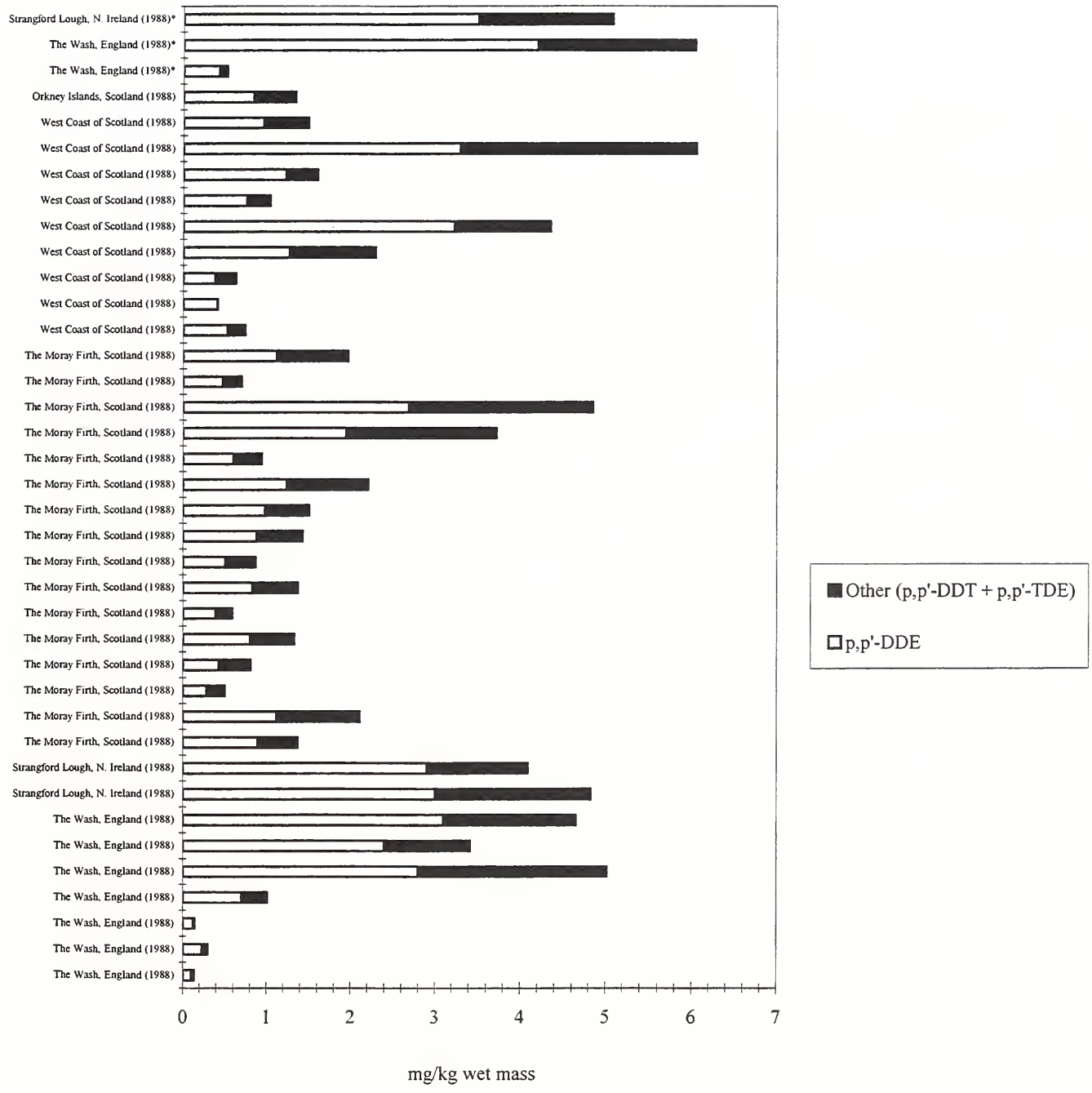

Figure 9. Concentration values of total DDT in blubber samples of female (*unknown sex) harbor seals in Europe.

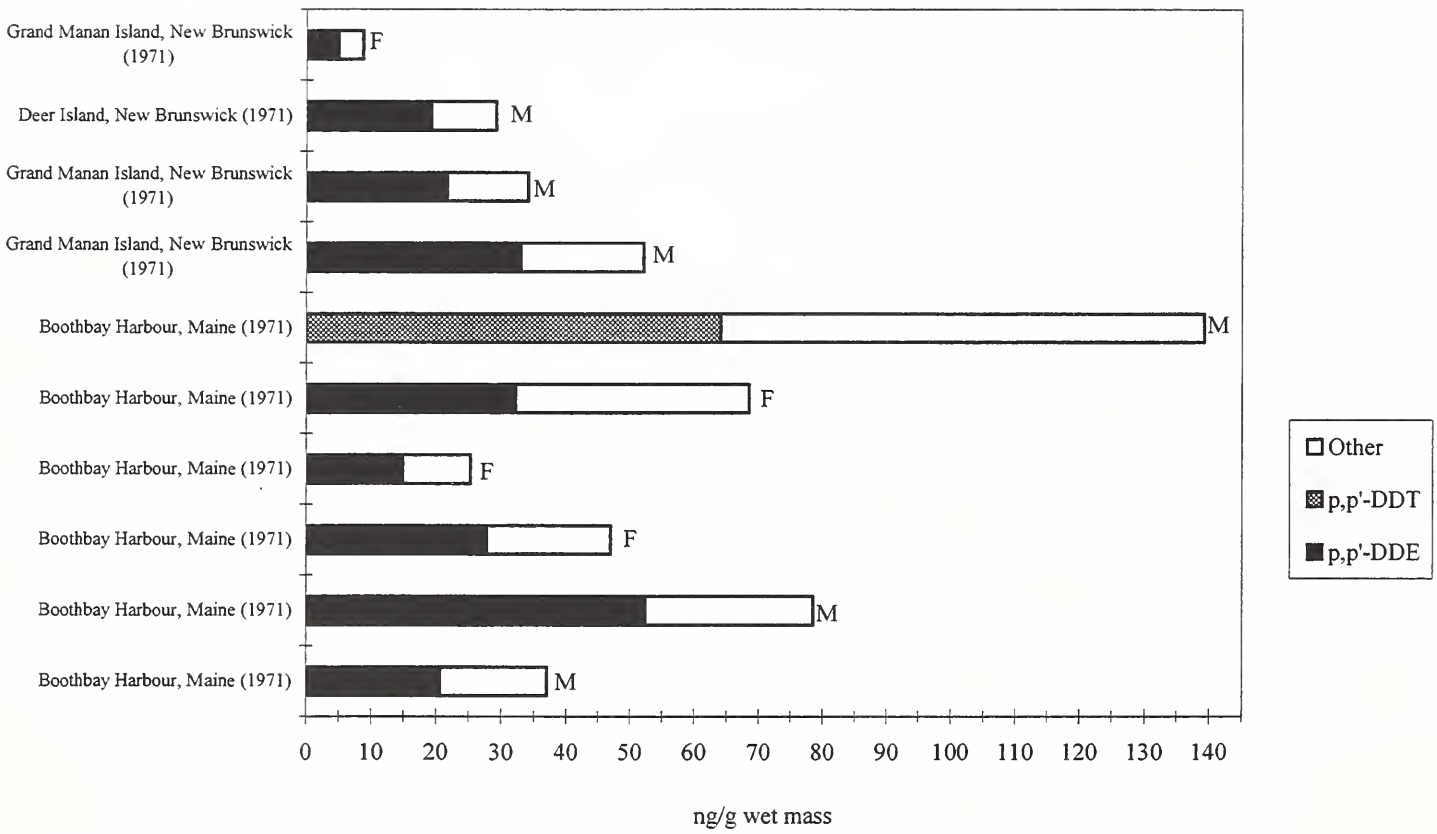

Figure 10. Concentration values of total DDT measured in blubber of harbor seals in the N.E. United States and Canada (M = male, F = female).

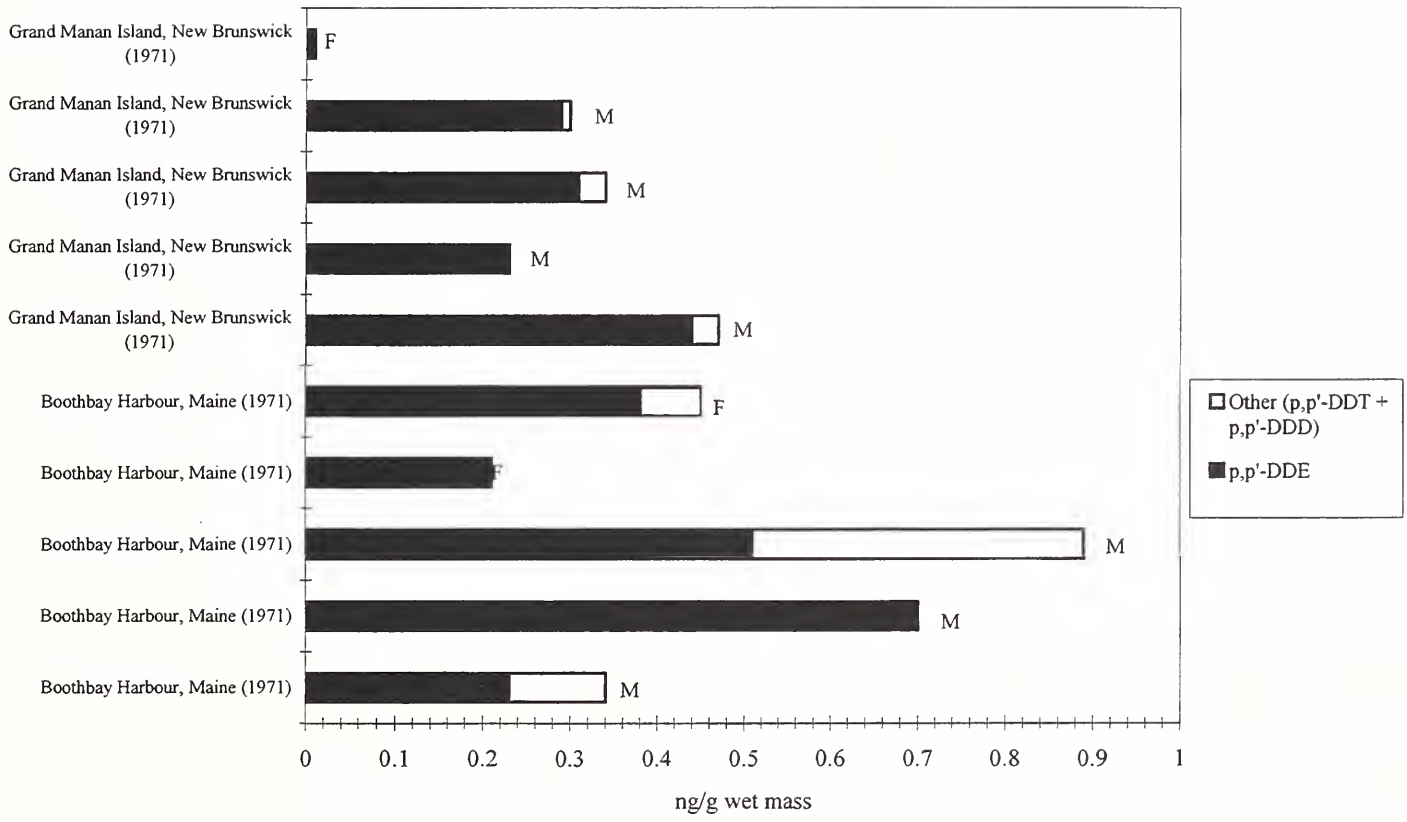

Figure 11. Concentration values of total DDT in cerebrum samples of harbor seals in the N.E. United States and Canada (M = male, F = female).

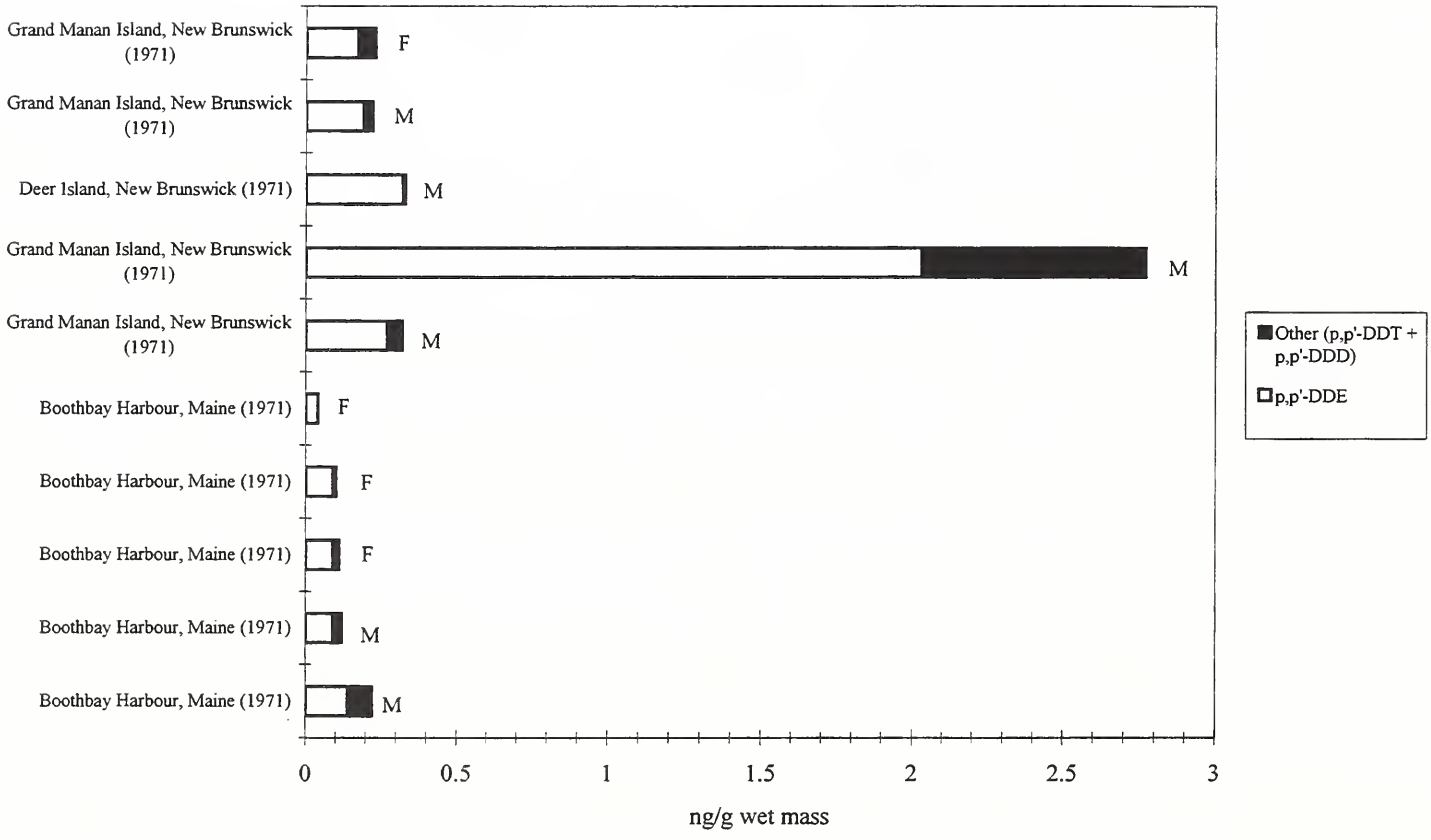

Figure 12. Concentration values of total DDT in muscle of harbor seals in the United States (M = male, F = female).

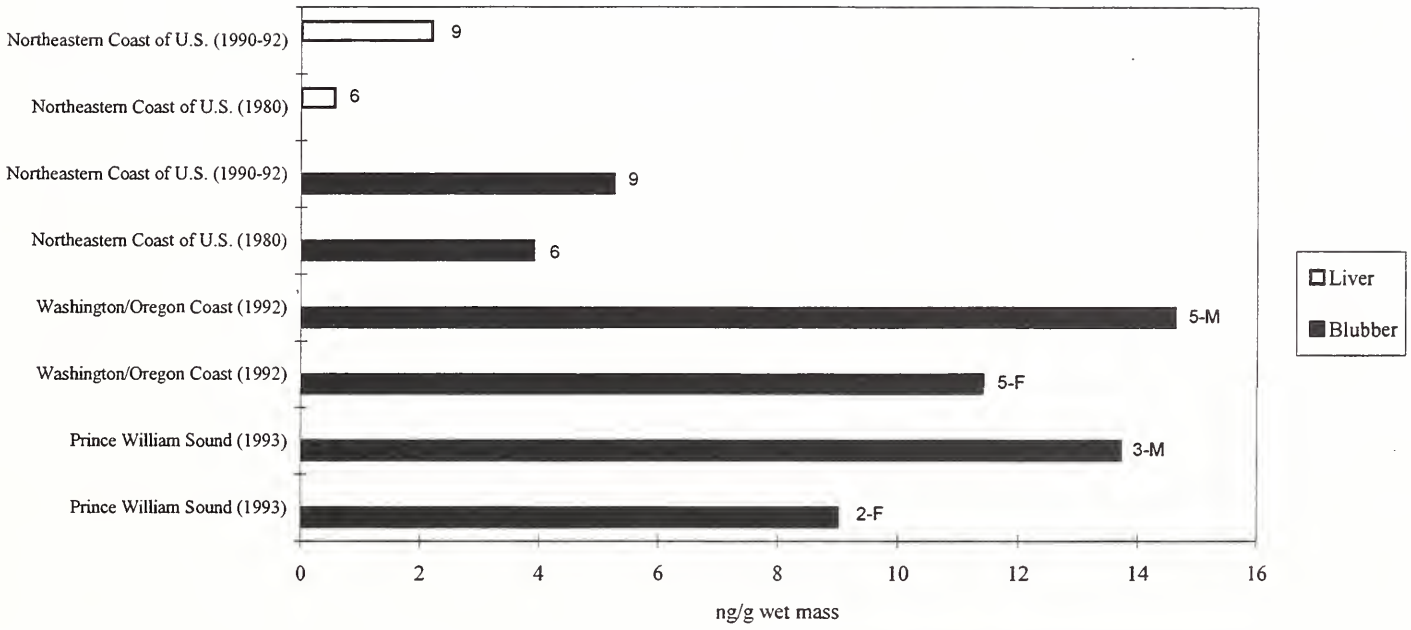

Figure 13. Concentration values (mean, n to the right of mean) of HCB in tissues of harbor seals in the United States, including Alaska (M = male, F = female).

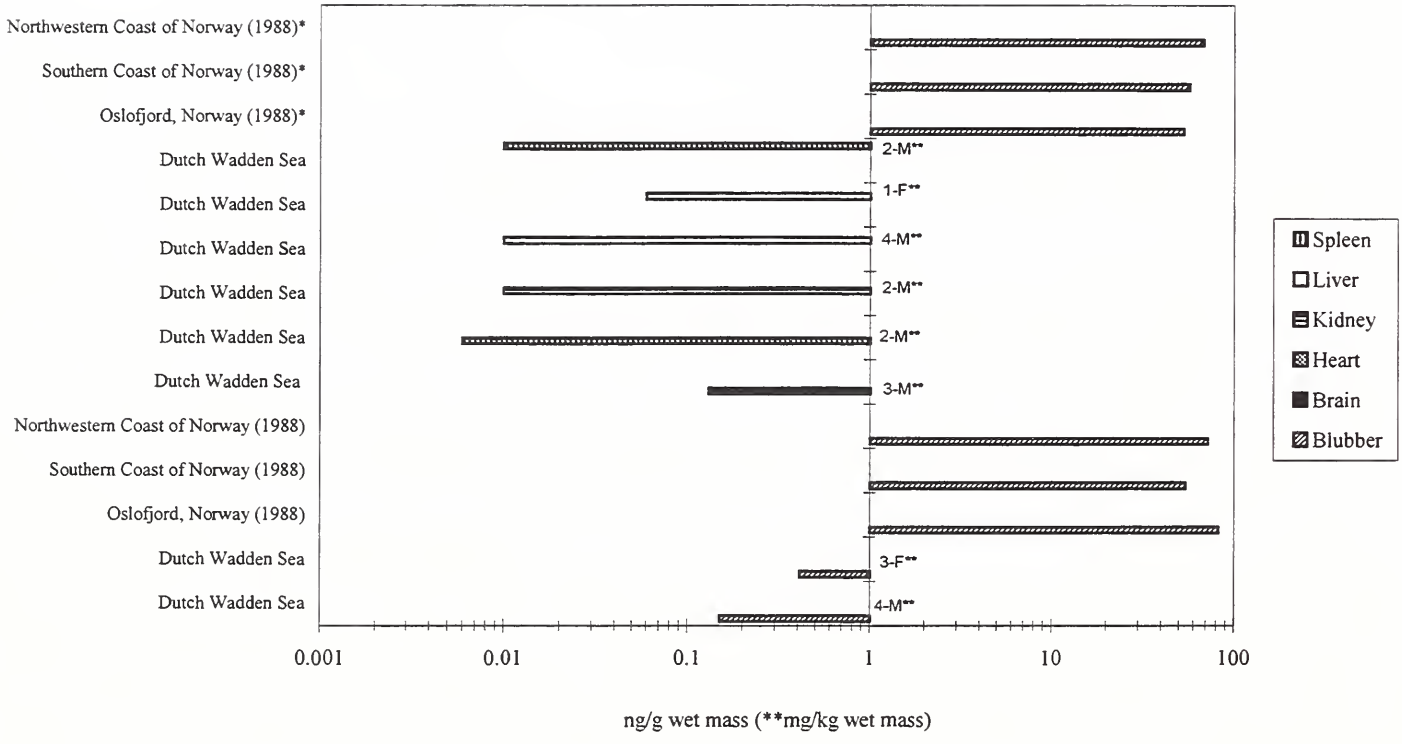

Figure 14. Concentration values (mean, n to the right of mean) of alpha-HCH and beta-HCH in tissues of harbor seals in Europe (M = male, F = female).

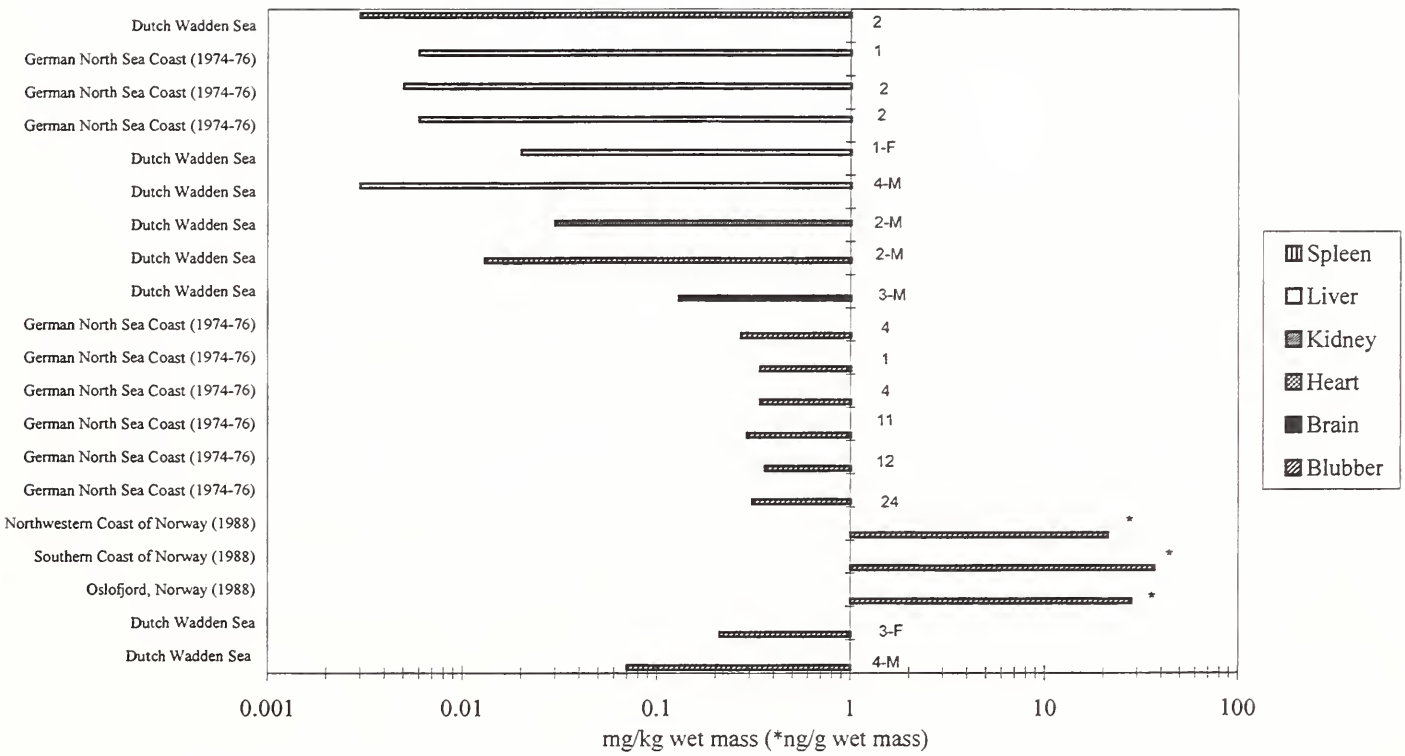

Figure 15. Concentration values (mean, n to the right of mean) of gamma-HCH (lindane) in tissues of harbor seals in Europe (M = male, F = female).

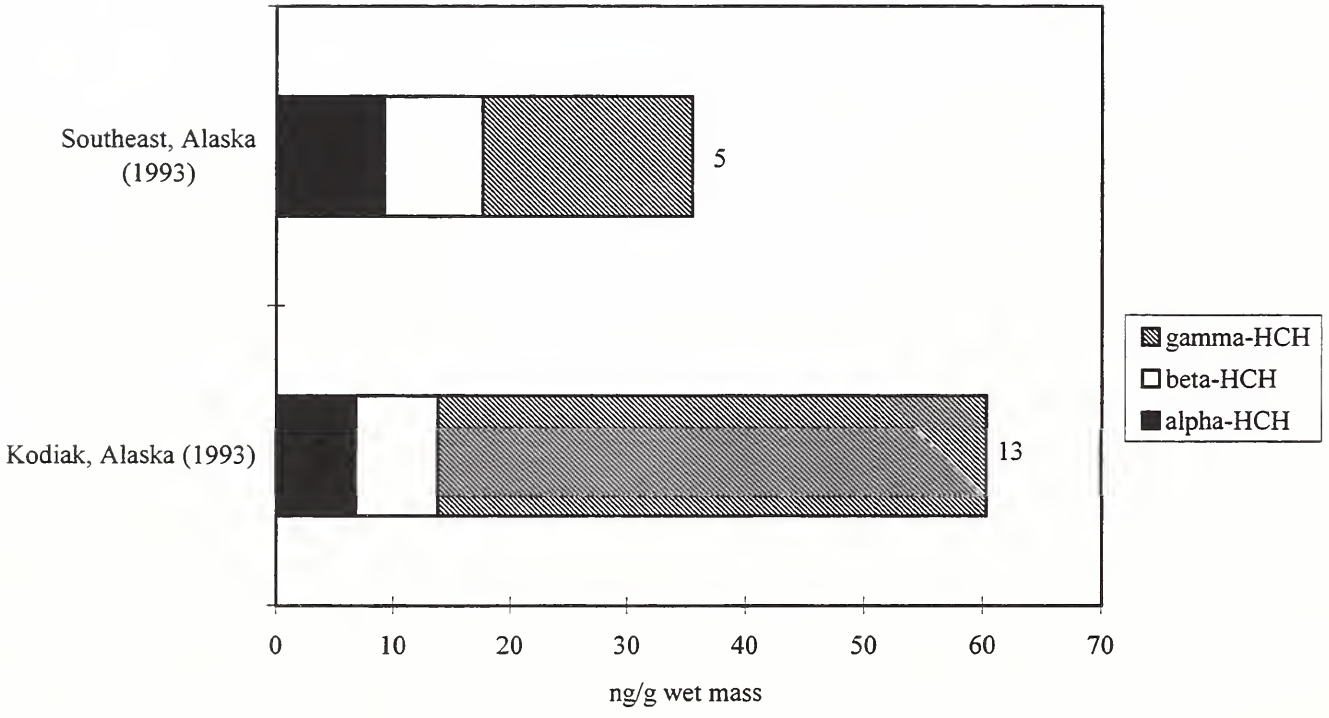

Figure 16. Concentration values (mean, n to the right of mean) of HCH in blubber of harbor seals in Alaska.

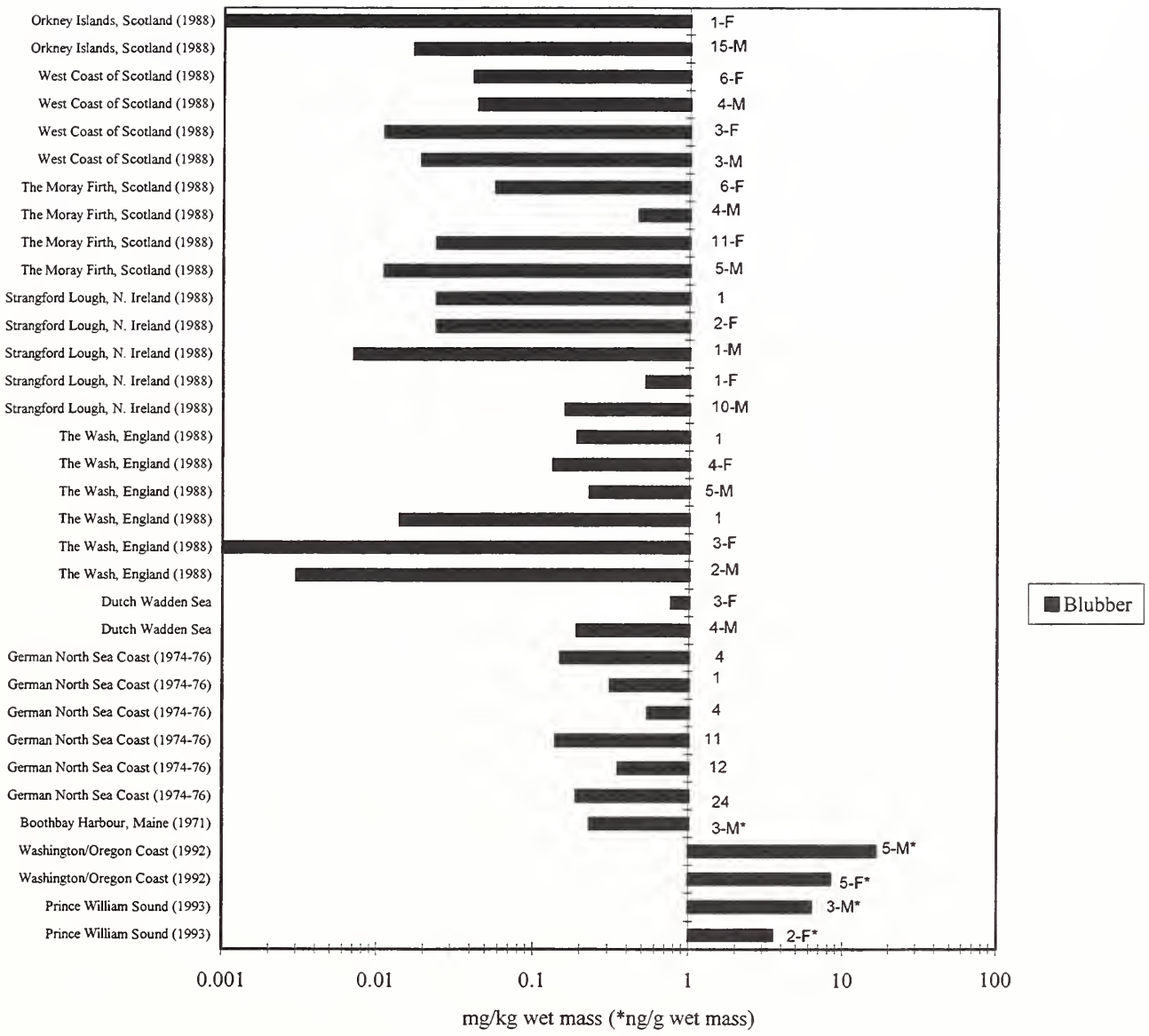

Figure 17. Concentration values (mean, n to the right of mean) of dieldrin in blubber of harbor seals in the United States, including Alaska, and Europe (M = male, F = female).

Chlordane-Related Compounds. Technical chlordane is a mixture of as many as 45 isomers and congeners of related cyclopentadienes. Chlordane-type compounds identified in marine mammal tissues include *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, oxychlordane, and heptachlor epoxide. Heptachlor has been used as a pesticide separate from technical chlordane. Not all investigators have measured all of these compounds and some have measured more. In many cases, it is very difficult to assess chlordane trends because it is not always clear from published reports which of the different chlordane group compounds were measured to derive the total chlordane values.

Individual isomers of chlordane differ in their degree of persistence and, therefore, their ability to accumulate in the food web. Based on evidence of relative concentrations in marine vertebrates, their prey, and in sea water (Kawano, et al. 1988), and correlations between octanol/water partition coefficients and bioconcentration values (Kawano, et al. 1984), it appears that of the two prominent isomers of technical chlordane, *trans*-chlordane is metabolized much more readily than *cis*-chlordane. However, the most prominent chlordane compounds in marine mammal tissues are trans-nonachlor, oxychlordane, and heptachlor epoxide, the latter two being metabolites.

Chlordane readily volatilizes following soil application. Long-range atmospheric transport appears to be an important mechanism for the global spreading of this compound (Wania and Mackay, 1993). Chlordane was second only to DDT and PCBs in abundance in 1981through 1982 samples of marine life from the Gulf of Alaska and Bering Sea (Kawano, et al. 1986).

Figure 18 compares concentration levels of chlordane compounds (*trans*-nonachlor, heptachlor epoxide, heptachlor, *alpha*-chlordane (*cis*-chlordane) and total chlordane) in liver and blubber tissues from harbor seals from Alaska with those from the contiguous United States. Levels in the Alaska animals are relatively low (205 ng/g ± 110 ng/g wet mass). Chlordane concentrations in Alaska pinnipeds are very similar (Table 1.1), except for the northern fur seals, which have higher levels (792 ng/g ± 361 ng\g wet mass) that are the same order of magnitude as reported for harbor seals from the Washington and Oregon coasts (Table 1.1).

Toxaphene. Technical toxaphene consists of a mixture of hundreds of polychlorinated camphenes and bornanes produced under the name "toxaphene." This pesticide was commonly used in agricultural areas of the southeastern United States before being banned in the early 1980s. Twenty polychlorinated camphenes have been reported in the biota of the Canadian Arctic including marine mammals (Muir et al., 1990; 1992). Toxaphene has also been reported in beluga whales of the Alaska Arctic at levels approaching those of PCBs and DDT (Becker et al., 1997). Due to the need for additional analytical techniques for toxaphene measurement and the need for the development of toxaphene standards, this group of compounds is not usually measured in marine mammal tissues. No toxaphene data are available for harbor seals in either Alaska or the contiguous United States.

Other POPs. Dioxins and furans, a group of chlorinated chemicals that are similar in molecular structure to PCBs, are primarily created in high temperature processes, such as waste incineration, metal industries, and pulp and paper mills that use chlorine in the bleaching process. The toxic mechanisms of dioxins and furans are also similar to coplanar PCBs and vary depending on the actual dioxin or furan compound involved. The compound, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), which is the most toxic of this group of compounds, is used as the basis for

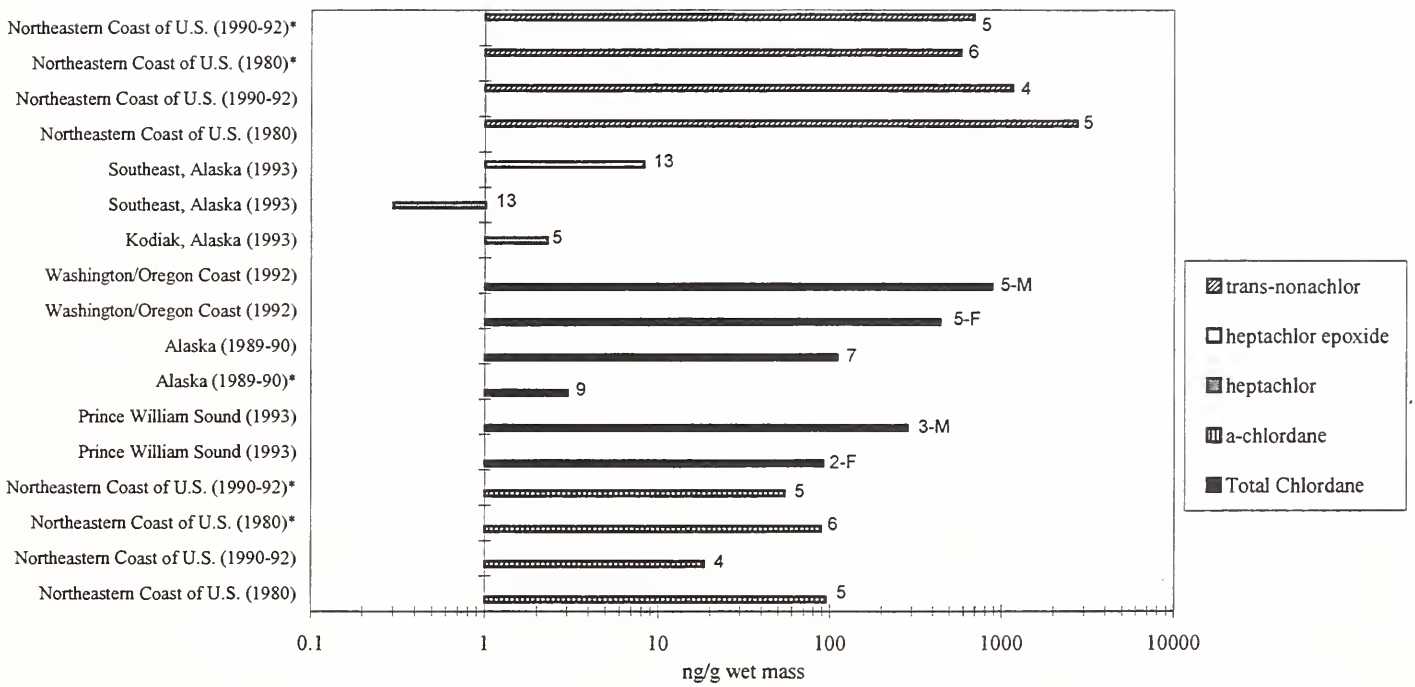

Figure 18. Concentration values (mean, n to the right of mean) of chlordanes in blubber (* liver) samples of harbor seals in the United States, including Alaska (M = male, F = female).

estimating the relative toxicity of other dioxin and furan compounds as well as specific PCB congeners through the calculation of "toxicity equivalents" (TEQs). Refer to Barnes (1991) for a review of TEQs. Although no concentration data have been published for these compounds in Alaska marine mammals, analysis of sea otter livers from Southeast Alaska and the Aleutian Islands have been completed (Doug Dascher, Alaska Department of Environmental Conservation, personal communication) and analysis of polar bear blubber samples from Arctic Alaska (Tom Evans, U.S. Fish and Wildlife, personal communication) has begun. The measurement of 2,3,7,8-substituted tetra- to octachloro dibenzo-*p*-dioxins and dibenzofurans in harbor seals might also be of interest in areas of suspected discharges (i.e., near pulp mills) in Southeast Alaska.

Other POPs that have not been measured in marine mammals, but due to their similarity in toxicity to PCBs, should also be considered for future measurement in harbor seals are polybrominated diphenyl ethers (PBDPEs) and polychlorinated diphenyl ethers (PCDPEs). These compounds have been commonly used as fire retardants and have become quite prevalent in the environment. The future measurement of these chemicals will depend on the development of analytical standards and methods since these are not presently readily available.

CONTAMINANT LEVELS AND HEALTH EFFECTS

Determining the role of contaminants on animal health and on the decline of an animal population requires much more than data on contaminant concentration in tissues or measurement of metabolite residues. Unless animal deaths or health decline can be linked directly to an actual pollution event, the linking of a negative response to a specific contaminant or group of contaminants is very difficult.

Heavy metals occur naturally in the environment and several, such as mercury, lead, arsenic, and cadmium, are highly toxic when in the appropriate valence state. The route of exposure for an animal (i.e., ingestion, inhaling, dermal absorption, etc.) is also critical in determining the toxicity of metals. Whether the metal is incorporated within an organic molecule (e.g., methylmercury and tributyltin) also effects toxicity. One can not equate the "normal" levels of a toxic metal in a terrestrial animal to that of a marine species. Bioaccumulation of trace elements and metals in the marine food web is a worldwide phenomenon. High levels of mercury commonly occur in upper trophic level fish. The same situation occurs for cadmium in some species of crustaceans and molluscs, and arsenic in many marine invertebrates and fish. Thus, marine mammals are commonly exposed to elevated levels of these, as well as other trace elements, via their food source. High liver or kidney levels of mercury or cadmium in a marine mammal does not necessarily mean that the animal is being detrimentally affected. The key to evaluating potential effects is to determine the form of the metal (organic or inorganic, associated with a protein complex [metallothionein] or other binding metal [selenium], valence state, etc.) Unfortunately, most metal concentrations in marine mammal tissues have been reported as "total" values, only.

Most of the persistent pesticides (chlorinated pesticides, such as DDT, dieldrin, endrin, chlordane, and toxaphene) that are now banned in most developed countries, have relatively low mammalian toxicity as compared to the less persistent current-use pesticides. However, persistent pesticides bioaccumulate and their effects are subtle, being carcinogenic and/or affecting immune functions,

hormone levels, embryological development, etc. Persistent industrial chemicals (e.g., PCBs, dioxins, and furans) have also been implicated in such subtle effects in mammals. When considering the potential for such effects to occur, one should remember that sensitivity to such chemicals varies by species, sex, reproductive status, age of mammals, and season, and that animals are exposed to not just one chemical, but to thousands of chemicals that may interact to either increase or decrease a specific response. Health of individual animals (and populations) is also affected by physical environmental conditions, the quality and abundance of food resources, disease organisms, hereditary disease, and naturally occurring biotoxins. Thus, animals are usually responding to a myriad of health insults, a potentially toxic compound (contaminant) being only one.

Historically, the most success in linking contaminants to health effects and population declines occurred in studies of ringed, grey (*Halichoerus grypus*), and harbor seal declines in the Baltic Sea during the 1980s (Olsson et al., 1992; 1994). In those cases, the levels of PCBs, DDTs, and other chlorinated pesticides in these animals were very high (two to three orders of magnitude higher than were reported in the harbor seals from Prince William Sound). The identification of these contaminants as a factor in the decline of the Baltic Sea animals developed out of an intensive effort to describe all factors affecting the health of the animals and the population overall, and to monitor these factors through several years. Key to these studies was the identification of pathologies characteristic of immune disfunction in the animals and reproductive impairment. Symptoms of immune disfunction included bone deterioration (particularly in the area around the teeth), loss of hair, abnormalities of the adrenal glands (observable by gross necropsies as well as histopath samples), emaciation, gastrointestinal lesions and proliferation of gastrointestinal parasites. Reproductive impairment was first noticed by the loss of fecundity in the animals, followed by documentation of abnormalities in the reproductive organs of the females (i.e., uterine stenosis or occlusions) (Olsson 1972; 1978). Monitoring these conditions through the years has resulted in a documentation of the reduction of the frequency of these conditions with decrease in industrial and municipal discharges into the Baltic, improvement in fishery resources, and a general improvement in the overall condition of biotic resources for this region. Although the pathologies documented for the seals in the Baltic Sea are among those characteristic of PCB and other chlorinated hydrocarbon effects, one should also remember that the Baltic Sea was a mixture of thousands of compounds and the food web supporting the seals had degenerated in diversity and function. Improvement in the condition of the Baltic seals has resulted from an overall improvement in the regional environment, not just the elimination of one or two anthropogenic contaminants.

Research on the health of beluga whales in the St. Lawrence Estuary represents a similar case study (Martineau et al., 1987; 1988; 1994). The St. Lawrence Estuary in Canada has a resident population of beluga whales (450 to 500 animals) that have been exposed chronically to a complex mixture of industrial chemicals for more than 50 years (Martineau et al., 1994). A 10-year study of the health of these animals, that relied to a large extent on stranded dead animals, revealed a low reproductive rate in the population, relatively high incidence of gastrointestinal tract lesions and parasites, lesions of the pulmonary tract and mammary glands; a 40 percent incidence of various carcinomas, and pathologies characteristic of immune deficiencies (tooth loss, endocrine gland pathologies, and decreased lymphocyte proliferation). The levels of chlorinated hydrocarbons and pathologies for these animals are similar to those that occurred in the Baltic seals. However, in the case of the belugas, additional chemical measurements have been made of metabolites and biomarkers in an attempt to link exposure to effects. These have included benzo[a]pyrene (B[a]P) metabolites, PCB

methylsulphones, DDT methylsulphones, B[a]P DNA adducts in the brain, and aromatic DNA adducts in the liver (Béland et al, 1993; Martineau et al., 1994).

The health abnormalities shown in the seals from the Baltic Sea and the beluga whales from the St. Lawrence Estuary were reflective of several toxic responses, including increased carcinogenesis, hormonal disruption, and immune deficiencies. Although other factors might be involved, exposure to chlorinated hydrocarbons (as well as some other anthropogenic contaminants) has been shown to also elicit such responses. PCB and DDT methylsulphones are stable metabolites that may be the actual compounds inducing toxic effects (Troisi and Mason, 1997); therefore, they may be appropriate biomarkers for indicating an initial physiological response to exposure to these compounds. The use of DNA adduct measurement also shows promise in linking exposure to effects. One of the responses to exposure to anthropogenic contaminants is modification of DNA (DNA adduct formation) which may be a precursor to toxic response, such as carcinogenesis.

A developing field of research is addressing questions regarding potential endocrine disruption by many of the anthropogenic compounds considered to be persistent toxicants (PCBs, DDT, chlordane, toxaphene, HCB, etc.), others thought to be broken down more readily in the environment (endosulphan, malathion, and parathion) and some heavy metals (tributyltin and mercury) (Harrison et al., 1997). The animal response to such compounds may be reflected in changes in reproductive capacity in adults and disruption of embryonic development. Reduction in productivity may, therefore, be the ultimate biotic response to such compounds. Endocrine disrupters cause adverse effects in an organism by interfering with normal hormonal processes. An early sign of endocrine disruption is the alteration of normal reproductive processes through decrease in blood levels of sex hormones (e.g., testosterone and progesterone) and alteration of steroid metabolism (Subramanian et al., 1987). Such a response ultimately leads to reproductive organ effects and decreased reproduction in the population. In addition, disruption of the endocrine system in animals may affect embryological development leading to non survival of developing fetus or decreased survival potential of the newborn. Again, the ultimate response of the population is decreased reproduction.

Microsomal cytochrome P-450 enzymes are involved in the biotransformation and metabolism of many chemicals, both endogenous and exogenous. There is some evidence (Colborn and Smolen, 1996) suggesting that reproductive toxicity of PCBs is initiated by interference with P-450 enzyme function. Induction of P-450 enzymes by PCBs may alter steroid chemistry and cause endocrine imbalance and enzyme inhibition. The toxic potentials of PCB congeners have been classified based on the type of P-450 enzyme systems they induce (bioactivate). The most toxic of PCBs (the coplanar PCB-77, -126, and -169) and 2,3,7,8-TCDD induce the 3-methylcholanthrene-type enzyme system, while the least toxic PCBs induce the phenobarbital-type system. Ortho-substituted derivatives of the coplanar PCBs (PCB-105, -118, -128, -138, -156, and -170) are mixed-type inducers, the ones eliciting the greatest 3-methylcholanthrene response being PCB-105 and -118. Although the non coplanar PCBs appear to be less toxic, through the use of TEQ calculations, PCBs such as 105 and 118 may contribute more to the total toxicity of PCB levels by being present in much higher concentrations than the coplanar compounds (Tanabe et al., 1997).

The issue of endocrine disrupters is very complicated and not easily addressed since animals are exposed to mixtures of these compounds that may interact in ways that are not easily understood. Although many chemicals have been identified as endocrine disrupters or potential endocrine

disrupters through testing of individual compounds, response to mixtures of these compounds is unknown. Critical in evaluating endocrine disrupters in marine mammals will be the development of refined research methods (both analytical and diagnostic) that can be applied to all classes of organisms. Reijnders (1994) has proposed that altered endocrine systems may be the common denominator for both reproductive and immunological disorders. He has also proposed two sets of indicators to evaluate toxicity of organochlorine residues found in marine mammal tissues: (1) interactions of chlorobiphenyls with the cytochrome P-450 enzyme system (enzyme induction studies) and (2) comparative physical and chemical blood parameters directly and indirectly obtained through functional immunoassay. In the case of the latter, this includes mitogen- and antigen-induced proliferative responses of peripheral blood mononuclear cells and natural killer cell activity. Both sets of indicators could provide a basis for multiple response assessment.

CONCLUSIONS AND RECOMMENDATIONS

Based on this review, it is apparent that there is very little published data on contaminant levels in Alaska harbor seals. This is particularly the case for heavy metals. The situation for persistent organic contaminants (e.g., chlorinated hydrocarbons) is little better. For both the heavy metals and persistent organic pollutants, many data are regionally very spotty and are 10 to 25 years old, suggesting that some data are useful for historical comparisons, but not appropriate for extrapolating to contemporary conditions. It therefore follows that little information is available to establish baseline levels of contaminants in harbor seals throughout this species' distribution in Alaska waters, much less evaluate likely impacts.

Status of Contaminants Loads. The amount of available data is presently insufficient to determine the status of contaminant loads in harbor seals throughout this species' range in Alaska. Recently published and other available data on persistent organic pollutants (PCBs and chlorinated pesticides) and heavy metals in Alaska harbor seals are very sparse and are restricted to animals of Prince William Sound, Southeast Alaska, and Kodiak. What little data exist indicate that levels of PCBs and DDT residues are an order of magnitude lower than what has been measured in this species from the Pacific coast of the lower 48 states and two orders of magnitude lower than what has been reported for these animals from the Baltic Sea, the Southern Coast of Norway, and the Dutch Wadden Sea during the late 1980s. However, no data are available for the animals of the Western Gulf of Alaska, particularly along the Aleutian Chain. It is recommended that levels of persistent organic pollutants be characterized for populations of harbor seals in the major areas of decline (the western Gulf of Alaska, including the Aleutian Chain). Particular contaminants of broad interest are PCBs, DDT compounds, chlordane compounds, toxaphene, and dieldrin. Other compounds of somewhat lesser interest at this time are HCB and HCH (particularly lindane). Dioxin is of interest in areas of suspected discharges (i.e., near pulp mills).

Tissues to be collected for analysis should include: blubber (for establishing body loads), blood (for obtaining some measure of recent exposure and compound mobilization during seasonal periods of blubber reduction), and liver. The collections should include specimens for immediate analysis as well as those to be archived for retrospective analyses for additional compounds, metabolites, etc.

Analyses of samples for PCBs, dioxins, and chlorinated pesticides are very expensive; however,

through appropriate use of less expensive analytical screening techniques, some broad-based analysis of selected samples can be conducted, with the idea of identifying trends and "hot-spots." Archived specimens can then be used to more completely characterize populations of particular interest. Screening techniques for initial quantification of the more toxic, coplanar compounds of PCBs, dioxins, and furans are available (Krahn et al., 1994). The quantification of these compounds, in addition to less toxic but related and usually more abundant PCB congeners, such as PCB-118 and -105, would provide a better estimate of the toxic fractions of the dioxin and related compounds present in animal tissues.

Chlordane compounds that are measured should be carefully defined to provide for data comparability. There are many compounds that are classified as chlordane and not all are measured or reported by analytical labs. It is probably not necessary to identify and report all chlordane compounds; however, for marine mammals the dominant fractions are trans-nonachlor and oxychlordane (a metabolite). One should ensure that at least these two compounds are quantified.

Toxaphene is a persistent organic pollutant that appears to be easily transported to the Arctic via the atmosphere. It is often present in relatively high levels in fish, and in the case of Arctic marine mammals, may occur at levels that are higher than those of DDT compounds. Although the toxicity of toxaphene may not be as great as that of some of the other dominant chlorinated hydrocarbons (i.e., coplanar PCBs, dioxin, chlordane) the fact that it does occur at relatively high levels in marine mammals and has been implicated in endocrine system disruption warrants attention. Toxaphene is the commercial name for a complex of many different polychlorinated camphene and bornane compounds. It is not easily measured and there are no commercial analytical standards. Because of this, much of the data on toxaphene reported in animal tissues is not comparable. It is strongly recommended that, if toxaphene is measured, careful consideration be given to selecting the appropriate laboratory.

For all routine analyses, the lipid content of the tissue being analyzed should be determined and the concentration data normalized to lipid concentration in order to reduce the data variation. The methods for lipid determination should be defined and standardized if more than one laboratory is involved in analyses. The lipid data should be available in order to base comparisons on fresh tissue sample weight if that is required.

Measurement of petroleum hydrocarbons in blubber or liver tissue is not recommended, since such compounds are readily metabolized by mammals and excreted. More feasible and less expensive is the collection of bile samples for PAH metabolite screening. Such analysis can be done inexpensively using fluorescence techniques to give some relative measure of exposure to petroleum-derived PAHs. The collection of the bile must be done as quickly as possible after the animal dies since the compounds of interest are heat-labile and light sensitive and quickly break down unless frozen right away and maintained in amber vials. Because of these technical difficulties, it would be most appropriate to limit such screening to animals occurring in areas where petroleum hydrocarbon contamination is of particular concern.

Only two papers were found that report concentrations of heavy metals (i.e., Cd, Pb, As, Hg, and Se) in Alaska harbor seals, but these data were for animals that were sampled 20 to 30 years ago at Kodiak Island and the Pribilofs. Although these data give some historical perspective for these

locations, they may not be indicative of the present situation. In order to define the degree of heavy metal contamination in Alaska harbor seals, baseline levels of Hg, Se, and Cd in selected tissues (liver, kidney, blood, hair, etc.) of this species should be established for Alaska regions. Mercury analysis should include methylmercury as well as total Hg, since the former is considered to be the more toxic form. One should not equate high levels of these elements to probable organ disfunction based on information on effects in other species (particularly terrestrial animals). Marine mammals as a group commonly concentrate these heavy metals to relatively high levels. One should also not equate high concentrations of these elements with upper trophic levels as one would see in lipophilic contaminants. For example, the bowhead whale, which occupies a lower level in the food web, has much higher levels of Cd in its kidneys than the beluga whale in Alaska. The factors involved in heavy metal uptake, distribution, and accumulation in marine mammals is very complicated and little understood.

Subsamples of tissues collected for Hg, Se, and Cd analyses should be archived for future retrospective analysis for other heavy metals or trace elements, if such elements become a health issue, or for the identification and quantification of metal-binding proteins and organic forms of elements, if such analyses are needed for evaluating the health effects of the elements of interest. The identification of other metals or associated elements for analysis should probably be based on identifying geographical areas where such materials might be of concern. One particular example might be analyses of livers for butyltin in areas where organotin compounds are suspected to be a problem. At a minimum, samples of kidney and liver should be collected for histopathology. Comparing histopathological data with concentrations of Cd and Hg could be a first step in linking any high metal levels with pathological response.

Percent moisture of samples analyzed for elements of interest should be determined and should be part of the database on the sample. This would allow for expressing concentration values on dry mass basis, thus reducing data variability. Having percent moisture as part of the database would also allow for comparisons with other databases that report values on only a wet mass basis.

Role of Contaminants in the Harbor Seal Decline. Based on the previous discussion on "Contaminant Levels and Health Effects," the following are recommended as the minimum approach to gathering information that may be used to evaluate the health of harbor seals relative to contaminant concentrations.

1. For each animal that is sampled for contaminant analysis, samples should be collected from as many tissue types as possible for histopathological analysis. These samples are simple to collect and preserve (in buffered formalin) and relatively inexpensive to analyze. Such samples are very important in identifying abnormalities that might be linked to contaminant exposure and accumulation. At a minimum histopath collections should include liver, kidney, adrenals, testes, ovaries, and any organs that appear to be abnormal.

2. Female reproductive tracts should be collected for evaluation of reproductive history as well as evaluation for abnormalities.

3. Where possible response measures, such as measurement of DNA adducts, P-450 analysis, and metabolites of contaminants such as methylsulphone forms of chlorinated hydrocarbons should

be incorporated into the analytical program.

4. There is a large gap between quantifying contaminant burdens (or exposure) and identifying a definite detrimental response in an animal. Although the measurements listed in item 3 narrow this gap, they do not bridge it. This is a fast developing field of research. It therefore becomes important to archive some of the samples collected for analysis to allow one to apply more refined and specific techniques in the future that will give a better measure of detrimental response to exposure.

5. Whole blood and serum samples should be collected for viral screening and for measurement of metabolites, biomarkers of exposure, and general blood chemistry of the animal. Handled correctly, the samples may be archived for future analysis.

SECTION II

DATA TABLES

Table 2.1. Mean Concentrations of Metals and Metalloids in Harbor Seals, *Phoca vitulina*, from Alaska[a]

General Location	Date	Sex[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Kodiak, AK	1976-78	M	Cd	11.2	0.3-44.0	15	kidney	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	M	Pb	0.7	0.3-2.0	15	kidney	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	Cd	2.5	0.3-44.0	8	kidney	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	Pb	0.9	0.3-2.2	8	kidney	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	M	As	0.09	n.d.[c]	15	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	M	Pb	0.7	0.2-2.1	15	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	M	Hg	4.8	0.4-72.0	15	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	M	Se	1.4	0.2-18.0	15	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	As	0.08	n.d.	8	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	Pb	0.7	0.2-2.1	8	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	Hg	5.5	0.4-72.0	8	liver	Miles, A.K., et al., 1992
Kodiak, AK	1976-78	F	Se	1.9	0.2-18.0	8	liver	Miles, A.K., et al., 1992
Pribilof Isl., AK	1971	M	Hg	2.3	0.6-8.9	2	liver	Anas, R.E., 1974
Pribilof Isl., AK	1971	F	Hg	3.2		1	liver	Anas, R.E., 1974

[a] mg/kg wet mass

[b] M-male; F-female

[c] n.d.- not determined

Table 2. 2. Mean Concentrations of Metals and Metalloids in Harbor Seals, *Phoca vitulina* , from the U.S. outside of Alaska[a]

General Location	Date	Sex[c]	Compound	Geometric Mean	Range	n	Tissue	Citation
San Miguel Isl., CA.	1971	F	Hg	213.24	81.0-700.0	3	liver	Anas, R.E., 1974
San Miguel Isl., CA.	1971	M	Hg	124		1	liver	Anas, R.E., 1974
Columbia River, OR	1971	M	Hg	0.3		1	liver	Anas, R.E., 1974
Columbia River, OR	1971	M	Hg	3.2		1	liver	Anas, R.E., 1974
Columbia River, OR	1971	F	Hg	68		1	liver	Anas, R.E., 1974
Washington Coast	1971	F	Hg	1.3		1	liver	Anas, R.E., 1974
Puget Sound, WA	1970	M	Hg	26.83	12.0-60.0	2	liver	Anas, R.E., 1974
Puget Sound, WA [b]	1972-82	n.d.	Ag	0.16 (0.039-0.63)	n.d.[d]	n.d.	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Al	240 (43-1,400)	n.d.	13	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Cd	0.78 (0.47-1.3)	n.d.	14	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Cu	30 (14-63)	n.d.	11	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Cr	0.37 (0.13-0.69)	n.d.	14	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Mg	9.6 (5.9-16)	n.d.	12	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Pb	0.44 (0.23-0.85)	n.d.	14	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Zn	140 (84-240)	n.d.	14	liver	Calambokidis, J., et al., 1984
Puget Sound, WA [b]	1972-82	n.d.	Hg	16 (3.3-78)	n.d.	14	liver	Calambokidis, J., et al., 1984
Northeastern Coast of U.S.	1980	n.d.	Hg	38.5 (7.86)	31.6-49.3	4	liver	Lake, C.A., et al., 1995
Northeastern Coast of U.S.	1991	n.d.	Hg	69.9 (62.1)	16.0-138	3	liver	Lake, C.A., et al., 1995
San Francisco Bay	1989-92	n.d.	Cd	0.02 (0.002)	0-0.1	55	blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-92	n.d.	Cu	0.92 (0.04)	0.4-1.74	55	blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-92	n.d.	Pb	0.03 (0.01)	0-0.54	55	blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-92	n.d.	Ni	0.04 (0.02)	0-0.86	55	blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-92	n.d.	Hg	0.28 (0.02)	0.08-0.73	55	blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-92	n.d.	Se	0.92 (0.04)	0.51-1.80	55	blood	Kopec, A.D. and Harvey, J.T., 1995
Southern Puget Sound	1989	n.d.	Cd	0.01 (0.002)	0.01-0.02	6	blood	Kopec, A.D. and Harvey, J.T., 1995
Southern Puget Sound	1989	n.d.	Cu	0.97 (0.03)	0.87-1.05	6	blood	Kopec, A.D. and Harvey, J.T., 1995

[a] mg/kg wet mass (± 1 SD)

[b] mg/kg dry mass (± 1 SD)

[c] M-male; F-female

[d] n.d.- not determined

Table 2.2. (continued)

General Location	Date	Sex[c]	Compound	Geometric Mean	Range	n	Tissue	Citation
Southern Puget Sound	1989	n.d.	Pb	0.05 (0.03)	0.04-0.14	6	blood	Kopec, A.D. and Harvey, J.T., 1995
Southern Puget Sound	1989	n.d.	Hg	0.29 (0.03)	0.20-0.40	6	blood	Kopec, A.D. and Harvey, J.T., 1995
Southern Puget Sound	1989	n.d.	Se	0.70 (0.02)	0.64-0.79	6	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Cd	0.02 (0.01)	0-0.04	3	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Cu	0.92 (0.05)	0.82-0.97	3	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Pb	0.06 (0.06)	0-0.18	3	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Ni	0.12 (0.06)	0-0.20	3	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Hg	0.10 (0.05)	0.05-0.20	3	blood	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	n.d.	Se	0.98 (0.17)	0.65-1.20	3	blood	Kopec, A.D. and Harvey, J.T., 1995
Monterey Coast	1992	n.d.	Cu	0.81 (0.16)	0.65-0.97	2	blood	Kopec, A.D. and Harvey, J.T., 1995
Monterey Coast	1992	n.d.	Hg	1.13 (0.57)	0.56-1.70	2	blood	Kopec, A.D. and Harvey, J.T., 1995
Monterey Coast	1992	n.d.	Se	0.73 (0.20)	0.53-0.92	2	blood	Kopec, A.D. and Harvey, J.T., 1995

[a] mg/kg wet mass (± 1 SD)

[b] mg/kg dry mass (± 1 SD)

[c] M-male; F-female

[d] n.d.- not determined

Table 2.3. Mean Concentrations of Metals and Metalloids in Harbor Seals, *Phoca vitulina* , from Regions Outside of the U.S.[a]

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Jarfjord	1989,'90	F,juv	Hg	0.30 (1.61)	0.15-0.52	4	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,a	Hg	0.83	0.40-1.27	2	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,juv	Hg	0.49 (0.23)	0.37-0.83	4	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,a	Hg	0.54	n.d.[c]	1	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,juv	Se	1.76 (1.49)	1.37-2.45	4	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,a	Se	3.73	3.03-4.43	2	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,juv	Se	2.13 (0.73)	1.59-3.18	4	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,a	Se	1.85		1	liver	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,juv	Hg	0.23 (0.12)	0.11-0.38	4	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,a	Hg	0.19	0.09-0.28	2	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,juv	Hg	0.21 (0.61)	0.17-0.29	4	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,a	Hg	0.33		1	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,juv	Se	2.86 (1.06)	1.68-4.12	4	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	F,a	Se	2.8	2.75-2.84	2	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,juv	Se	4.45 (2.33)	2.50-7.68	4	kidney	Skaare, J.U.,et al., 1994
Jarfjord	1989,'90	M,a	Se	2.95		1	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,juv	Hg	6.85 (5.26)	2.47-16.02	6	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,a	Hg	1.96 (2.54)	0.21-4.87	3	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,juv	Hg	6.68 (4.88)	0.68-13.85	5	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,a	Hg	10.48	1.99-18.96	2	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,juv	Se	4.54 (2.16)	2.65-7.78	6	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,a	Se	2.22 (1.46)	1.08-3.86	3	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,juv	Se	4.66 (2.42)	1.99-8.52	5	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,a	Se	5.6	2.48-8.73	2	liver	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,juv	Hg	0.85 (0.35)	0.57-1.50	6	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,a	Hg	0.89 (0.51)	0.41-1.41	3	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,juv	Hg	1.06 (0.38)	0.41-1.38	5	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,a	Hg	1.72	1.42-2.01	2	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	F,juv	Se	5.67 (0.88)	4.68-6.68	6	kidney	Skaare, J.U.,et al., 1994

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Vesteralen	1989,'90	F,a	Se	3.85 (1.10)	2.65-4.79	3	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,juv	Se	5.79 (1.13)	4.49-6.94	5	kidney	Skaare, J.U.,et al., 1994
Vesteralen	1989,'90	M,a	Se	5.94	5.54-6.33	2	kidney	Skaare, J.U.,et al., 1994
West Coast of N. Germany	1988	M,p	Cd	0.09 (0.03)	n.d.[c]	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,a	Cd	0.17 (0.12)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,p	Cd	0.13 (0.11)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,a	Cd	0.1 (0.09)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,p	Pb	0.5 (0.1)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,a	Pb	0.6 (0.3)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,p	Pb	1.1 (0.8)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,a	Pb	0.6 (0.3)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,p	Hg	22.1 (20.3)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,a	Hg	25.0 (16.1)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,p	Hg	21.2 (23.4)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,a	Hg	55.9 (61.3)	n.d.	n.d.	hair	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,p	Hg	0.12 (0.08)	n.d.	n.d.	skin	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	M,a	Hg	0.44 (0.31)	n.d.	n.d.	skin	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,p	Hg	0.34 (0.18)	n.d.	n.d.	skin	Wenzel, C., et al., 1993
West Coast of N. Germany	1988	F,a	Hg	0.59 (0.67)	n.d.	n.d.	skin	Wenzel, C., et al., 1993
Sea of Okhotsk	1989	n.d.	T-Hg	16.7 (15.8)	n.d.	15	liver	Himeno, S., et al., 1989
Sea of Okhotsk	1989	n.d.	I-Hg	14.3 (15.6)	n.d.	15	liver	Himeno, S., et al., 1989
Sea of Okhotsk	1989	n.d.	Se	34.7 (15.3)	n.d.	15	liver	Himeno, S., et al., 1989
Sea of Okhotsk	1989	n.d.	T-Hg	3.60 (1.55)	n.d.	15	kidney	Himeno, S., et al., 1989
Sea of Okhotsk	1989	n.d.	I-Hg	2.75 (1.30)	n.d.	15	kidney	Himeno, S., et al., 1989
Sea of Okhotsk	1989	n.d.	Se	66.5 (29.7)	n.d.	15	kidney	Himeno, S., et al., 1989
Skagerrak	1988	juv	Al	1	<0.02-3.83	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Ca	57	44-91	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Cd	0.04	<0.02-0.10	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Co	<0.002	<0.002-0.035	10	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Skagerrak	1988	juv	Cr	0.025	0.017-0.035	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Cu	9.3	5.0-16	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Fe	369	248-642	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Hg	3.56	0.72-7.69	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Mg	156	135-186	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Mn	4.1	2.4-5.1	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Ni	0.017	≤0.006-0.028	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Pb	0.12	0.09-0.25	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Se	2.04	1.17-4.88	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	V	0.045	0.018-0.173	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Zn	36	25-46	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Al	0.41	0.10-0.60	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Ca	65	59-78	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cd	0.21	0.07-0.44	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Co	0.022	0.015-0.025	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cr	0.07	0.056-0.110	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cu	3.5	2.6-5.7	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Fe	169	118-274	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Mg	149	125-171	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Mn	0.9	0.7-1.1	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Ni	≤0.006	<0.006-0.014	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Pb	0.04	<0.02-0.07	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	V	0.018	0.011-0.040	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Zn	19	15-27	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	As	1.6	1.1-2.5	10	blubber	Frank, A., et al., 1992
Kattegat	n.d.	juv	Al	0.65	≤0.02-1.38	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Ca	58	48-69	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Cd	0.04	≤0.02-0.06	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Co	0.019	≤0.002-0.025	10	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Kattegat	n.d.	juv	Cr	0.032	0.023-0.058	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Cu	12	8.1-20	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Fe	319	204-668	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Hg	2.42	1.44-5.29	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Mg	179	147-202	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Mn	4.7	4.1-5.0	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Ni	0.02	0.008-0.033	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Pb	0.08	0.03-0.91	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Se	2.07	1.42-3.58	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	V	0.042	0.022-0.077	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Zn	0.35	32-43	10	liver	Frank, A., et al., 1992
Kattegat	n.d.	juv	Al	0.29	0.18-1.75	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Ca	64	53-82	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Cd	0.23	0.12-0.57	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Co	0.018	<0.002-0.025	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Cr	0.044	0.020-0.140	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Cu	3.6	2.6-4.1	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Fe	155	139-193	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Mg	149	138-171	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Mn	0.9	0.7-1.2	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Ni	0.014	0.008-0.029	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Pb	0.04	<0.02-0.07	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	V	0.015	0.006-0.026	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	Zn	21	19-22	10	kidney	Frank, A., et al., 1992
Kattegat	n.d.	juv	As	2.3	1.4-3.4	10	blubber	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Al	1.88	0.23-5.64	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Ca	64	49-91	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Cd	0.02	≤0.02-0.06	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Co	0.008	≤0.002-0.022	10	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (±1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Kalmarsund	n.d.	juv	Cr	0.138	0.107-0.157	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Cu	4	2.2-9.2	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Fe	350	188-855	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Hg	0.44	0.20-0.85	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Mg	174	143-238	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Mn	3.7	1.4-6.2	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Ni	≤0.006	≤0.006-0.010	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Pb	0.1	0.04-0.22	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Se	1.02	0.69-1.42	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	V	0.024	0.015-0.056	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Zn	28	22-40	10	liver	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Al	0.59	0.17-2.08	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Ca	69	61-82	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Cd	0.1	<0.02-0.24	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Co	0.017	0.005-0.036	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Cr	0.139	0.069-0.150	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Cu	3.3	2.8-4.0	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Fe	150	115-237	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Mg	163	139-187	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Mn	0.9	0.7-1.3	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Ni	≤0.006	<0.006-0.027	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Pb	0.07	0.03-0.21	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	V	0.018	0.010-0.066	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	Zn	21	19-47	10	kidney	Frank, A., et al., 1992
Kalmarsund	n.d.	juv	As	0.83	0.3-1.7	10	blubber	Frank, A., et al., 1992
Skagerrak	1988	juv	Al	0.14	0.03-0.36	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Ca	44	28-80	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Cd	0.03	<0.02-0.11	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Co	0.013	0.007-0.020	10	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Skagerrak	1988	juv	Cr	0.07	0.053-0.170	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Cu	5.2	3.0-12	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Fe	353	189-546	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Hg	2.84	0.24-7.30	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Mg	161	129-213	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Mn	3.8	2.3-6.2	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Ni	≤0.006	≤0.006-0.029	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Pb	0.06	0.04-0.08	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Se	2.35	1.50-4.72	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	V	0.02	0.003-0.067	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Zn	36	23-62	10	liver	Frank, A., et al., 1992
Skagerrak	1988	juv	Al	0.1	0.07-1.13	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Ca	60	55-72	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cd	0.32	0.16-0.78	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Co	0.017	0.011-0.022	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cr	0.081	0.066-0.155	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Cu	6.4	4.2-12	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Fe	167	136-254	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Mg	155	142-168	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Mn	0.8	0.7-1.0	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Ni	0.04	0.024-0.071	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Pb	0.04	0.03-0.05	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	V	0.009	0.007-0.021	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	Zn	30	27-49	10	kidney	Frank, A., et al., 1992
Skagerrak	1988	juv	As	1.7	1.1-2.2	10	blubber	Frank, A., et al., 1992
Maklappen	1988	juv	Al	1.98	1.45-2.25	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Ca	58	44-72	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Cd	0.03	≤0.02-0.07	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Co	0.003	≤0.02-0.09	10	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Maklappen	1988	juv	Cr	0.106	0.091-0.125	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Cu	5.7	4.0-7.9	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Fe	698	409-751	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Hg	1.16	1.56-2.38	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Mg	156	146-166	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Mn	3.4	1.9-3.8	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Ni	≤0.006	≤0.006-0.011	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Pb	0.09	0.04-0.10	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Se	1.11	0.58-1.98	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	V	0.017	0.004-0.028	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Zn	45	42-49	10	liver	Frank, A., et al., 1992
Maklappen	1988	juv	Al	0.51	0.29-0.74	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Ca	60	49-75	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Cd	0.22	≤0.02-0.66	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Co	0.009	0.004-0.018	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Cr	0.13	0.121-0.154	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Cu	5.4	4.0-5.8	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Fe	168	133-281	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Mg	157	130-159	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Mn	0.9	0.7-0.9	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Ni	0.015	0.008-0.018	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Pb	0.04	0.03-0.04	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	V	0.007	0.004-0.009	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	Zn	34	31-47	10	kidney	Frank, A., et al., 1992
Maklappen	1988	juv	As	1.7	0.7-2.2	7	blubber	Frank, A., et al., 1992
Skagerrak	n.d.	a	Al	0.66	0.25-2.78	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Ca	53	39-71	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Cd	0.09	0.04-0.18	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Co	0.019	0.011-0.044	8	liver	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.3. (continued)

General Location	Date	Sex/Age[b]	Compound	Geometric Mean	Range	n	Tissue	Citation
Skagerrak	n.d.	a	Cr	0.049	≤0.002-0.128	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Cu	8.6	1.4-13	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Fe	808	586-1790	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Hg	26	1.31-66	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Mg	174	146-202	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Mn	3.7		8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Ni	0.026	≤0.006-0.171	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Pb	0.16	0.11-0.23	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Se	11	3.92-26	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	V	0.094	0.027-0.282	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Zn	54	19-62	8	liver	Frank, A., et al., 1992
Skagerrak	n.d.	a	Al	0.22	0.09-0.44	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Ca	65	50-66	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Cd	0.46	0.23-0.74	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Co	0.012	0.007-0.023	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Cr	0.154	0.126-0.190	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Cu	4.5	2.7-5.9	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Fe	201	138-300	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Mg	146	123-158	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Ni	≤0.006	≤0.006-0.021	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Pb	0.05	0.04-0.10	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	V	0.028	0.008-0.120	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	Zn	29	25-40	8	kidney	Frank, A., et al., 1992
Skagerrak	n.d.	a	As	1.6	0.96-2.3	8	blubber	Frank, A., et al., 1992

[a] mg/kg wet mass (± 1 SD)

[b] M-male; F-female; juv-juvenile; p-pup; a-adult

[c] n.d.- not determined

Table 2.4. Mean Concentrations of Persistant Organochlorine Contaminants in Harbor Seals, *Phoca vitulina*, from Alaska[a]

General Location	Date	Sex[c]	Compound	Geometric Mean	Range	n	Tissue	Citation
Prince William Sound[b]	1993	F	sPCB	233 (7)	n.d.[d]	2	Blubber	Krahn, M., et al., 1996
Prince William Sound[b]	1993	M	sPCB	599 (143)	n.d.	3	Blubber	Krahn, M., et al., 1996
Prince William Sound[b]	1993	F	sDDT	139 (9)	n.d.	2	Blubber	Krahn, M., et al., 1996
Prince William Sound[b]	1993	M	sDDT	430 (67)	n.d.	3	Blubber	Krahn, M., et al., 1996
Prince William Sound[b]	1993	F	Chlordanes	91 (11)	n.d.	2	Blubber	Krahn, M., et al., 1996
Prince William Sound[b]	1993	M	Chlordanes	281 (38)	n.d.	3	Blubber	Krahn, M., et al., 1996
Prince William Sound	1993	F	HCB	9.0 (1.0)	n.d.	2	Blubber	Krahn, M., et al., 1996
Prince William Sound	1993	M	HCB	13.7 (2.6)	n.d.	3	Blubber	Krahn, M., et al., 1996
Prince William Sound	1993	F	dieldrin	3.5 (0.5)	n.d.	2	Blubber	Krahn, M., et al., 1996
Prince William Sound	1993	M	dieldrin	6.3 (2.1)	n.d.	3	Blubber	Krahn, M., et al., 1996
Kodiak, Alaska	1993	n.d.	4,4'-DDD	0	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	4,4'-DDE	14.8	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	4,4'-DDT	1.7	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	Endrin Aldehyde	1	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	Heptachlor	2.3	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	alpha-HCH	6.8	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	beta-HCH	7	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	gamma-HCH	46.5	n.d.	5	Blubber	Lewis, J.P. 1995
Kodiak, Alaska	1993	n.d.	4,4'-DDD	0.5	n.d.	5	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	4,4'-DDE	292.5	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	4,4'-DDT	3.6	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Aldrin	0.4	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Endosulfan I	10.4	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Endosulfan II	0.3	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Endrin	1	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Endrin Aldehyde	38.1	n.d.	13	Blubber	Lewis, J.P. 1995

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]M-male; F-female

[d] n.d. - not determined

Table 2.4. (continued)

General Location	Date	Sex[c]	Compound	Geometric Mean	Range	n	Tissue	Citation
Southeast, Alaska	1993	n.d.	Heptachlor	0.3	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	Heptachlor Epoxide	8.2	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	alpha-HCH	9.2	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	beta-HCH	8.4	n.d.	13	Blubber	Lewis, J.P. 1995
Southeast, Alaska	1993	n.d.	gamma-HCH	17.9	n.d.	13	Blubber	Lewis, J.P. 1995
Alaska[b]	1989-1990	n.d.	PCBs	21.0 (2.0)	n.d.	9	Liver	Varanasi, U., et. al, 1993
Alaska[b]	1989-1990	n.d.	PCBs	340.0 (42.0)	n.d.	7	Blubber	Varanasi, U., et. al, 1993
Alaska[b]	1989-1990	n.d.	DDTs	9.0 (1.0)	n.d.	9	Liver	Varanasi, U., et. al, 1993
Alaska[b]	1989-1990	n.d.	DDTs	260.0 (38.0)	n.d.	7	Blubber	Varanasi, U., et. al, 1993
Alaska[b]	1989-1990	n.d.	Chlordanes	3.0 (0.4)	n.d.	9	Liver	Varanasi, U., et. al, 1993
Alaska[b]	1989-1990	n.d.	Chlordanes	110.0 (20.0)	n.d.	7	Blubber	Varanasi, U., et. al, 1993

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]M-male; F-female

[d] n.d. - not determined

Table 2.5. Mean Concentrations of Persistent Organochlorine Contaminants in Harbor Seals, *Phoca vitulina* , from the U.S. Outside Alaska[a]

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Southern Puget Sound[b]	1972-1981	M,p	PCB	31 (15-64)	n.d.[e]	3	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	M,sa	PCB	72 (38-130)	n.d.	4	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	M,a	PCB	240 (210-280)	n.d.	3	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	F,p	PCB	97 (58-160)	n.d.	4	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	F,sa	PCB	310 (170-570)	n.d.	5	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	F,a	PCB	21.00		1	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	M,p	PCB	12 (7.4-21)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	M,a	PCB	93 (82-100)	n.d.	2	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	F,p	PCB	8.30		1	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	M,p	PCB	9.80		1	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	M,a	PCB	27 (24-30)	n.d.	2	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	F,p	PCB	8.3 (4.5-15)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,p	PCB	6.2 (3.1-13)	n.d.	5	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,sa	PCB	16 (9.4-28)	n.d.	11	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,a	PCB	24 (15-39)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,p	PCB	1.90		1	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,sa	PCB	13 (7.9-22)	n.d.	3	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,a	PCB	17 (6.5-43)	n.d.	7	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	M,p	DDE	2.6 (0.93-7.4)	n.d.	3	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	M,sa	DDE	6.7 (3.9-11)	n.d.	4	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	M,a	DDE	17 (15-20)	n.d.	3	Blubber	Calambokidis, J., et.al., 1984

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Southern Puget Sound[b]	1972-1981	F,p	DDE	12 (7.2-21)	n.d.	4	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	F,sa	DDE	30 (21-41)	n.d.	5	Blubber	Calambokidis, J., et.al., 1984
Southern Puget Sound[b]	1972-1981	F,a	DDE	1.30		1	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	M,p	DDE	1.8 (1.0-3.1)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	M,a	DDE	13 (12-14)	n.d.	2	Blubber	Calambokidis, J., et.al., 1984
Hood Canal[b]	1972-1981	F,p	DDE	1.00		1	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	M,p	DDE	2.60		1	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	M,a	DDE	9.5 (8.4-11)	n.d.	2	Blubber	Calambokidis, J., et.al., 1984
Northern Puget Sound[b]	1972-1981	F,p	DDE	2.3 (1.1-4.8)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,p	DDE	2.9 (1.5-5.8)	n.d.	5	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,sa	DDE	9.3 (5.6-15)	n.d.	11	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	M,a	DDE	12 (9.5-16)	n.d.	6	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,p	DDE	0.80		1	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,sa	DDE	5.7 (1.9-17)	n.d.	3	Blubber	Calambokidis, J., et.al., 1984
Outer Coast[b]	1972-1981	F,a	DDE	6.3 (2.6-15)	n.d.	7	Blubber	Calambokidis, J., et.al., 1984
Washington/Oregon Coast[b]	1992	F	PCBs	2,077 (586)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast[b]	1992	M	PCBs	4,227 (1,414)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast[b]	1992	F	DDTs	2,313 (791)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast[b]	1992	M	DDTs	5,200 (1,855)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast[b]	1992	F	Chlordanes	439 (152)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast[b]	1992	M	Chlordanes	875 (236)	n.d.	5	Blubber	Krahn, M., et al., 1996

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Washington/Oregon Coast	1992	F	HCB	11.4 (1.4)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast	1992	M	HCB	14.6 (5.0)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast	1992	F	dieldrin	8.4 (1.9)	n.d.	5	Blubber	Krahn, M., et al., 1996
Washington/Oregon Coast	1992	M	dieldrin	16.6 (5.8)	n.d.	5	Blubber	Krahn, M., et al., 1996
Boothbay Harbour, Maine	1971	M	p,p'-DDE	38.80	20.66-53.86	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDE	0.11	0.09-0.14	2	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDE	0.86	0.45-1.23	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDE	0.43	0.23-0.70	3	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDD	8.01	4.03-21.29	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDD	0.02	0.01-0.04	2	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDD	0.41	0.19-0.81	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDD	0.12	0.07-0.19	2	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	o,p'-DDT	0.31		1	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	o,p'-DDT	trace		1	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	o,p'-DDT	not detected	n.d.	n.d.	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	o,p'-DDT	not detected	n.d.	n.d.	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDT	24.83	11.98-64.02	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDT	0.03	0.02-0.04	2	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDT	0.16	0.11-0.26	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	p,p'-DDT	0.09	0.04-0.19	2	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	dieldrin	0.23	0.15-0.38	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	dieldrin	trace	n.d.	n.d.	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	dieldrin	0.04		1	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	M	dieldrin	0.01		1	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	M	PCB	100.46	35.12-240.21	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	M	PCB	0.37	0.28-0.50	2	Muscle	Gaskin, D.E. et al., 1973

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix 1

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Boothbay Harbour, Maine[b]	1971	M	PCB	2.47	1.00-6.00	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	M	PCB	1.28	0.62-2.8	3	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDE	23.64	14.86-32.10	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDE	0.07	0.04-0.09	3	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDE	0.16	0.05-0.40	2	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDE	0.28	0.21-0.38	2	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDD	3.44	1.14-11.20	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDD	0.01	0.01-0.01	2	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDD	0.10	0.02-0.25	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDD	0.07		1	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	o,p'-DDT	0.09	0.09-0.09	2	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	o,p'-DDT	not detected	n.d.	n.d	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	o,p'-DDT	not detected	n.d.	n.d	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	o,p'-DDT	not detected	n.d.	n.d	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDT	15.47	9.23-25.05	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDT	0.01		1	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDT	0.05	0.02-0.11	2	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	p,p'-DDT	not detected	n.d.	n.d	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	dieldrin	0.14	0.06-0.35	2	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	dieldrin	trace	trace	3	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	dieldrin	trace	trace	3	Liver	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine	1971	F	dieldrin	not detected	n.d.	n.d	Cerebrum	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	F	PCB	44.68	27.93-99.78	3	Blubber	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	F	PCB	0.17	0.10-0.25	3	Muscle	Gaskin, D.E. et al., 1973
Boothbay Harbour, Maine[b]	1971	F	PCB	0.30	0.10-0.68	3	Liver	Gaskin, D.E. et al., 1973

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Boothbay Harbour, Maine[b]	1971	F	PCB	0.33		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDE	26.71	21.62-33.00	2	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDE	0.47	0.19-2.03	3	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDE	0.86	0.34-1.79	3	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDE	0.31	0.23-0.44	4	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDD	0.71	0.36-1.41	2	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDD	0.05	0.02-0.12	3	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDD	0.15	0.01-0.73	3	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDD	0.02	0.01-0.03	3	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	o,p'-DDT	n.d.	n.d.	n.d.	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	o,p'-DDT	n.d.	n.d.	n.d.	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	o,p'-DDT	n.d.	n.d.	n.d.	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	o,p'-DDT	n.d.	n.d.	n.d.	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDT	14.58	12.01-17.70	2	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDT	0.04	0.01-0.62	3	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDT	0.21		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	p,p'-DDT	n.d.	n.d.	n.d.	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	dieldrin	0.29	0.27-0.31	2	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	dieldrin	0.03		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	dieldrin	0.02	0.02-0.03	2	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	M	dieldrin	0.02		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	M	PCB	46.83	43.00-51.00	2	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	M	PCB	0.85	0.30-5.10	3	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	M	PCB	2.02	0.80-4.50	3	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	M	PCB	0.49	0.20-0.80	4	Cerebrum	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	p,p'-DDE	19.27		1	Blubber	Gaskin, D.E. et al., 1973

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Deer Island, New Brunswick	1971	M	p,p'-DDE	0.32		1	Muscle	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	p,p'-DDD	1.86		1	Blubber	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	p,p'-DDD	0.01		1	Muscle	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	o,p'-DDT	trace		1	Blubber	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	o,p'-DDT	not detected		1	Muscle	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	p,p'-DDT	8.00		1	Blubber	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	p,p'-DDT	not detected		1	Muscle	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	dieldrin	1.16		1	Blubber	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick	1971	M	dieldrin	0.01		1	Muscle	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick[b]	1971	M	PCB	63.00		1	Blubber	Gaskin, D.E. et al., 1973
Deer Island, New Brunswick[b]	1971	M	PCB	0.50		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDE	4.90		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDE	0.17		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDE	0.22		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDE	0.01		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDD	0.18		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDD	0.01		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDD	0.13		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDD	not detected		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	o,p'-DDT	not detected		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	o,p'-DDT	not detected		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	o,p'-DDT	not detected		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	o,p'-DDT	not detected		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDT	3.56		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDT	0.05		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	p,p'-DDT	not detected		1	Liver	Gaskin, D.E. et al., 1973

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Grand Manan Island, New Brunswick	1971	F	p,p'-DDT	not detected		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	dieldrin	0.04		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	dieldrin	trace		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	dieldrin	trace		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick	1971	F	dieldrin	not detected		1	Cerebrum	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	F	PCB	7.10		1	Blubber	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	F	PCB	0.02		1	Muscle	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	F	PCB	0.13		1	Liver	Gaskin, D.E. et al., 1973
Grand Manan Island, New Brunswick[b]	1971	F	PCB	0.01		1	Cerebrum	Gaskin, D.E. et al., 1973
Southern Puget Sound	1977-78	n.d.	PCB	171 (162)	n.d.	20	Blubber	Calambokidis, J. et al., 1979
Southern Puget Sound	1977-78	n.d.	p,p'-DDE	15.2 (12.0)	n.d.	20	Blubber	Calambokidis, J. et al., 1979
Gertrude Island, S. Puget Sound	1977-78	n.d.	PCB	171.0 (81.0)	n.d.	11	Blubber	Calambokidis, J. et al., 1979
Gertrude Island, S. Puget Sound	1977-78	n.d.	p,p'-DDE	16.0 (7.7)	n.d.	11	Blubber	Calambokidis, J. et al., 1979
Northern Puget Sound	1977-78	n.d.	PCB	14.8 (8.73)	n.d.	8	Blubber	Calambokidis, J. et al., 1979
Northern Puget Sound	1977-78	n.d.	p,p'-DDE	4.64 (3.5)	n.d.	8	Blubber	Calambokidis, J. et al., 1979
Hood Canal	1977-78	n.d.	PCB	31.0 (3.63)	n.d.	9	Blubber	Calambokidis, J. et al., 1979
Hood Canal	1977-78	n.d.	p,p'-DDE	4.38 (5.0)	n.d.	9	Blubber	Calambokidis, J. et al., 1979
Grays Harbor	1977-78	n.d.	PCB	18.8 (14.5)	n.d.	28	Blubber	Calambokidis, J. et al., 1979
Grays Harbor	1977-78	n.d.	p,p'-DDE	9.00 (6.2)	n.d.	28	Blubber	Calambokidis, J. et al., 1979
Outer Coast	1977-78	n.d.	PCB	16.3 (11.4)	n.d.	6	Blubber	Calambokidis, J. et al., 1979
Outer Coast	1977-78	n.d.	p,p'-DDE	8.34 (4.1)	n.d.	6	Blubber	Calambokidis, J. et al., 1979
San Francisco Bay	1989-90	F	p,p'-DDE	7.5 (1.2)	0-15.0	19	Herapin	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-90	M	p,p'-DDE	17.0 (2.1)	6.0-48.0	22	Herapin	Kopec, A.D. and Harvey, J.T., 1995
San Nicolas Island	1990	M,sa	p,p'-DDE	17.0 (1.0)	15.0-18.0	3	Herapin	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-90	F	PCB Aroclor 1260	10.7 (5.9)	0-79.0	19	Herapin	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay	1989-90	M	PCB Aroclor 1260	77.7 (16.5)	0-330	22	Herapin	Kopec, A.D. and Harvey, J.T., 1995

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
San Francisco Bay[b]	1991-92	F	PCB	47.9 (12.9)	12.0-152.0	10	Blood	Kopec, A.D. and Harvey, J.T., 1995
San Francisco Bay[b]	1991-92	M	PCB	57.0 (11.7)	30.0-79.0	4	Blood	Kopec, A.D. and Harvey, J.T., 1995
Monterey Coast[b]	1992	n.d.	PCB	175.0 (161.0)	14.0-336.0	2	Blood	Kopec, A.D. and Harvey, J.T., 1995
Smith Island[b,c]	1990	M,p	PCB	2.43	1.1-19	4	Blubber	Calambokidis, J. et al., 1991
Smith Island[b,c]	1990	F,p	PCB	1.80		1	Blubber	Calambokidis, J. et al., 1991
Gertrude Island[b,c]	1990	F,p	PCB	17.97	12.0-23.0	4	Blubber	Calambokidis, J. et al., 1991
Gertrude Island[b,c]	1990	M,p	PCB	22.00	n.d.	1	Blubber	Calambokidis, J. et al., 1991
Smith Island[c]	1990	M,p	p,p'-DDE	1.06	0.4-6.5	4	Blubber	Calambokidis, J. et al., 1991
Smith Island[c]	1990	F,p	p,p'-DDE	1.00		1	Blubber	Calambokidis, J. et al., 1991
Gertrude Island[c]	1990	F,p	p,p'-DDE	2.15	1.5-2.8	4	Blubber	Calambokidis, J. et al., 1991
Gertrude Island[c]	1990	M,p	p,p'-DDE	2.60		1	Blubber	Calambokidis, J. et al., 1991
Northeastern Coast of U.S.[b]	1980	n.d.	PCB	12000 (6340)	7300-24300	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	p,p'-DDE	10900 (5790)	6520-21900	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	HCB	3.90 (2.37)	n.d.	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	alpha-chlordane	94.1 (36.3)	n.d.	5	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	trans-nonachlor	2740 (2180)	n.d.	5	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	mirex	56.7 (28.7)	n.d.	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	PCB 77	0.316 (0.145)	0.198-0.504	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	PCB 126	1.450 (0.868)	0.628-2.910	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	PCB 169	0.019 (0.023)	n.d.-0.050	6	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.[b]	1990-92	n.d.	PCB	6660 (2780)	2610-11300	9	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	p,p'-DDE	4120 (1890)	1830-7840	9	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	HCB	5.25 (2.46)	n.d.	9	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	alpha-chlordane	18.4 (14.6)	n.d	4	Blubber	Lake, C. A. et al., 1995

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.5. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Northeastern Coast of U.S.	1990-92	n.d.	trans-nonachlor	1150 (467)	n.d	4	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	mirex	31.6 (13.5)	n.d	9	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1991-92	n.d.	PCB 77	0.073 (0.0055)	0.068-0.080	4	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1991-92	n.d.	PCB 126	0.533 (0.310)	0.326-0.992	4	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1991-92	n.d.	PCB 169	0.013 (0.0091)	n.d.-0.021	4	Blubber	Lake, C. A. et al., 1995
Northeastern Coast of U.S.[b]	1980	n.d.	PCB	9860 (3340)	6290-16000	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	p,p'-DDE	4690 (2180)	1930-7930	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	HCB	0.560 (0.190)	n.d.	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	alpha-chlordane	88.2 (47.2)	n.d.	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	trans-nonachlor	574 (193)	n.d.	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1980	n.d.	mirex	40.3 (14.0)	n.d.	6	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.[b]	1990-92	n.d.	PCB	6260 (8070)	528-25300	9	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	p,p'-DDE	3390 (4360)	94.8-13000	9	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	HCB	2.19 (3.03)	n.d.	9	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	alpha-chlordane	54.0 (103)	n.d.	5	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	trans-nonachlor	686 (755)	n.d.	5	Liver	Lake, C. A. et al., 1995
Northeastern Coast of U.S.	1990-92	n.d.	mirex	29.5 (33.8)	n.d.	9	Liver	Lake, C. A. et al., 1995

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds-See Appendix I

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female; p-pup; sa-subadult; a-adult

[e] n.d. - not determined

Table 2.6. Mean Concentrations of Persistent Organochlorine Contaminants in Harbor Seals, *Phoca vitulina*, from Regions Outside of the U.S.[a]

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Skageraak[b,c]	1988	n.d.[g]	sDDT	4.1	2.3-6.3	5	Blubber	Blomkvist, G., et.al., 1992
Kattegat[b,c]	1988	n.d.	sDDT	6.9	2.4-13.0	5	Blubber	Blomkvist, G., et.al., 1992
Kalmarsund (Baltic)[b,c]	1988	n.d.	sDDT	27	12.0-60.0	5	Blubber	Blomkvist, G., et.al., 1992
Skageraak[c]	1988	n.d.	PCB Aroclor 1254	18	18.0-60.0	5	Blubber	Blomkvist, G., et.al., 1992
Kattegat[c]	1988	n.d.	PCB Aroclor 1254	15	6.3-29.0	5	Blubber	Blomkvist, G., et.al., 1992
Kalmarsund (Baltic)[c]	1988	n.d.	PCB Aroclor 1254	36	16.0-98.0	5	Blubber	Blomkvist, G., et.al., 1992
Limfjord, Denmark[b]	1988	n.d.	PCB	4.8	2.97-6.08	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Wadden Sea[b]	1988	n.d.	PCB	17.52	11.9-34.0	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Kattegat[b]	1988	n.d.	PCB	9.94	5.87-14.0	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Limfjord[b,h]	1988	n.d.	nCB	255.53	199-334	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Wadden Sea[b,h]	1988	n.d.	nCB	458.01	338-631	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Kattegat[b,h]	1988	n.d.	nCB	464.15	383-577	7	Blubber	Storr-Hansen, E. and Spliid, H., 1993
Southern Coast of Norway[b]	1988	M	PCB	960	560-4300	10	Brain	Bernhoft, A. and Skaare, J.U., 1994
Southern Coast of Norway[b]	1988	M	PCB	6,600	4,200-22,000	10	Kidney	Bernhoft, A. and Skaare, J.U., 1994
Southern Coast of Norway[b]	1988	M	PCB	10,000	4,500-33,000	10	Liver	Bernhoft, A. and Skaare, J.U., 1994
Southern Coast of Norway[b]	1988	M	PCB	15,000	3,400-29,000	10	Blubber	Bernhoft, A. and Skaare, J.U., 1994
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	1.14	0.53-1.53	3	Brain	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	167.8	27.3-480.7	24	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	135.5	61.0-208.0	12	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	1.38	0.252-2.96	4	Brain	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	162.8	28.5-564.0	11	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	87.3	50.3-136.0	4	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	0.48		1	Brain	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	71.1		1	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	164.6	32.3-256.0	4	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.093	0.058-0.127	3	Brain	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	10.3	4.4-23.3	24	Blubber	Drescher, H.E., et al., 1977

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g]n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
German North Sea Coast[b,c]	1974-76	n.d.	DDT	7.7	2.9-14.7	12	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.1	0.039-0.161	11	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	8.8	2.2-27.2	11	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	6	5.5-6.2	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.038		1	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	4.6		1	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	6.3	4.6-7.8	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	trace		n.d.	Brain	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.19	0.06-0.56	24	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.35	0.14-0.8	12	Blubber	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	trace	n.d.	n.d.	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.14	0.04-0.36	11	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.54	0.14-0.9	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	trace	n.d.	n.d.	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.31		1	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.15	0.1-0.2	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	trace	n.d.	n.d.	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.31	0.04-0.78	24	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.36	0.24-0.98	12	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	trace	n.d.	n.d.	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.29	0.16-0.54	11	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.34	0.26-0.56	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	trace	n.d.	n.d.	Brain	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.34		1	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.27	0.24-0.35	4	Blubber	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroelor 1254	0.87	n.d.	2	Kidney	Dreseher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroelor 1254	2.02	n.d.	2	Liver	Drescher, H.E., et al., 1977

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, ete.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extraeted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	0.38	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	0.22	n.d.	2	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	PCB Aroclor 1254	0.49		1	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.25	n.d.	2	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.25	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.11	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.05	n.d.	2	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[b,c]	1974-76	n.d.	DDT	0.06		1	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	trace	n.d.	n.d.	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.016	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.01	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	trace	n.d.	n.d.	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	dieldrin	0.024		1	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	trace	n.d.	n.d.	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.006	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.005	n.d.	2	Liver	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	trace	n.d.	n.d.	Kidney	Drescher, H.E., et al., 1977
German North Sea Coast[c]	1974-76	n.d.	lindane	0.006		1	Liver	Drescher, H.E., et al., 1977
Dutch Wadden Sea[b,c]	n.d.	M	PCB	6.85	1.5-36.0	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	M	PCB	8.34	1.4-46	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	M	PCB	109.03	22-576	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	M	PCB	7.04	1.6-31	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	M	PCB	2.35	1.1-5.0	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	M	PCB	9.17	2.1-40	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	F	PCB	120.5	41.0-220.0	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[b,c]	n.d.	F	PCB	28		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.01	0.001-0.02	4	Liver	Duinker, J.C., et al., 1979

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.13	0.08-0.16	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.15	0.03-0.34	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.01	0.001-0.01	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.01	0.001-0.01	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	alpha-HCH	0.006	0.004-0.01	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	alpha-HCH	0.41	0.22-0.95	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	alpha-HCH	0.06		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.003	0.001-0.01	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.13	0.001-0.13	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.07	0.03-0.23	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.03	<0.001-0.03	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.003	0.001-0.01	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	gamma-HCH	0.013	0.006-0.03	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	gamma-HCH	0.21	0.14-.039	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	gamma-HCH	0.02		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.016	0.009-0.04	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.009	<0.003-0.02	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.19	<0.02-.26	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.01	<0.001-0.01	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.004	0.002-0.01	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	dieldrin	0.03	0.012-0.07	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	dieldrin	0.76	0.46-1.4	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	dieldrin	0.03		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	<0.001-0.004	n.d.	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	0.006	<0.003-0.02	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	0.06	<0.02-1.18	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	<0.001	<0.001-0.002	2	Kidney	Duinker, J.C., et al., 1979

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	<0.001	<0.001	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	o,p'-DDD	0.003	<0.001-0.007	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	o,p'-DDD	0.035	<0.02-0.07	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	o,p'-DDD	0.001		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.13	0.048-.046	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.08	<0.01-0.22	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.43	<0.05-4.5	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.017	<0.003-0.1	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.008	<0.001-0.07	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDD	0.09	0.051-0.12	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDD	0.2	0.096-0.55	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDD	0.08		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.05	<0.08-0.06	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.04	<0.01-0.9	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.56	<0.1-2.5	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.007	<0.006-<0.008	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.003	<0.003-<0.004	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDT	0.106	0.08-0.14	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDT	3.06	0.92-6.9	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDT	0.05		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	0.24	0.07-0.88	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	0.38	0.06-1.97	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	4.37	0.51-20.3	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	0.18	0.05-0.66	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	0.06	0.03-0.122	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	p,p'-DDE	0.2	0.12-0.34	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDE	4.52	1.63-9.4	3	Blubber	Duinker, J.C., et al., 1979

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Dutch Wadden Sea[c]	n.d.	F	p,p'-DDE	0.23		1	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	mirex	0.005	<0.0010.05	4	Liver	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	mirex	0.03	<0.01-.25	3	Brain	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	mirex	0.31	<0.1-1.1	4	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	mirex	0.006	<0.006-0.006	2	Kidney	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.[f]	M	mirex	0.003	<0.003-0.003	2	Spleen	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	M	mirex	0.023	<0.005-0.11	2	Heart	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	mirex	0.95	0.6-1.3	3	Blubber	Duinker, J.C., et al., 1979
Dutch Wadden Sea[c]	n.d.	F	mirex	0.02		1	Liver	Duinker, J.C., et al., 1979
The Wash, England[e]	1988	M	4,4'-DDE	0.204	0.16-0.26	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	4,4'-DDD	0.000	0	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	4,4'-DDT	0.059	0.05-0.07	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB28	0.005	0.005-0.005	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB52	0.005	0.005-0.005	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB101	0.056	0.024-0.130	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB118	0.005	0.005-0.005	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB138	0.332	0.22-0.50	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB153	0.555	0.35-0.88	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	PCB180	0.179	0.08-0.40	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	Aroclor 1254 equiv.	3.244	1.818-5.787	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	dieldrin	0.003	0.001-0.012	2	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDE	0.140	0.10-0.23	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDD	0.000	0	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDT	0.035	0.02-0.07	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB28	0.005	0.005-0.005	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB52	0.005	0.005-0.005	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB101	0.024	0.020-0.030	3	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
The Wash, England[c]	1988	F	PCB118	0.005	0.005	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	F	PCB138	0.207	0.11-0.45	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	F	PCB153	0.323	0.28-0.67	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	F	PCB180	0.094	0.05-0.21	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	F	Aroclor 1254 equiv.	1.873	1.069-3.411	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	F	dieldrin	0.001	0.001-0.001	3	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	4,4'-DDE	0.43		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	4,4'-DDD	0		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	4,4'-DDT	0.09		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB28	0.005		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB52	0.032		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB101	0.073		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB118	0.03		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB138	0.52		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB153	0.71		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	PCB180	0.18		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	Aroclor 1254 equiv.	3.567		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	n.d.	dieldrin	0.014		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	4,4'-DDE	2.853	1.6-4.6	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	4,4'-DDD	0.030	0.01-0.09	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	4,4'-DDT	1.431	0.76-3.3	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB28	0.011	0.006-0.033	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB52	0.578	0.350-0.840	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB101	0.243	0.150-0.400	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB118	0.203	0.140-0.490	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB138	1.883	1.10-3.00	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[c]	1988	M	PCB153	1.752	0.60-3.60	5	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
The Wash, England[e]	1988	M	PCB180	0.806	0.80-1.10	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	Aroelor 1254 equiv.	17.204	16.048-21.419	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	M	dieldrin	0.227	0.120-0.530	5	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDE	1.954	0.70-3.1	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDD	0.030	0.02-0.05	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	4,4'-DDT	0.969	0.27-2.2	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB28	0.010	0.005-0.014	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB52	0.673	0.45-1.1	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB101	0.166	0.29-0.17	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB118	0.144	0.08-0.29	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB138	1.338	0.65-2.2	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB153	1.888	0.90-2.80	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	PCB180	0.715	0.26-1.2	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	Aroelor 1254 equiv.	15.944	6.794-24.26	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	F	dieldrin	0.133	0.076-0.26	4	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	4,4'-DDE	4.2		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	4,4'-DDD	0.04		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	4,4'-DDT	1.8		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB28	0.014		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB52	1.1		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB101	0.42		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB118	0.18		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB138	2.5		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB153	3.2		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	PCB180	1.1		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	Aroelor 1254 equiv.	23.668		1	Blubber	Hall, A.J., et al., 1992
The Wash, England[e]	1988	n.d.	dieldrin	0.19		1	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDE	1.394	0.03-3.2	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDD	0.044	0.02-0.22	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDT	0.386	0.3-1.9	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB28	0.001	0.001-0.001	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB52	0.010	0.001-0.17	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB101	0.090	0.001-0.9	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB118	0.279	0.001-4.9	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB138	2.553	0.02-14.0	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB153	3.893	0.03-17.0	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB180	2.663	0.00-12.0	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	Aroclor 1254 equiv.	21.523	0.273-99.694	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	dieldrin	0.159	0.087-0.53	10	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDE	3		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDD	0.33		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDT	1.5		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB28	0.001		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB52	0.001		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB101	0.97		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB118	1.7		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB138	9.5		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB153	13		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB180	4.8		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	Aroclor 1254 equiv.	44.861		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	dieldrin	0.52		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDE	1.4		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDD	0.33		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	4,4'-DDT	0.79		1	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Strangford Lough, N. Ireland[c]	1988	M	PCB28	0.005		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB52	0.026		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB101	0.084		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB118	0.032		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB138	1.3		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB153	1.7		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	PCB180	0.69		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	Aroclor 1254 equiv.	10.096		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	M	dieldrin	0.007		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDE	0.341	0.04-2.9	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDD	0.067	0.05-0.09	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	4,4'-DDT	0.771	0.54-1.1	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB28	0.005	0.005-0.005	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB52	0.085	0.056-0.085	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB101	0.183	0.16-0.21	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB118	0.076	0.059-0.097	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB138	2.291	1.5-3.5	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB153	3.589	2.3-5.6	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	PCB180	2.408	2.0-2.9	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	Aroclor 1254 equiv.	34.708	30.902-38.98	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	F	dieldrin	0.024	0.02-0.03	2	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	4,4'-DDE	3.5		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	4,4'-DDD	0.08		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	4,4'-DDT	1.5		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB28	0.005		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB52	0.13		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB101	0.27		1	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[c]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB118	0.081		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB138	3.3		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB153	4.1		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	PCB180	2		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	Aroclor 1254 equiv.	31.567		1	Blubber	Hall, A.J., et al., 1992
Strangford Lough, N. Ireland[c]	1988	n.d.	dieldrin	0.024		1	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	4,4'-DDE	0.860	0.43-1.68	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	4,4'-DDD	0.041	0.013-0.09	3	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	4,4'-DDT	0.567	0.28-1.12	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB28	0.000	0.000	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB52	0.118		1	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB101	0.244	0.198-0.37	3	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB118	0.047	0.019-0.09	3	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB138	0.678	0.31-1.23	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB153	0.959	0.47-1.56	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	PCB180	0.425	0.02-46.0	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	Aroclor 1254 equiv.	3.944	0.797-9.573	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	M	dieldrin	0.011	0.001-0.1	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	4,4'-DDE	0.504	0.04-1.12	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	4,4'-DDD	0.048	0.03-0.14	10	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	4,4'-DDT	0.380	0.18-0.85	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB28	0.000	0.000	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB52	0.000	0.000	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB101	0.238	0.062-17.0	9	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB118	0.028	0.018-0.045	8	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB138	0.539	0.24-0.97	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[c]	1988	F	PCB153	0.783	0.47-1.87	11	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g]n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
The Moray Firth, Scotland[e]	1988	F	PCB180	0.243	0.09-0.56	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	Aroclor 1254 equiv.	4.939	2.34-11.47	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	dieldrin	0.024	0.001-0.059	11	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	4,4'-DDE	1.500	0.89-2.8	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	4,4'-DDD	0.268	0.05-0.78	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	4,4'-DDT	1.209	0.36-2.49	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB28	0.000	0.000	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB52	0.124		1	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB101	0.320	0.194-0.556	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB118	0.069	0.038-0.095	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB138	2.035	0.61-3.82	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB153	2.819	0.8-5.14	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	PCB180	1.191	0.28-2.49	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	Aroclor 1254 equiv.	17.728	5.027-40.67	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	M	dieldrin	0.470	0.022-0.069	4	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	4,4'-DDE	1.126	0.47-2.68	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	4,4'-DDD	0.152	0.07-0.43	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	4,4'-DDT	0.630	0.16-1.35	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB28	0.000	0.000	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB52	0.057	0.012-0.157	5	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB101	0.243	0.113-0.605	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB118	0.094	0.038-0.239	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB138	1.155	0.46-2.53	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB153	1.860	0.71-4.42	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	PCB180	0.955	0.25-3.03	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	Aroclor 1254 equiv.	17.041	6.228-46.079	6	Blubber	Hall, A.J., et al., 1992
The Moray Firth, Scotland[e]	1988	F	dieldrin	0.057	0.033-0.172	6	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds (PCB, DDT, etc.)

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female

[e]mean and range values based on results from 10-15 laboratories for one animal

[f]ng/g extracted lipid mass

[g] n.d. - not determined

[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
West Coast of Scotland[c]	1988	M	4,4'-DDE	0.845	0.68-1.25	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	4,4'-DDD	0.080		1	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	4,4'-DDT	0.217	0.17-0.26	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB28	0.000	0.000	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB52	0.044		1	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB101	0.129		1	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB118	0.016		1	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB138	0.582	0.54-.063	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB153	0.916	0.8-0.99	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	PCB180	0.249	0.21-0.32	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	Aroclor 1254 equiv.	5.385	4.039-6.732	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	dieldrin	0.019	0.001-0.087	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	4,4'-DDE	0.435	0.38-0.53	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	4,4'-DDD	0.040		1	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	4,4'-DDT	0.206	0.17-0.25	2	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB28	0.000	0.000	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB52	0.000	0.000	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB101	0.097	0.081-0.116	2	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB118	0.024	0.016-0.035	2	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB138	0.487	0.35-0.6	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB153	0.863	0.65-1.02	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	PCB180	0.402	0.32-0.45	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	Aroclor 1254 equiv.	7.669	6.145-9.37	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	F	dieldrin	0.011	0.001-0.05	3	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	4,4'-DDE	1.352	0.65-4.34	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	4,4'-DDD	0.181	0.11-0.47	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[c]	1988	M	4,4'-DDT	0.828	0.6-1.65	4	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
West Coast of Scotland[e]	1988	M	PCB28	0.010	0.006-0.016	2	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB52	0.035	0.009-0.088	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB101	0.381	0.211-0.567	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB118	0.102	0.036-0.833	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB138	2.437	1.63-5.49	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB153	4.336	2.45-8.42	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	PCB180	1.977	1.07-4.34	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	Aroclor 1254 equiv.	27.719	19.07-54.865	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	M	dieldrin	0.044	0.01-0.099	4	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	4,4'-DDE	1.515	0.76-3.29	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	4,4'-DDD	0.167	0.12-0.31	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	4,4'-DDT	0.543	0.13-2.45	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB28	0.006	0.001-0.031	5	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB52	0.064	0.018-0.199	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB101	0.321	0.11-1.203	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB118	0.114	0.051-0.198	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB138	1.383	0.95-2.62	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB153	1.995	1.38-3.63	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	PCB180	0.756	0.47-1.07	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	Aroclor 1254 equiv.	12.902	10.11-20.46	6	Blubber	Hall, A.J., et al., 1992
West Coast of Scotland[e]	1988	F	dieldrin	0.041	0.004-0.127	6	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	4,4'-DDE	0.654	0.3-1.28	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	4,4'-DDD	0.092	0.01-0.31	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	4,4'-DDT	0.484	0.17-1.84	9	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	PCB28	0.000	0.000	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	PCB52	0.028	n.d.	1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[e]	1988	M	PCB101	0.112	0.061-0.226	11	Blubber	Hall, A.J., et al., 1992

[a]ng/g wet mass (± 1 SD)

[b]sum of compounds (PCB, DDT, etc.)

[c]mg/kg wet mass (± 1 SD)

[d]M-male; F-female

[e]mean and range values based on results from 10-15 laboratories for one animal

[f]ng/g extracted lipid mass

[g] n.d. - not determined

[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Orkney Islands, Scotland[c]	1988	M	PCB118	0.008	0.002-0.023	5	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	M	PCB138	0.776	0.22-2.08	14	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	M	PCB153	1.222	0.32-3.88	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	M	PCB180	0.427	0.1-1.56	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	M	Aroclor 1254 equiv.	8.217	2.699-24.841	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	M	dieldrin	0.017	0.001-0.057	15	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	4,4'-DDE	0.84		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	4,4'-DDD	0		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	4,4'-DDT	0.5		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB28	0		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB52	0		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB101	0.068		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB118	0		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB138	0.45		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB153	0.7		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	PCB180	0.74		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	Aroclor 1254 equiv.	12.373		1	Blubber	Hall, A.J., et al., 1992
Orkney Islands, Scotland[c]	1988	F	dieldrin	0.001		1	Blubber	Hall, A.J., et al., 1992
Coast of Norway[b,c]	1988	n.d.	PCB	7.1 (3.8)	n.d.	33	Blubber	Skaare, J.U., et al., 1990
Coast of Norway[b,c]	1988	n.d.	Total DDT	2.6 (1.3)	n.d.	33	Blubber	Skaare, J.U., et al., 1990
Coast of Norway[b,c]	1988	F	PCB	8.2 (3.6)	n.d.	17	Blubber	Skaare, J.U., et al., 1990
Coast of Norway[b,c]	1988	F	Total DDT	3.1 (1.5)	n.d.	17	Blubber	Skaare, J.U., et al., 1990
Coast of Norway[b,c]	1988	M	PCB	14.5 (2.1)	n.d.	26	Blubber	Skaare, J.U., et al., 1990
Coast of Norway[b,c]	1988	M	Total DDT	3.9 (2.1)	n.d.	26	Blubber	Skaare, J.U., et al., 1990
Oslofjord, Norway	1988	n.d.	alpha-HCH	82	39-240	n.d	Blubber	Skaare, J.U., et al., 1990
Southern Coast of Norway	1988	n.d.	alpha-HCH	54	17-95	n.d	Blubber	Skaare, J.U., et al., 1990
Northwestern Coast of Norway	1988	n.d.	alpha-HCH	72	8-119	n.d	Blubber	Skaare, J.U., et al., 1990
Oslofjord, Norway	1988	n.d.	beta-HCH	53	14-352	n.d	Blubber	Skaare, J.U., et al., 1990

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Southern Coast of Norway	1988	n.d.	beta-HCH	57	7.0-21	n.d	Blubber	Skaare, J.U., et al., 1990
Northwestern Coast of Norway	1988	n.d.	beta-HCH	68	13-167	n.d	Blubber	Skaare, J.U., et al., 1990
Oslofjord, Norway	1988	n.d.	gamma-HCH	28	7-116	n.d	Blubber	Skaare, J.U., et al., 1990
Southern Coast of Norway	1988	n.d.	gamma-HCH	37	5-123	n.d	Blubber	Skaare, J.U., et al., 1990
Northwestern Coast of Norway	1988	n.d.	gamma-HCH	21	7.0-32	n.d	Blubber	Skaare, J.U., et al., 1990
Oslofjord, Norway	1988	n.d.	Oxychlordane	160	35-395	n.d	Blubber	Skaare, J.U., et al., 1990
Southern Coast of Norway	1988	n.d.	Oxychlordane	176	99-418	n.d	Blubber	Skaare, J.U., et al., 1990
Northwestern Coast of Norway	1988	n.d.	Oxychlordane	186	11-440	n.d	Blubber	Skaare, J.U., et al., 1990
Island of Sylt, North Sea[c,e]	1990	F	PCB-052	0.092	0.005-0.17	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	PCB-101	0.33	0.08-0.43	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	PCB-138	5.6	2.22-7.0	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	PCB-153	7.8	4.9-10	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	PCB-180	1.8	0.71-3.0	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	4,4'-DDT	0.2	0.1-0.36	1	Blubber	Rimkus, G., et al., 1993
Island of Sylt, North Sea[c,e]	1990	F	4,4'-DDE	1.35	0.96-11.8	1	Blubber	Rimkus, G., et al., 1993
Skagerrak[f]	1988	n.d.	PCB 49	0.07		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 52	0.3		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 101	0.51		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 118	0.26		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 138	3.6		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 153	3.8		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 180	0.96		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 49	n.d.		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 52	0.24		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 101	0.76		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 118	n.d.		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 138	5.1		1	Blubber	Haraguchi, K., et al., 1992
Kattegat[f]	1988	n.d.	PCB 153	5.7		1	Blubber	Haraguchi, K., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Kattegat[f]	1988	n.d.	PCB 180	2		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 49	0.06	0.06-0.07	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 52	0.21	0.19-0.24	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 101	0.34	0.20-0.44	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 118	0.21	0.16-0.27	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 138	1.96	1.6-2.3	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 153	2.1	1.6-2.4	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 180	0.57	0.40-0.67	5	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 49	0.07		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 52	0.27		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 101	0.5		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 118	0.26		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 138	3.2		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 153	3.3		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	1988	n.d.	PCB 180	0.8		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 49	0.09		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 52	0.6		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 101	1.8		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 118	0.93		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 138	5.8		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 153	5.5		1	Blubber	Haraguchi, K., et al., 1992
Baltic Maklappen[f]	1988	n.d.	PCB 180	1.5		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 49	0.02		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 52	0.18		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 101	0.47		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 118	0.22		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 138	15		1	Blubber	Haraguchi, K., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

Table 2.6. (continued)

General Location	Date	Sex[d]	Compound	Geometric Mean	Range	n	Tissue	Citation
Skagerrak[f]	n.d.	M	PCB 153	22		1	Blubber	Haraguchi, K., et al., 1992
Skagerrak[f]	n.d.	M	PCB 180	66		1	Blubber	Haraguchi, K., et al., 1992

[a]ng/g wet mass (± 1 SD)
[b]sum of compounds (PCB, DDT, etc.)
[c]mg/kg wet mass (± 1 SD)
[d]M-male; F-female
[e]mean and range values based on results from 10-15 laboratories for one animal
[f]ng/g extracted lipid mass
[g] n.d. - not determined
[h]pg/g wet mass (± 1 SD)

SECTION III

ANNOTATED BIBLIOGRAPHY

Harbor Seal (*Phoca vitulina*)

Addison RF. 1989. Organochlorines and Marine Mammal Reproduction. Can. J. Fish Aquat. Sci. 46:360-8.

ABSTRACT: Reproductive failures in four populations of marine mammals, Californian sea lions (*Zalophus californianus*), Bothnian Bay ringed seals (*Pusa hispida*), Dutch Waddensea harbour seals (*Phoca vitulina*), and most recently, Gulf of St. Lawrence beluga whales (*Delphinapterus leucas*), have been attributed to the effects of contamination by organochlorine (OC) residues. In this article, I review the evidence for these effects. I conclude that since (a) crucial biological information in light of which OC residue data can be interpreted is often missing, (b) the nature of the supposed reproductive effect is variable, and (c) the OC residues to which these effects are attributed vary qualitatively and quantitatively, correlations between observed residue concentrations and apparent reproductive changes do not provide any firm evidence for a cause-effect relationship. In a single experimental study, a diet with a higher OC content that was used as a control impaired reproduction in harbour seals; however, dietary components other than OC content also differed. Although there appears to be no firm correlative evidence linking residue concentrations in marine mammals with reproductive effects, there is enough concern about possible links to justify more experimental studies, with the aim of identifying the possible biochemical mechanisms involved.

KEY WORDS: biochemical mechanisms, marine mammals, organochlorines, review.

Addison RF, Brodie PF, Edwards A, and Sadler MC. 1986. Mixed Function Oxidase Activity in the Harbour Seal (*Phoca vitulina*) from Sable Is., N.S. Comp. Biochem. Physiol. C. 85(1):121-4.

ABSTRACT: One adult male, eight pups (including two full term foetuses) and nine adult female harbour seals (*Phoca vitulina*) were analysed for indices of mixed function oxidase (MFO) activity. MFO activity was present in liver samples, but was at or below detection limits in samples of kidney, lung, and pancreas. Hepatic ethoxyresorufin O-de-ethylase and benzo[a]pyrene hydroxylase activities were similar to those reported in other seals and in other mammals. Cytochromes P-450 and b5 concentrations were slightly lower than those observed in other mammals. MFO activities in newborn pups and foetuses were significantly lower than those in adult females. No qualitative differences in cytochrome P-450 isozyme distribution between foetal and adult samples could be discerned by electrophoresis.

KEY WORDS: cytochrome P450 isozyme, foetuses, harbour seal, mixed function oxidase, newborn pups.

Aguilar A. 1987. Using Organochlorine Pollutants to Discriminate Marine Mammal Populations: A Review and Critique of the Methods. Marine Mammal Science 3(3):242-62.

ABSTRACT: Organochlorine pollutants are potentially useful for identifying discrete populations of marine mammals that overlap in geographic distribution. However, many factors unrelated to geographical distribution may affect the chemical burden of individual animals or of entire population components even within a homogeneously distributed population. These factors include, among others, nutritional state, sex, age,

trophic level, distance of habitat from mainland and pollution source, excretion, metabolism, and tissue composition. Sample storage and analytical methodology may also be an important source of variation. These, and any other factors, must be identified and their effect ascertained before attempting any comparison between populations. This paper critically examines the nature and magnitude of the effects of these factors on organochlorine tissue loads in marine mammals. Pollutant concentrations can be strongly biased if carefully designed sampling regimes are not followed, but they are affected only moderately by sample treatment after collection. Conversely, ratios between concentrations of compounds, such as the DDE/tDDT or the tDDT/PCB ratios, seem less dependent on sampling regime but more affected by storage, analytical procedures, and ecological variations such as distance from pollutant source or trophic level. Taking these effects into account, advice is provided about sampling and strategies for selection of variables that will improve the reliability of the comparisons between populations.
KEY WORDS: cetaceans, distribution, marine mammals, organochlorines, pollutants, population discreteness, pinnipeds, stock identity, techniques.

Aguilar A, and Borell A. 1997. Marine Mammals and Pollutants: An Annotated Bibliography. Fundacio Pel Desenvolupament Sostenible (Ed.), Barcelona, Spain :251 pp.
ABSTRACT: Here we present a compilation of references that includes 541 titles published during the period of 1966- early 1996 and a number of indices to facilitate bibliographical search. It is expected that this bibliography will be useful not only for finding a needed reference on a particular subject, but also to gain overall perspective on the amount of information available and current challenges faced by this research field. The short review article entitled Thirty Years of Research on Pollutants in Marine Mammals (1966-1996), included in the present volume, attempts to describe the history of research on pollutants in marine mammals, its shortcomings, and its future perspectives.
KEY WORDS: bibliography, marine mammals, pollutants, review.

Alaska Fish and Game Department DoS. 1990. Heavily Oiled Seals Show Contamination in Blubber Only. The Oil Spill Health Task Force, September-October 1990 Report :3-4.
KEY WORDS: Alaska, blubber, contamination, harbor seal, hydrocarbon, liver, marine mammals, muscle, oil spill, sea lion.

Alaska Fish and Game Department DoS. 1990. No Contamination Found in Subsistence Seals, Sea Lions. The Oil Spill Health Task Force, June 1990 Report, 1-2.
KEY WORDS: Alaska, blubber, contamination, harbor seal, hydrocarbon, kidney, liver, marine mammals, muscle, oil spill, sea lion.

Alaska Fish and Game Department DoS. 1993. Oil Contamination in Prince William Sound Seals Down Dramatically from 1989 Levels. Subsistence Restoration Project, February 1994 Report :1-2.
KEY WORDS: Alaska, blubber, contamination, harbor seal, hydrocarbon, marine mammals.

Alcorn DJ, Fancher LE, and Moss JG. 1980. Harbor Seal and Fish Population - Before and After a Sewage Spill in South San Francisco Bay. Calif. Fish and Game 66(4):238-40.

ABSTRACT: A sewage spill occurred in September of 1979 at the San Jose-Santa Clara Water Pollution Control Plant which flowed into the Artesian Slough. Samples of fish and harbor seals were taken before during and after the spill. Results showed minimal to no obvious short-term effects on the animals but long-term effects were possible.
KEY WORDS: California, harbor seal, marine organisms, sewage spill.

Allen S. 1980. Notes on the Births and Deaths of Harbor Seal Pups at Double Point, California. Murrelet 61(1):41-3.

Anas RE. 1974. DDT Plus PCBs in Blubber of Harbor Seals. Pesticides Monitoring Journal 8:12-14.

ABSTRACT: Samples of blubber from 13 harbor seals (*Phoca vitulina* richardii) were collected in 1971 from San Miguel Island, Calif.; the Columbia River, Oreg.; Puget Sound, Wash.; and the Pribilof Islands, Alaska. Total amounts of DDT plus PCBs ranged from 380.7 to 2350.0 ppm in five San Miguel Island seals; 459.4 to 1,620.0 ppm in two Puget Sound seals; and 6.8 to 27.8 ppm in the three Pribilof Islands seals. There was no indication of loss of total DDT plus PCBs in three samples reanalyzed after 2 years in frozen storage.
KEY WORDS: blubber, DDT, eastern North Pacific, harbor selas, organochlorine pesticides, PCB, *Phoca vitulina*.

Anas RE. 1974. Heavy Metals in the Northern Fur Seal, *Callorhinus ursinus*, and Harbor Seal, *Phoca vitulina richardi*. Fishery Bulletin 72(1):133-7.

ABSTRACT: Samples of liver, muscle, and kidney from fur seal, *Callorhinus ursinus*, and liver from harbor seal, *Phoca vitulina richardi*, were analyzed for total mercury. Liver and kidney of fur seals were analyzed for lead, cadmium, and arsenic. Fur seals were from the Pribilof Islands, Alaska, and from off the Washington coast. Harbor seals were from the waters of southern California, Oregon, Washington, and the Bering Sea. All of the samples, including a fetus taken 3 mo. before birth, contained mercury, lead, and cadmium. Arsenic was not detected. Mercury was highest in liver, followed by kidney, then muscle. The maximum concentration of mercury in liver was about 700 ppm in a southern California harbor seal and 170 ppm in a fur seal taken off the Washington coast. Concentrations of cadmium and lead were highest in the kidney (maximums of 1.8 ppm lead and 15.6 ppm cadmium) of fur seals. Concentrations of mercury did not correlate with age in muscle or kidney ($P>0.05$) but did correlate significantly with age in liver ($P<0.01$). Concentrations of cadmium and lead in liver and kidney did not correlate with age ($P>0.05$). In samples of liver collected from harbor seals, the highest concentrations of mercury were from southern California seals.
KEY WORDS: Alaska, fur seal, harbor seal, heavy metals, total mercury, Washington Coast.

Anderson SS. 1981. Seals in Shetland Waters. Proc. R. Soc. Edinb. Sect. B Biol. 80:181-7.
KEY WORDS: distribution, mammals, oil pollution, pesticides/pollution, status.

Beck H, Breuer EM, Dross A, and Mather W. 1990. Residues of PCDFs and PCBs and Other Organochlorine Compounds in Harbour Seals and Harbour Porpoise. Chemosphere 20:1027-34.

Becker PR, Mackey EA, Demiralp R, Schantz MM, Koster BJ, and Wise SA. 1997. Concentrations of Chlorinated Hydrocarbons and Trace Elements in Marine Mammal Tissues Archived in the U.S. National Biomonitoring Specimen Bank. Chemosphere 34(9/10):2067-98.
ABSTRACT: The U.S. National Biomonitoring Specimen Bank (NBSB) provides for the long term storage of well documented and preserved specimens representing several types of environmental matrices. A major part of this inventory consists of marine mammal tissues (e.g. blubber, liver, kidney, and muscle). Within the NBSB selected specimens are periodically analyzed for chlorinated hydrocarbons and trace elements. Although only 20% of the 560 marine mammal specimens in the NBSB have been analyzed, the database is of value in evaluating the stability of analytes and sample degradation during storage, for comparing with results from samples collected in the future for long-term monitoring, and for comparing with analytical results from other laboratories on samples collected at the same time for monitoring purposes. The NBSB analytical database contains results for 37 elements, many of which are not analyzed routinely by conventional analytical techniques used in monitoring programs, and the following organic compounds: selected PCB congeners, DDT compounds, gamma HCH, HCB, heptachlor epoxide, oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and dieldrin in 9 marine mammal species: northern fur seal (*Callorhinus ursinus*), ringed seal (*Phoca hispida*), spotted seal (*P. largha*), bearded seal (*Erignathus barbatus*), pilot whale (*Globicephala melas*), harbor porpoise (*Phocoena phocoena*), white-sided dolphin (*Lagenorhynchus acutus*), beluga whale (*Delphinapterus leucas*), and bowhead whale (*Balaena mysticetus*). Analyses of beluga whale blubber for toxaphene and additional chlorinated hydrocarbons are obtained through collaboration with the Department of Fisheries and Oceans Canada.
KEY WORDS: database, marine mammal tissues, organic compounds, trace elements, U.S. National Biomonitoring Specimen Bank.

Bergek S, Bergqvist P, Hjelt M, Olsson M, Rappe C, Roos A, and Zook D. 1992. Concentrations of PCDDs and PCDFs in Seals from Swedish Waters. Ambio 21(8):553-6.
ABSTRACT: The distribution and concentrations of selected 2,3,7,8-substituted polychlorinated dibenzo-para-dioxins and dibenzofurans (PCDD/Fs) are presented for ringed (*Phoca hispida*), grey (*Halichoerus grypus*), and harbor seals (*Phoca vitulina*) from the Baltic, Kattegat, and Skagerrak. The study was initiated to determine if factors including spatial variation, age, sex, species or health status could be correlated to the concentrations and patterns of PCDD/Fs in seal. A total of 15 pooled samples were analyzed, including seals killed during the 1988 epizootic, which represent the most diverse set of PCDD/F measurements for seal in Scandinavian waters to date. Our results show remarkably low variations in blubber concentrations of the study compounds with respect to many of the above sample parameters. A rapid catabolism or elimination of PCDD/Fs is suggested to explain surprising similarities seen in the blubber concentrations of these compounds for seals from the Swedish west coast and Baltic. This contrasts to PCDD/F concentrations in herring, a key seal prey from the regions of study, which are known to differ. The relatively low concentrations of PCDD/Fs found in seal versus their expected high intake from fish further supports a presumed rapid catabolism or elimination. The most obvious variation seen is the higher relative concentration of PCDD/Fs in ringed versus either grey or harbor seal. This confirms an

earlier finding to the same effect and might be attributed to a feeding behavior or a lower catabolism/elimination capacity unique to ringed seal.
KEY WORDS: Baltic, Kattegat, PCDDs, PCDFs, seals, Skagerrak, spatial distribution.

Bernhoft A, and Skaare JU. 1994. Levels of Selected Individual Polychlorinated Biphenyls in Different Tissues of Harbour Seals (*Phoca vitulina*) from the Southern Coast of Norway. Env. Poll. 86:99-107.
ABSTRACT: Concentrations of individual polychlorinated biphenyls (PCBs) were determined in blubber, liver, kidney and brain tissues of 10 male harbour seals (*Phoca vitulina*) of different ages. The animals were found dead or dying on the southern coast of Norway in 1988 during the morbillivirus epizootic. Twenty-three PCB congeners were investigated in all tissues by capillary gas chromatography with electron capture detection and comparison with standards of the respective congeners (IUPAC numbers, 28, 52, 74, 99, 101, 105, 110, 114, 118, 128, 138, 141, 149, 153, 156, 157, 170, 180, 183, 187, 194, 206 and 209). In addition, three toxic coplanar congeners (IUPAC numbers 77, 126, and 169) were investigated in the blubber samples. Total PCB (sum of the determined congeners) in kidney (12-60 nmol g^{-1}), liver (12-90 nmol g^{-1}) and blubber (10-79 nmol g^{-1}) were similar on extractable lipid basis, while total PCB in brain lipid was about 1/10 (1.6-12 nmol g^{-1}). The absolute concentrations of the individual congeners in brain lipid correlated poorly with the respective concentrations in each of the other tissues, while the individual congener concentrations in the lipid fractions of kidney, liver and blubber tended to correlate with each other. The relative concentrations of the sum of the most persistent congeners (PCB-99, -128, -138, -153, -170, -180, -187, and -194) correlated in all tissues, and an increase of the relative concentrations of these congeners, most distinct in blubber, with higher carcass weight, was shown. Also, total PCB in blubber correlated with carcass weight. When comparing the relative concentration patterns of individual congeners (per cent of total) in the four tissues, six congeners differed significantly between tissues, and the relative brain concentrations showed most deviation from the other tissues. The concentration of the coplanar PCBs was 1:1000 - 1:10000 of the total PCB concentration. The results demonstrate a lower accumulation together with a different concentration pattern in the brain as compared to other tissues.
KEY WORDS: individual congeners, PCB, persistence, *Phoca vitulina*, tissue distribution.

Blomkvist G, Roos A, Jensen S, Bignert A, and Olsson M. 1992. Concentrations of sDDT and PCB in Seals from Swedish and Scottish Waters. Ambio 21(8):539-45.
ABSTRACT: Blubber samples from 109 specimens of ringed (*Phoca hispida botnica*), grey (*Halichoerus grypus*) and harbor (*Phoca vitulina vitulina*) seals from Swedish waters were analyzed for concentrations of sDDT and PCB. Seven juvenile grey seals from the northeast coast of Scotland were analyzed for comparison. The Swedish material was divided into groups according to sampling areas, species, sex, age and signs of diseases. In general, variations in contaminant concentrations within groups and between subgroups were not substantial. Concentrations did not differ significantly between juvenile harbor seals found dead during the 1988 virus epizootic and animals collected before the outbreak of the disease or in unaffected areas. No significant difference was found between adult female grey seals suffering from hyperadrenocorticism and apparently healthy females. Starved females, however, showed

very high concentrations of these organochlorine compounds in blubber was indicated in the material studied. Studies on juvenile specimens indicate that the concentration of PCB in harbor seals from the Baltic is twice as high as in the same species along the Swedish west coast, while the concentration of sDDT is about four times higher. Ringed seals from the Baltic show PCB concentrations equal to those of the harbor seals from the west coast, but sDDT concentrations are about three times higher. Grey seals from the Baltic show the highest concentrations of both sDDT and PCB. Comparison of the present results with earlier studies on grey seals shows that a considerable decrease in concentrations of sDDT has taken place since the early 1970s. In ringed seals the concentrations of both sDDT and PCB have decreased.

KEY WORDS: contaminants, marine mammals, PCB, sDDT, seals, Swedish and Scottish waters.

Boon JP, Eijgenraam F, and Everaarts JM. 1989. A Structure-Activity Relationship (SAR) Approach Towards Metabolism of PCBs in Marine Animals from Different Trophic Levels. Mar. Environ. Res. 27:159-76.

ABSTRACT: A qualitative structure-activity relationship (SAR) to estimate the influence of biotransformation on the degree of bioaccumulation of chlorinated biphenyl (CB) congeners under field conditions, is presented. The CB patterns of different animal species from the western part of the Dutch Wadden Sea are used to illustrate the SAR. The CB pattern in a particular species was compared with that of the bivalve mollusc *Macoma balthica*. It is assumed that no biotransformation occurs in this species, the CB pattern being determined only by equilibrium partitioning between tissues and the ambient water. When no significant differences in the pattern of a group of persistent congeners existed between a given species and *Macoma balthica*, significantly lower relative concentrations of congeners with vicinal H-atoms in the *meta*- and *para*-positions in that species were attributed to biotransformation. The contribution of metabolizable congeners decreased in the order *Macoma balthica* >*Nereis diversicolor* > *Pleuronectes platessa, Haematopus ostralegis* (male juv.) > *H. ostralegis* (male sub-adult), *Phoca vitulina*. No significant differences in the patterns of persistent congeners were observed between the latter four species. *Phoca vitulina* was the only species with a lowered relative concentration of CB-118. Biotransformation of congeners with this configuration, i.e. possessing vicinal H-atoms only in the *o,m* position and (at maximum) one *ortho*-chlorine, may be significant from toxicological point of view, as a number of toxic congeners belong to this group.

KEY WORDS: biotransformation, chlorinated biphenyl congener, marine organisms, structure-activity relationship.

Boon JP, Reijnders PJH, Dols J, Wensvoort P, and Hillebrand MTJ. 1987. The Kinetics of Individual Polychlorinated Biphenyl Congeners in Female Harbour Seals (*Phoca vitulina*), With Evidence for Structure-Related Metabolism. Aquatic Toxicology 10:307-24.

ABSTRACT: Female harbour seals were held in captivity. During a period of two years, one group received contaminated fish from the Dutch Wadden Sea, while a second group was given relatively clean fish from the Atlantic Ocean. Concentrations of individual polychlorinated biphenyl (PCB) congeners were measured in fish, seal blood and occasionally in faeces of seals. The PCB patterns within each of these three matrices

were highly similar, but differed between them. According to their degree of biomagnification in seal blood, PCBs could be divided into persistent congeners and congeners with lowered concentrations. This behavior was related to molecular structural features; congeners showing lowered concentrations possessed vicinal H atoms at either a *meta-para* position or at an *ortho-meta* position. Only in the latter case the number of *ortho*-chlorines present in mono-*ortho* chlorine containing congeners. Enzyme-mediated metabolism is the most probable cause for the relatively low contribution of such congeners to the PCB pattern in seal blood. On a wet-weight basis, the concentrations of all congeners were lower in seal blood than in their food, but when expressed on a lipid basis, the non-metabolized congeners were biomagnified. At the end of the experiment, the PCB concentrations were significantly lower ($P<0.001$) in the seals which had received fish from the Atlantic Ocean.
KEY WORDS: marine mammal, metabolism, PCB, *Phoca vitulina*.

Brouwer A, Reijnders PJH, and Koeman JH. 1989. Polychlorinated Biphenyl (PCB)-Contaminated Fish Induces Vitamin A and Thyroid Hormone Deficiency in the Common Seal (*Phoca vitulina*). Aquatic Toxicology 15:99-106.
ABSTRACT: In this study the effect of polychlorinated biphenyl (PCB)-contaminated fish on plasma retinol (vitamin A) and thyroid hormone concentrations, i.e. sensitive indicators of PCB-intoxication, were investigated in the common seal *Phoca vitulina*. Seals fed fish from the Wadden Sea (high-level PCB contamination) had significantly lower concentrations of plasma retinol, total (TT4) and free thyroxin (FT4) and triiodothyronin (TT3) as compared to seals fed fish from the north-east Atlantic (low-level PCB contamination). The PCB-induced reduction in plasma retinol levels disappeared when seals on a Wadden Sea fish diet were subsequently fed Atlantic Ocean fish. It is suggested that reduced plasma retinol and thyroid hormone levels, which may result in an increased susceptibility to microbial infections, reproductive disorders and other pathological alterations, are critically involved in the recently reported reproductive disorders and the lethal viral infections in seals and other marine mammal populations in the Baltic, North Sea and Wadden Sea.
KEY WORD: plasma, polychlorinated biphenyl, seal, thyroid hormone, vitamin A.

Calambokidis J, Buchanan JB, Steiger GH, and Evenson JR. 1991. Toxic Contaminants in Puget Sound Wildlife: Literature Review and Recommendations for Research and Monitoring. Prepared for: U.S. Environmental Protection Agency, EPA Contract 68-D8-0085, PTI Contract C744-30. 1991. 96 pp.
ABSTRACT: The objective of the research was to determine whether detrimental effects possibly caused by toxic chemicals could be observed in Puget Sound marine mammals and marine birds. The study design was based on examination of a wide variety of indices of population and individual health and comparison of these indices from areas of suspected high contaminant levels (target areas) to those from areas of suspected low contaminant levels (reference areas) and to those reported by other researchers. Primary species considered here are harbor seal, Glaucous-winged Gull, Great Blue Heron, and Pigeon Guillemot; these species were chosen because they reside, feed, and breed in some of the most contaminated portions of Puget Sound. Three other mammal species (killer whale, harbor porpoise, and river otter) were chosen as secondary study species either because they seasonally occur in contaminated areas of Puget Sound or they were found

through previous research to be experiencing problems that might be pollutant-related. (DBO).

KEY WORDS: aquatic birds, Aves, Mammalia, marine mammals, pollution effects, pollution surveys, Puget Sound, Washington.

Calambokidis J, Carter S, and Cubbage J. 1979. The Concentrations and Dynamics of Chlorinated Hydrocarbon Contaminants in Harbor Seals and Their Use in Gaining Biological Information. Third Biennial Conference on the Biology of Marine Mammals, October 7-11, 1979, Seattle, Washington. 6 pp.

ABSTRACT: Polychlorinated biphenyls and DDE, a common breakdown product of the pesticide DDT, are toxic contaminants that are fat soluble and stable in the environment. High concentrations of these chlorinated hydrocarbon contaminants were first seen in the early 1970s in Puget Sound harbor seals (*Phoca vitulina*) and were suggested as a possible cause of the high pup mortality observed at the major breeding areas in Southern Puget Sound. During 1977-78, samples of blubber were taken from 71 harbor seals from Washington State, fish were collected in Southern Puget Sound and Hood Canal and harbor seal scat were collected from haul out areas in the region to determine concentrations of PCB and DDE. Significant concentrations of chlorinated hydrocarbons were found in areas of highest pup mortality and it is possible they could be a contributing factor to the observed mortalities. Concentrations of contaminants were also 400-1000 times higher by wet weight in harbor seal blubber than in fish (for each region). Results also indicate variations in contaminant concentrations and ratios of contaminants to harbor seals from different regions which can be used to learn more on harbor seal biology.

KEY WORDS: contaminants, harbor seals, marine mammals, polychlorinated biphenyls, Southern Puget Sound.

Calambokidis J, Peard J, Steiger GH, and Cubbage JC. 1984. Chemical Contaminants in Marine Mammals From Washington State. NOAA Technical Memorandum NOS OMS 6 :167 pp.

ABSTRACT: The objectives of this study were to report the results of recent analyses of environmental toxicants in Washington marine mammals and evaluate the evidence for pollutant-related effects in marine mammals. In the last eight years samples of close to 100 marine mammals from Washington State have been analyzed for concentrations of the chlorinated hydrocarbons: polychlorinated biphenyls (PCBs) and 2,2-bis (*p*-chlorophenyl)-1, 1-dichloroethylene (DDE). These samples have consisted primarily of harbor seal tissues, but also include minke whale, killer whale, pygmy sperm whale, harbor porpoise, Dall's porpoise, an unknown species of sea lion, and river otter. Data from these analyses are summarized in this report. Tissues from an additional 17 harbor seals from Southern Puget Sound were analyzed for a broader range of synthetic chlorinated organics, metals, and other trace elements, and polyaromatic hydrocarbons. These results are also reported. PCB and DDE concentrations on harbor seals varied widely; the highest concentrations of PCBs was 750 ppm (wet weight) found in the blubber of one harbor seal from Southern Puget Sound. PCB concentrations were substantially higher than DDE concentrations in all samples except in a couple of the cetacean samples. Concentrations of PCBs and DDE varied significantly by location. Seals from Southern Puget Sound contained the highest levels. Concentrations of PCBs

and DDE also varied significantly by age, with adults showing higher concentrations than pups and subadults. The concentrations of PCBs and DDE are substantially higher in harbor seals than in the fish they eat. We found PCBs in the scat of seals and found evidence that some PCB components are metabolized by seals. However, an examination of the body burden of PCBs and DDE in seals indicates seals absorb most of the PCBs and DDE present in their diet and retain it in their blubber. A number of other synthetic chlorinated organics were detected in harbor seals but in substantially lower concentrations than PCBs and DDE. Analyses for metals and trace elements in harbor seal liver and kidney revealed high concentrations of mercury (Hg) in some samples. High mercury concentrations occur frequently in marine mammals. We analyzed for polyaromatic hydrocarbons, but none were detected. PCBs appear to be the primary pollutants of concern in Puget Sound marine mammals. PCBs have been implicated as the cause of reproductive problems in pinnipeds from the Baltic and Wadden Seas in European waters and the Channel Islands in Southern California. PCB concentrations in Southern Puget Sound harbor seals are among the highest found anywhere in the world and are in the same range as those implicated as causing biological disorders in other areas. Reproductive disorders in harbor seals from Southern Puget Sound were reported in the early 1970s and pollutants may have been a contributing factor. A thorough study to determine the presence of possible contaminant-related disorders is needed.
KEY WORDS: environmental toxicants, harbor seals, marine mammals, organochlorines, pollutants, Southern Puget Sound, Washington.

Calambokidis J, Speich SM, Peard J, Steiger GH, and Cubbage JC. 1985. Biology of Puget Sound Marine Mammals and Marine Birds: Population Health and Evidence of Pollution Effects. NOAA Tech. Memo. NTIS Order No. PB91-172734/GAR :170 pp.
ABSTRACT: The objective of the research was to determine whether detrimental effects possibly caused by toxic chemicals could be observed in Puget Sound marine mammals and marine birds. The study design was based on examination of a wide variety of indices of population and individual health and comparison to these indices from areas of suspected high contaminant levels (target areas) to those from areas of suspected low contaminant levels (reference areas) and to those reported by other researchers. Primary species considered here are harbor seal, Glaucous-winged Gull, Great Blue Heron, and Pigeon Guillemot; these species were chosen because they reside, feed, and breed in some of the most contaminated portions of Puget Sound. Three other mammal species (killer whale, harbor porpoise, and river otter) were chosen as secondary study species wither because they seasonally occur in contaminated areas of Puget Sound or they were found through previous research to be experiencing problems that might be pollutant-related.
KEY WORDS: aquatic birds, Aves, Mammalia, marine mammals, pollution effects, pollution surveys, Puget Sound, Washington.

Calambokidis J, Steiger GH, Lowenstine LJ, and Becker DS. 1991. Chemical Contamination of Harbor Seal Pups in Puget Sound. Prepared for: U.S. Environmental Protection Agency, EPA Contract 68-D8-0085, PTI Contract C744-30. 1991. 43 pp.
ABSTRACT: Dead newborn harbor seals (*Phoca vitulina*) were collected from Smith Island in the Strait of Juan de Fuca and from Gertrude Island in Southern Puget Sound. A variety of chemical contaminants were measured in different kinds of tissue from seven

harbor seal pups from each location. Various tissues were also evaluated microscopically for histopathological abnormalities. Two methods for determining the concentrations of PCBs and DDE in blubber tissues were compared. Concentrations of PCBs, lead and silver were significantly higher in the seals from Gertrude Island than those from Smith Island. However, the concentrations of PCBs in seal pups from both locations have declined significantly since testing began in 1972.
KEY WORDS: chemical pollutants, DDE, histopathology, lead, PCB, *Phoca vitulina*, pollution monitoring, Puget Sound, research programmes, silver, Washington.

Castellini M, Fadely B, Jemison L, Kelly B, Lewis J, Lowry L, O'Corry-Crowe G, Pendleton G, Pitcher K, Swain U and others. 1996. Annual Report Harbor Seal Investigations In Alaska NOAA Grant NA57FX0367. Alaska Dept. of Fish and Game, Div. of Wildlife Conservation :203 pp.
ABSTRACT: In response to a continuing and severe decline in the number of harbor seals in the Gulf of Alaska, the National Marine Fisheries Service provided annual grants of $500,000 to the Alaska Department of Fish and Game to investigate the causes of the decline and to monitor current trends in the population. Results obtained in the area of decline were compared to results obtained in southeastern Alaska (SE) where seals have remained abundant. Aerial surveys of trend sites in the Kodiak and Ketchikan areas suggest seal numbers are increasing in both areas. Seals numbers along the Ketchikan route increased at an annual rate of approximately 8 percent since 1983. While in the Kodiak area numbers were stable or possibly increasing. Aerial surveys of seals along the Sitka trend route indicate a stable population since 1983. Satellite-linked time depth recorders (SDRs) were attached to 27 seals in 1993 and 1994 to monitor their movements, and haulout and diving behaviors. Based on the 27 seals, movements were highly variable by individual. Seals generally remained in the area of their capture with most traveling less than 50 km. Some individuals were relocated up to 150 kilometers from their capture site, but all eventually returned to their resident haulout. Individual seals used open water habitats, heads of bays, river mouths, and glacial fjords suggesting harbor seals are exploiting a wide variety of habitats. An additional 21 satellite-linked time depth recorders were attached to seals in 1995; those data will be processed and reported in the 1996 contract year. There was no statistical difference in the proportion of time seals in SE Alaska and Kodiak spent hauled out, however, there were seasonal trends in haulout patterns. Seals spent more time hauled out during summer and less time during winter. Small sample sizes and sampling biases confounded interpretation of these data. The diving behavior of these 27 harbor seals was characterized by relatively short and shallow dives. The majority of dives were less than 4 minutes in duration and less than 50 m in depth. Harbor seals rarely dove deeper than 150 m, with only 1-2 precent of all dives being to greater depths. The distribution of dives among different depth categories varied considerably by seals and by area. Data on maximal dive depths seemed to indicate harbor seals were sometimes diving to the bottom. Seals in SE dove deeper than seals near Kodiak, reflecting the deeper bathymetry of the area. Harbor seals in both areas showed strong seasonal patterns in dive depth. The percentage of shallow dives increased markedly during the late spring and summer while deeper dives were more common during the fall and winter. Subadults in Kodiak dove deeper and more frequently than subadults in SE Alaska, although very small sample sizes preclude definite conclusions. Adult males also dove more frequently in Kodiak than in SE

Alaska. Since dive frequency in Kodiak is suggestive of greater foraging effort and hence lower food availability. Future analyses will investigate other potential indices of foraging effort, such as the actual time spent diving (i.e., time submerged) and will associate location data with the dive data. Seals were tested for phocine herpesvirus, phocine distemper virus, *Brucella* spp., influenza virus, *Toxoplasma gondii*, *Chlamydia psittaci*, and caliciviruses. Seals have apparently been exposed to phocine herpesvirus, phocine distemper virus, *Brucella* spp., *Toxoplasma gondii*, and *Chlamydia psittaci*. Most titers to these agents were low and no seals exhibiting symptoms of these diseases have been found. The significance of exposure to these disease agents is unknown. There is no evidence of exposure to influenza or caliciviruses. Blood samples were analyzed for standard clinical chemistry and hematology values, and work continues on other hematological indicators of health. Several hematological values were significantly affected by age, sex, animal and sample handling, region and season. Consequently, this variation must be taken into account when regional and interannual comparisons are performed. Preliminary comparisons showed that some hematological values of seals from SE Alaska differed in magnitude and patterns of seasonal change as from seals sampled within Kodiak or Prince William Sound area. While we currently do not understand the implications of these differences, there did not appear to be widespread indications of poor health or disease from any region. Composition counts of the seals at Tugidak Island suggest a decrease in the proportion of yearlings from approximately 15 percent of the total number of seals in the 1970s to 4-8 percent in 1994-1995. Based on these counts, the percentage of pups on the southwestern beach has not changed since the 1970s but pupping is approximately 8-10 days earlier than in the 1970s. The decreased proportion of yearlings ashore may reflect reduced first-year survival rates, changes in behavior, or both. Samples of skin for genetics studies were taken from all seals handled. A preliminary analysis grouped samples according to the three areas used by NMFS in stock assessment reports. Based on the 114 (of 351 samples available) samples from Alaska, no statistically significant genetic differentiation was found among the three areas combined. However, pair-wise comparisons among the three areas showed that the Bering Sea sample was significantly differentiated from the Gulf of Alaska. If Russian samples are included with others from the Alaskan Bering Sea, both Gulf of Alaska and SE Alaska show significant genetic differences from Bering Sea seals. There is either no geographic population structuring or the power of the statistical tests for detecting differences was too low possibly due to small sample sizes.
KEYWORDS: composition, dive behavior, genetics, harbor seals, hematology, movements, *Phoca vitulina*, population, viruses..

Clausen B. 1978. Diseases and Toxichemicals in the Common Seal in Denmark. Finnish Game Res. 37:38-9.
KEY WORDS: mammals, parasites/diseases, pesticides, pesticides/pollution.

De Swart RL, Ross PS, Timmerman HH, Vos HW, Reijnders PJH, Vos JG, and Osterhaus DME. 1995. Impaired Cellular Immune Response in Harbour Seals (*Phoca vitulina*) Feeding on Environmentally Contaminated Herring. Clin. Exp. Immunol. 480-6.
ABSTRACT: In a 2.5-year immunotoxicological study, two groups of captive harbour seals (*Phoca vitulina*) were fed herring from the heavily polluted Baltic Sea and from the relatively uncontaminated Atlantic Ocean. Blood samples were collected at regular

intervals, and functional immunological parameters were monitored. T cell mitogen and mixed lymphocyte-induced proliferative responses of peripheral blood mononuclear cells (PBMC) obtained from seals fed Baltic herring were significantly reduced over the course of the experiment. Upon immunization with rabies virus antigen (RV) and tetanus toxoid (TT), specific proliferative responses of PBMC from the seals fed Baltic herring were also significantly reduced. Impairment of T cell-mediated immune responses became especially apparent during the second year on the respective diets, and correlated significantly to 2,3,7,8-tetrachloro-dibenzo-p-dioxin toxic equivalent levels in blubber biopsies taken from the seals after 2 years on the respective diets. Humoral immune responses, including lipopolysaccharide (LPS)-induced lymphoproliferative responses, *in vitro* immunoglobulin production by PBMC, as well as RV, TT- and poliovirus-specific serum antibody responses following immunization, remained largely unaffected. We conclude that suppression of the cellular immune response in the seals fed Baltic herring was induced by the chronic exposure to immunotoxic environmental contaminants accumulated through the food chain. Since cellular immune responses are known to be of crucial importance in the clearance of morbillivirus infections, these results suggest that environmental pollution-related immunosuppression may have contributed to the severity and extent of recent morbillivirus-related mass mortalities among marine mammals.
KEY WORDS: immunosuppression, immunotoxicology, marine mammals, *Phoca vitulina*, phocine distemper virus.

De Swart RL, Ross PS, Vos JG, and Osterhaus ADME. 1996. Impaired Immunity in Harbour Seals (*Phoca vitulina*) Exposed to Bioaccumulated Environmental Contaminants: Review of a Long-Term Study. Env. Health Perspect. 104(4):823-8.

ABSTRACT: Mass mortalities among seals and dolphins inhabiting contaminated marine regions have led to speculation about a possible involvement of immunosuppression associated with environmental pollution. To evaluate whether contaminants at ambient environmental levels can affect immune function of seals, we carried out an immunotoxicological study under semi field conditions. Two groups of 11 harbour seals (*Phoca vitulina*) originating from a relatively uncontaminated area were fed herring from either the highly polluted Baltic Sea or the relatively uncontaminated Atlantic Ocean. Changes in immune function were monitored over a 2.5-year period. The seals that were fed contaminated Baltic herring developed significantly higher body burdens of potentially immunotoxic organochlorines and displayed impaired immune responses as demonstrated by suppression of natural killer cell activity and specific T-cell responses. During a 2-week fasting experiment performed at the end of the feeding study, mobilization of organochlorines from the blubber did not lead to a strong increase of contaminant levels in the blood, and no enhancement of the existing immunosuppression was observed. These results demonstrate that chronic exposure to environmental contaminants accumulated through the food chain affects immune function in harbour seals, whereas short-term fasting periods, which are normal for seals, do not seem to pose an additional risk. The seals of this study were not exposed perinatally to high levels of environmental chemicals, and body burdens of organochlorines measured near the end of the study were lower than those generally observed in free-ranging seals inhabiting many contaminated regions. Therefore, it may be expected that environmental contaminants adversely affect immune function of free-ranging seals inhabiting contaminated regions at least as seriously as observed in these studies.

KEY WORDS: environmental contaminants, harbour seals, immunotoxicology, marine mammals, organochlorines, *Phoca vitulina*, review.

De Swart RL, Visser IKG, Ross PS, Reijnders PJH, Uytdehaag FGCM, Vos JG, and Osterhaus ADME. 1992. The Influence of Environmental Contaminants on the Functioning of the Immune System of Pinnipeds. Proceedings of the 7th International Wadden Sea Symposium, Ameland 1990 Publication Series No. 20:295-7.
ABSTRACT: The virus epidemic among harbour seals, *Phoca vitulina*, in Europe in 1988 and other recent disease outbreaks among marine mammals have raised serious questions about possible immunosuppression caused by environmental pollutants in these animals. Some persistent and potentially immunotoxic chemicals are known to accumulate in the food chain, leading to extremely high concentrations of these chemicals in top-predators like seals. We now started an experiment in which two groups of young harbour seals are being fed fish containing high or low levels of pollutants, respectively. Over the next three years the functioning of the immune system of the seals in both groups will be monitored and compared. In this way effects of environmental pollutants on immune function can be assessed.
KEY WORDS: diet, environmental contaminants, harbor seals, immunosuppression, marine mammals, *Phoca vitulina*.

De Swart RL, Ross PS, Timmerman HH, Hijman WC, DeRuiter EM, Liem AKD, Brouwer A, Van Loveren H, Reijnders PJH, Vos JG and others. 1995. Short Term Fasting Does Not Aggravate Immunosuppression in Harbour Seals (*Phoca vitulina*) With High Body Burdens of Organochlorines. Chemosphere 31(10):4289-306.
ABSTRACT: Two groups of 11 harbour seals (*Phoca vitulina*) with different body burdens of organochlorines were subjected to an experimental 15-day fasting period, during which they lost an average 16.5 percent of their body weights. Blood levels of the most persistent organochlorines showed an approximate twofold increase, while levels of aryl hydrocarbon receptor-binding organochlorines remained largely unaffected. Few differences in immunological parameters were observed between the two dietary groups. Numbers of circulating lymphocytes dropped to about 65 percent of the initial values and NK cell activity showed a slight increase in both groups. Mitogen- and antigen-induced lymphoproliferative responses of the Baltic group of seals remained within normal ranges. These results suggest that relatively short-term fasting periods do not present an additional immunotoxicological risk to seals with high body burdens of organochlorines.
KEY WORDS: bioaccumulation, diets, life history studies, organochlorine compounds, *Phoca vitulina*, pollutants, seals.

De Swart RL, Ross PS, Voss JG, and Osterhaus A. 1996. Impaired Immunity in Harbour Seals (*Phoca vitulina*) Fed Environmentally Contaminated Herring. Vet Q 18:127-8.
ABSTRACT: In recent years, mass mortalities among seals and dolphins have been attributed to infections with different morbilliviruses, In all cases, these marine top predators were exposed to high levels of persistent lipophilic environmental contaminants accumulated through the food chain. This observation led to the hypothesis that a contaminant related suppression of the immune system might have contributed to the severity of the virus outbreaks. We conducted a semi field feeding experiment, in which we fed two groups of harbour seals (*Phoca vitulina*) fish with different levels of

contaminants. During a period of 2.5-years, blood samples were taken at regular intervals, and the functioning of different compartments of the immune system was monitored and compared, We found impaired natural killer (NK) and specific T cell responses in the seals fed contaminated fish. This is the first demonstration of immunosuppression in mammals following chronic exposure to environmental contaminants at ambient environmental levels.
KEY WORDS: environmental contaminants, harbour seals, herring, immune system, immunosuppression marine mammals, morbillivirus.

Dickson D. 1988. Mystery Disease Strikes Europe's Seals. Science 241:893-5.
ABSTRACT: Over 90% of seal pups at the Pieterburn Center in the Netherlands are suffering from a mysterious disease. This disease has possibly killed over 7,000 common seals off the coast of Denmark, Sweden, Norway, West Germany and the Netherlands. Two viruses have been discovered, a herpes virus and picornavirus. Some scientists believe the symptoms are more complicated and the seals are suffering from a suppression of the immune system. Investigations remain open to the link between this suppression and the discharge of toxic chemicals in the North Sea. The chemical pollution may be increasing the stress on seals. A joint scientific meeting was held in London which recommended the start of a research project to study the etiological role of viruses that have already been found as well as investigations of pollutants and other environmental factors and their effects on the immune system of seals.
KEY WORDS: common seals, herpes virus, immune system, Netherlands, North Sea, picornavirus, pollutants.

Dietz R, Heide-Jorgensen MP, and Harkonen T. 1989. Mass Deaths of Harbor Seals (*Phoca vitulina*) in Europe. Ambio 18:258-64.
ABSTRACT: Since April 1988, an epizootic disease raged among harbor seals (*Phoca vitulina*) in Europe. The disease began on Anholt in central Kattegat, but quickly spread to almost all seal herds in Europe. So far, almost 18,000 seals have died from the disease. The cause is most likely a virus belonging to the morbilli group; but the dispersal and triggering mechanisms behind the infection remain obscure. Compared to past incidents of seal epizootic this outbreak was far more dramatic in terms of mortality and is by far the best documented. The highest mortality was found in areas where the disease was introduced during the summer when seal congregate on land for reproduction and molt. Seal herds infected during the autumn were less affected by the disease. The role of environmental factors in the course and development of the disease, such as weather conditions or pollution, remains unclear.
KEY WORDS: environmental factors, Europe, harbor seals, morbilli virus epizootic, pollution.

DiMolfetto-Landon L, Erickson KL, Blanchard-Channell M, Jeffries S J, Harvey JT, Jessup DA, Ferrick DA, and Stott JL. 1995. Blastogenesis and Interleukin-2 Receptor Expression Assays in the Harbor Seal (*Phoca vitulina*). J Wildl Dis 31(2):150-8.
ABSTRACT: Two in vitro functional assays were developed to evaluate mitogen-induced responses of peripheral blood mononuclear leukocytes (PBML) from free-ranging harbor seals, *Phoca vitulina*. Lymphocyte proliferation was measured by a standard blastogenesis assay following optimization of culture conditions including

mitogen concentration, cell density, and incubation time. These optimized parameters, with the exception of incubation time, were subsequently employed to measure lymphocyte activation by analytical flow cytometry using fluorochromebased identification of cell surface interleukin-2 receptor (IL-2r) expression. Baseline values established for free-ranging harbor seals had extensive animal variability; there was evidence that the samples were derived from a group of animals with a normal distribution. Positive correlations were observed between blastogenesis assays, and between blastogenesis and activation assays, when using pokeweed or concanavalin A as the stimulus. However, no relationship was found in the expression of the IL-2r induced by these mitogens. This result supports the contention that the two mitogens stimulate different lymphocyte subpopulations. This was observed only with the IL-2r expression assay because of its unique ability to measure the number of T lymphocytes initially activated rather than the ultimate number of progeny cells identified by blastogenesis. Both assays, used concurrently, should provide a more comprehensive representation of lymphocyte competence and serve as a measure of animal health.
KEY WORDS: blastogenesis, harbor seal, interleukin-2 receptor, mitogen, *Phoca vitulina*.

Drescher HE. 1978. Skin Lesions in the Harbour Seal *Phoca vitulina* Linne, 1758, in the North Sea. Saeugetierk. Mitt. 26:50-9.

Drescher HE, Harms U, and Huschenbeth E. 1977. Organochlorines and Heavy Metals in the Harbour Seal *Phoca vitulina* from the German North Sea Coast. Marine Biology 41:99-106.
ABSTRACT: Samples of various tissues and organs from healthy, sick and dead harbour seals (*Phoca vitulina*) from the North German Waddensea collected during the years 1974-1976 were analysed for copper, zinc, total mercury, cadmium, lead, and organochlorine pesticide residues (PCB, DDT, Lindane and Dieldrin). The investigations were carried out in order to increase our knowledge about the actual degree of heavy metal and organochlorine pesticide accumulation in these animals. The study was also directed towards a comparison of healthy and sick young seals and those found dead for a possible relation between the condition and concentration of pollutants in the organs. There was great variation within all series of compounds investigated, but in general the analytical data obtained indicated that high amounts of heavy metals and organochlorine pesticides can be present even in young seals. An age-specific increase in the mercury and cadmium content in liver samples could be demonstrated. The results are compared with data published by British and Dutch authors for other North Sea regions, and with a few exceptions, no significant differences can be established: cadmium (kidney) and DDT (blubber) contents in areas off the British coast. There was no clear evidence that the concentrations of any of the compounds investigated had negative effects on the health of the seals. However, possible combined effects cannot be excluded.
KEY WORDS: German North Sea Coast, harbour seals, heavy metals, organochlorines.

Duguy R, and Babin P. 1975. Acute Intoxication by Hydrocarbons Observed in a Harbour Seal *Phoca vitulina*. Rapp. P.-V. Reun. Cons. Int. Explor. Mer., Marine Mammal Comm., C.M. 52 pp.

Duignan PJ, Sadove S, Saliki JT, and Geraci JR. 1993. Phocine Distemper in Harbor Seals (*Phoca vitulina*) from Long Island, New York. J Wildl Dis 29(3):465-9.
ABSTRACT: The first occurrence of phocine distemper (PD) disease in harbor seals (*Phoca vitulina*) from the United States is reported. Two seals stranded on Long Island, New York (USA) in February 1992 with clinical signs of respiratory distress fever, and depression. Pneumonia and diffuse pulmonary congestion were the most significant post mortem findings. On histological examination one seal had a diffuse broncho-interstitial pneumonia with formation of syncytia. The principal lesion in the second animal was nonsuppurative meningoencephalitis. Using immunoperoxidase staining, PD viral antigen was found in the cytoplasm of bronchiolar epithelium and cerebral cortex neurons. With a differential virus neutralization test, there were higher titers against phocine distemper virus (PDV) than against canine distemper virus. Thus, PDV is the most likely agent responsible for the observed lesions.
KEY WORDS: bronco-interstitial pneumonia, first case, harbor seal, immunoperoxidase, morbillivirus, meningoencephalitis, *Phoca vitulina*, phocine distemper, syncytia, virus neutralization titer.

Duinker JC, Hillebrand MTJ, and Nolting RF. 1979. Organochlorines and Metals in Harbour Seals (Dutch Wadden Sea). Mar. Poll. Bull. 10:360-4.
ABSTRACT: Maximum concentrations of PCB and members of the DDT family in liver, brains, kidney, spleen and heart and Cu, Pb, Zn and Cd in brains of harbour seals found dead in the Dutch Wadden Sea are higher than those reported for specimens from the German Wadden Sea, where the population is stable in contrast to the strong reduction observed for the population in the former part. Results are also compared with data from the east coast of England.
KEY WORDS: DDT, Dutch Wadden Sea, harbour seals, metals, organochlorines, polychlorinated biphenyls.

Early G. 1992. Summary Report and Evaluation of the 1992 Seal Distemper Testing Program with Comparison of Mortality Rates. NFFM1020200394 .
ABSTRACT: Mass die-offs of marine mammals have become great concern for scientists and have also become the focus of public attention. Scientists reported that the morbillivirus, phocine distemper virus, was associated with the death of over 17,000 harbor seals (*Phoca vitulina*) in northwestern Europe in 1988. In November of 1991, the New England Aquarium (NEA) recorded the second highest total of stranded harbor seals along the coasts of Massachusetts, New Hampshire, and Maine for that year. A total of 233 animals were reported stranded and 143 of them were recovered and tested for antibodies to morbillivirus. A similar stranding pattern also occurred on Long Island, New York that following year. The mortality pattern and serology findings of all seals that were recovered during 1991-1992 were reported by the NEA. The Canine distemper antibody titration assay, a useful tool for determining morbillivirus activity in seal populations, was performed on the recovered animals. The data indicated that the increased strandings may have been the result of an increased morbidity within the population due to contact with morbillivirus. Overall, it is unlikely that an epizootic was the cause of this mass stranding.
KEY WORDS: harbor seals, mass strandings, morbillivirus, mortality, northeastern coast of U.S, *Phoca vitulina*, phocine distemper virus.

Engelhardt FR. 1983. Petroleum Effects on Marine Mammals. Aquatic Toxicology 4:199-217.
ABSTRACT: Interest in the effects of petroleum on marine mammals has been stimulated both by the general presumption of impact of oil spills on marine mammals and by some recent experimental evidence which better delineates the sensitivity to oil of this varied group of mammals. Case reports and investigations of oil spill incidents have generally not been conclusive in defining the toxicity of petroleum in seals, sea otters, or whales, even though mortality has been attributed to oil exposure at sea. Contact with viscous oils can lead to long-term coating of the body surface, which may interfere with swimming ability in seals, with filtering capabilities by baleen whales, and with thermoregulation in the furred marine mammals. Thermal stress as a result of increased conductance in oil-fouled fur is a primary threat to sea otters and polar bears, resulting in decreased body temperature and an increased metabolic rate. It has been demonstrated in seals and polar bears that these species can absorb oil through the skin, through the gastrointestinal tract, and probably by inhalation. Absorbed oil is distributed to all tissues in varying amounts. A survey of stranded cetaceans showed low hydrocarbon levels in many tissues. Clearance of accumulated oil appears to be rapid. A high renal clearance has been demonstrated in seals. Both seals and cetaceans have a potential for metabolizing oil by their mixed function oxygenase complement demonstrated as cytochrome P-450 in the liver of cetaceans and as aryl hydrocarbon hydroxylase in liver and kidney tissues of seals. Kidney enzymes were inducible by petroleum exposure in seals. A limited comparative data base suggest that seals, cetaceans and polar bears differ in their susceptibility to clinical damage following oil exposure. Ringed seals and bottlenosed dolphin were little affected in hematological, plasma chemistry or histopathological measures after oil immersion and ingestion. Localized treatment of the skin of several cetaceans resulted in transient skin damage. In polar bears, however contact and ingestion resulted in sever but latent hematological and renal abnormalities, along with related pathological changes. This review demonstrates that while the marine mammal species tend to be grouped as one because of their unique life habits, their susceptibility to petroleum toxicity is less general, showing species-specific responses in the major effects indices. At the present level of knowledge, prediction of the effects of petroleum on a given species will require much correlation and inference from what is known about the natural history and physiology of the species, and about the characteristic toxicities of oil in mammalian systems.
KEY WORDS: marine mammals, metabolism, pathology, petroleum, review, thermoregulation, uptake.

Fall JA. 1995. Harbor Seal and Sea Otter Cooperative Subsistence Harvest Assistance. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Projects 94244 and 95244), Alaska Department of Fish and Game, Division of Subsistence, Anchorage, Alaska .
ABSTRACT: The project's goal was to develop an ongoing exchange of information and consensus building between subsistence hunters, scientists, and agencies regarding actions to support the recovery of injured populations of harbor seals and sea otters. Information on harbor seal and sea otter populations and trends was compiled, presented at workshops, and distributed in a report. Three workshops involving scientists and subsistence hunters occurred. Participants concurred that harbor seal populations remain depressed, and that hunters and scientists should work together to restore the populations.

Most hunters believed that sea otter populations have largely recovered from the oil spill. Scientists and hunters can work together on biosampling programs, inclusion of hunters in scientific studies, and integration of traditional ecological knowledge into biological studies. Consensus-building was impeded by the lack of a formal organization representing subsistence users of harbor seals. However, as an outcome of the process initiated by this project, the subsistence users themselves formed an Alaska Native Harbor Seal Commission as a formal co-management body, which will be directly involved in this continuing project. Additionally, research was conducted to collect traditional knowledge and data on harbor seal harvest locations. A video entitled Alaskan Harbor Seals: Science and Subsistence was produced.
KEY WORDS: Cook Inlet, *Enhydra lutris*, *Exxon Valdez*, harbor seals, *Phoca vitulina*, Prince William Sound, sea otters, subsistence uses.

Fossi MC, and Marsili L. 1997. The Use of Non-Destructive Biomarkers in the Study of Marine Mammals. Biomarkers 2:205-16.
ABSTRACT: Marine mammals have been subject to heavy anthropogenic pressure by direct killing and chemical pollution all over the world. Most studies of contamination and biomarker responses in marine mammals have been conducted using animals killed by hunting (out of a total of 12 cetacean species, studied, 45% of the specimens were obtained by sacrificing the animal; out of a total of eight pinniped species studied, 40% of the specimens were obtained by killing). The development of a series of non-destructive techniques to evaluate biomarker responses and residue levels is recommended for the hazard assessment and conservation of endangered species of marine mammals. Here we review the current status of the non-destructive tests in stranded (brain, liver, blood, skin, subcutaneous blubber, muscle and fur) and free-ranging animals (blood, skin biopsy, fur and faeces) and the respective biomarker techniques (mixed function oxidase activity and DNA damage in skin biopsy samples; porphyrins in faeces and fur; esterases, porphyrins, clinical biochemical parameter, vitamin A and micronuclei in blood samples). Residue analysis can be carried out in the various biological materials. We also report the results of applying this methodological approach to cetaceans (minke whale-*Balaenoptera acutorostrata*, fin whale- *Balaenoptera physalus*, beluga whale- *Delphinapterus leucas*, short-finned pilot whale- *Globicephala macrorhynchus*, harbour porpoise- *Phocoena phocoena*, Rissos dolphin- Risso's *Grampus griseus*, Dall's porpoise- *Phocoenoides dalli dalli*, melon-headed whale- *Peponocephala electra*, bottlenose dolphin- *Tursiops truncatus*, striped dolphin- *Stenella coeruleoalba*, spinner dolphin- *Stenella longirostris*, killer whale- *Orcinus orca*) and pinnipeds (northern fur seal- *Callorhinus ursinus*, hooded seal- *Cystophora cristata*, grey seal- *Halichoerus grypus*, harbour seal- *Phoca vitulina*, ringed seal- *Phoca hispida*, harp seal- *Phoca groenlandica*, ribbon seal- *Phoca fasciata*, largha seal- *Phoca largha*, southern sea lion- *Otaria flavascens*) in field studies for prognostic and diagnostic purposes.
KEY WORDS: biomarkers, contaminants, ecotoxicological risk, endangered species, marine mammals.

Frank A, Galgan V, Olsson M, Petersson LR, and Bignert A. 1992. Metal Concentrations in Seals from Swedish Waters. Ambio 21(8):529-38.
ABSTRACT: Organ tissues from 109 seals were grouped by sampling area, species, sex, age and health status. The concentration of Al, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni,

Pb, V, W, and Zn were determined in liver and kidney cortex by simultaneous direct current plasma atomic-emission spectrometry (DCP-AES). Concentrations of Hg and Se in liver as well as in blubber were determined by continuous hydride atomic absorption spectrometry (AAS). Harbor seal (*Phoca vitulina vitulina*) from the Skagerrak, the Kattegat and the Baltic, grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida botnica)* from the Baltic were studied. Juveniles were used for comparison of concentrations between areas and species, and seals hit by the PDV epizootic with uninfected specimens. Adult males were compared to juveniles. Adult female grey seals, apparently healthy, were compared to unstarved and starved females showing the symptoms of the disease complex earlier described as hyperadreno-corticism. The concentrations of most elements were at similar levels in corresponding tissues from Baltic harbor seals and harbor seals from the Swedish west coast. However, concentrations of several elements were generally lower in the coastal living Baltic harbor seals compared with Baltic grey and ringed seals. Increasing concentrations with age were ascertained for Cd, Hg and Se. Diseased old adult female grey seals had altered concentrations of Al, As, Ca, Cr, and Fe compared to the undiseased female, adult males and/or juveniles. No support was found for the assumption, that heavy metals contributed to the outbreak of the epizootic among harbor seals in 1988. The distribution pattern of some elements appeared to be influenced by infectious and inflammatory processes in animals that died during the epizootic.
KEY WORDS: grey seal, *Halichoerus grypus*, harbor seal, heavy metals, *Phoca hispida*, *Phoca vitulina*, ringed seal, Swedish Coast.

Frost KJ, and Lowry LF. 1994. Assessment of Injury to Harbor Seals in Prince William Sound, Alaska, and Adjacent Areas Following the *Exxon Valdez* Oil Spill. *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Marine Mammal Study Number 5, Restoration Study Number 73), Alaska Department of Fish and Game, Wildlife Conservation Division, Fairbanks, Alaska .
ABSTRACT: In the weeks following the *Exxon Valdez* oil spill (EVOS) harbor seals, *Phoca vitulina richardsi*, swam through oil and inhaled aromatic hydrocarbons as they breathed at the air/water interface. Some pups were born on oiled haulouts and nursed on oiled mothers. By May over 80% of the seals in oiled areas had oiled pelage. Heavily oiled seals were observed to be sick, lethargic, or unusually tame. Concentrations of fluorescent aromatic compounds in bile clearly indicated that most seals from oiled areas had been exposed to hydrocarbons. Microscopic examination of tissues revealed severe neurological lesions in a heavily oiled seal collected 35 days post spill. Similar but milder lesions were found in the brains of seals collected three months post-spill. Before the EVOS, harbor seals in Prince William Sound were declining at an average annual rate of 12% in both oiled and unoiled sites versus an 11% decline at unoiled sites. By 1992 there were still 34% fewer seals at oiled sites than before the spill. The proportion of pups in the oiled area in 1989 was significantly lower than in subsequent years. Total spill-caused mortality in Prince William Sound was estimated to be 300 seals.
KEY WORDS: Alaska, aromatic hydrocarbons, *Exxon Valdez* oil spill, harbor seals, injury, mother-pup pairs, oil effects, oiled pelage, *Phoca vitulina*, Prince William Sound.

Frost KJ, Ballachey BE, Dahlheim ME, and Laughlin TR. 1993. Effects of the *Exxon Valdez* Oil Spill on Marine Mammals in Prince William Sound. *Exxon Valdez* Oil Spill Symposium,

Abstract Book. 34-6.
KEY WORDS: Alaska, contamination, effects, *Exxon Valdez*, harbor and Dall's porpoise, harbor seal, humpback whale, hydrocarbon, killer whale, marine mammals, oil spill, sea lion, sea otter.

Frost KJ, Lowry LF, Small RJ, and Iverson SJ. 1996. Monitoring Habitat Use, and Trophic Interactions of Harbor Seals in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 95064), Alaska Department of Fish and Game, Division of Subsistence, Anchorage, Alaska .
ABSTRACT: Aerial surveys of harbor seals, *Phoca vitulina richardsi*, at 25 trend sites in Prince William Sound (PWS) during 1989 -1995, showed significant declines in counts during the molt (19%) and during pupping (31%) when corrected for effects of date, time of day, and tide relative to low tide. A Leslie matrix population model indicated large changes in vital parameters must have occurred to cause the 1984-1989 decline. Preliminary results indicate that projections for population recovery will depend in the carrying capacity level and pattern of density dependence assumed in the model. Forty-two seals were sampled in 1995, and satellite linked depth recorders were attached to 14. Tagged seals were tracked for up to 267 days. Most stayed within PWS near the capture site; one moved to Middleton Island, one to Yakutat Bay. Data analyses indicate that seals show considerable fidelity to haulout sites and haul out more regularly during May-July. Diving behavior was variable among individuals. Seals that moved out of PWS made longer feeding trips than those within PWS. Fatty acid analyses found differences in seal prey by species, area, and season. Fatty acid signatures indicated differences in seal diets between southeast Alaska, Kodiak and PWS, and between areas within PWS.
KEY WORDS: Behavior, diving, *Exxon Valdez* oil spill, fatty acids, habitat use, harbor seal, movements, *Phoca vitulina richardsi*, population modeling, population monitoring, Prince William Sound, recovery, satellite telemetry.

Funke C, King DP, Brotheridge RM, Adelung D, and Stott JL. 1997. Harbor Seal (*Phoca vitulina*) C-Reactive Protein (C-RP): Purification, Characterization of Specific Monoclonal Antibodies and Development of an Immuno-Assay to Measure Serum C-RP Concentrations. Vet. Immunol. Immunopathol. 5835:1-11.
ABSTRACT: C-reactive protein (C-RP) was purified from harbor seal (*Phoca vitulina*) serum by calcium dependent phosphoryl-choline and protein A affinity chromatography. Polyacrylamide gel electrophoresis under reducing conditions revealed a single protein moiety with a molecular weight of approximately 25 kDa. An internal peptide derived from this purified protein was subjected to N-terminal amino acid sequencing. A high amino acid sequence similarity was obtained with other published mammalian C-RP molecules confirming that the purified protein was a C-RP homologue. Eight specific monoclonal antibodies (P13, P51, P87, P101, P106, P130, P157 and P219) were raised against this purified protein. All 8 monoclonal antibodies immunoblotted with the 25 kDa C-RP subunit under reducing conditions. A competitive immunoassay was developed, identifying elevated C-RP concentrations in harbor seal serum samples with clinical evidence of inflammatory disease. Applications of this immunoassay for the measurement C-RP may provide valuable information for the clinical assessment of harbor seal health.

KEY WORDS: acute phase, C-reactive protein, harbor seal, immunoassay, inflammation, monoclonal antibody.

Galster W, and Burn J. 1972. Accumulation of Pesticides in Alaskan Marine Mammals. Proceedings of the 23rd Alaska Scientific Conference, Fairbanks, Alaska. Alaska Division of the American Association for the Advancement of Science. Pp 50.
KEY WORDS: Alaska, bearded seal, contamination, DDD, DDE, DDT, dieldrin, harbor seal, hydrocarbon, lindane, marine mammals, organochlorines, PCB, polar bear, ringed seal, stellar sea lion, walrus..

Gaskin DE, Frank R, Holdrinet M, Ishida K, Walton CJ, and Smith M. 1973. Mercury, DDT, and PCB in Harbour Seals (*Phoca vitulina*) from the Bay of Fundy and Gulf of Maine. J. Fish. Res. Board Can. 30:471-5.
ABSTRACT: Samples of blubber, longissimus muscle, liver, and cerebrum from 12 harbour seals (*Phoca vitulina*) were analyzed for DDT, dieldrin, PCBs, and total mercury content. The results were compared with those obtained previously for harbour porpoises (*Phocoena phocoena*). DDT and PCB levels appear to be of the same magnitude in the fat of seals from both southern New Brunswick and southern Maine, being lowest in a lactating female. Virtually no *p,p*-DDT and relatively little dieldrin were found in seal fat, in contrast to porpoises, which contained significant amounts of both in the depot fat. Mercury levels were generally similar to those found for porpoises, but total liver Hg was considerably greater in adults from the New Brunswick islands than in those from the southern Maine ledges.
KEY WORDS: DDT, dieldrin, harbour porpoises, harbour seals, mercury, organochlorine pesticides, *Phoca vitulina*, *Phocoena phocoena*, polychlorinated biphenyls.

Geraci JR, and St. Aubin DJ. 1987. Effects of Offshore Oil and Gas Development on Marine Mammals and Turtles. In: Donald F. Boesch and Nancy N. Rabalais (Eds.). 1987. Long-Term Environmental Effects of Offshore Oil and Gas Development. Elsevier Applied Science, New York. 708 pp.
ABSTRACT: During the past five years, studies on marine mammals have brought us closer to an understanding of basic behavioral and physiological responses to oil. For example, experiments have shown that dolphins can detect oil and, under certain circumstances, will avoid it. Oil can cause subtle damage to their skin, the full impact of which is still being assessed. The threat to otters and polar bears is unequivocal. Oiled fur is ineffective as an insulator, and attempts to groom can lead to oil ingestion. Fouling of baleen has short-term effects on water flow and feeding efficiency, although the consequences may not be as great as was predicted. Noise and disturbance associated with offshore production may be within the limits of tolerance for some species. The full range of effects on turtles is poorly understood. Young turtles can eat tarballs which seal their mouths and interfere with normal feeding. Oil fouling of nests can lead to embryonic abnormalities and hatchling mortality. Turtles are particularly vulnerable to disturbances during the nesting season. The greatest impact of offshore oil and gas activities may result not from direct mortality, but rather through subtle alterations of habitat, in association with intrinsic stressors within the environment. We provide recommendations which reflect our interpretation of the most significant data gaps and

emphasize the need for selective long-term monitoring.
KEY WORDS: gas, marine mammals, offshore oil, oil fouling, recommendations, turtles.

Geraci JR, and St. Aubin DJ. 1980. Offshore Petroleum Resource Development and Marine Mammals: A Review and Research Recommendations. Marine Fisheries Review 42:1-12.
ABSTRACT: The development of offshore oil and gas reserves presents a number of potential threats to marine mammals. Seismic surveys employing various high explosives can be lethal at close range. Noise is associated with all phases of petroleum exploration and production. The physical, physiological, and behavioral effects of noise disturbance on marine mammals are poorly understood and need to be investigated. Exposure to spilled oil have been implicated as the cause of death of pinnipeds and cetacean, however much of the evidence has been inconclusive. Surface contact is threatening to those species which rely on hair or fur for thermal insulation, such as sea otters, fur seals, and polar bears. Though cetaceans are not likely to accumulate oil on their body surfaces, the unique metabolic and physiologic properties of cetacean skin may be impaired by toxic fractions in crude oil. Marine mammals are unlikely to ingest sufficient quantities of oil to cause acute toxicity. However, the long-term effects of accumulation of petroleum fractions through the food chain are unknown. Inhalation of toxic vapors would occur in any oil spill situation, and can be life threatening in the case of prolonged exposure. The ability of marine mammals to detects and avoid oil slicks in critical to any assessment of the potential impact of oil, and yet such information is clearly lacking. This review summarized field observations and experimental studies of the effects of oil and oil exploration on marine mammals, identifies gaps in our knowledge, and established priorities for future research.
KEY WORDS: marine mammals, offshore oil, petroleum, review, toxicity.

Geraci JR, St. Aubin DJ, Barker IK, Webster RG, Hinshaw VS, Bean WJ, Ruhnke HL, Prescott JH, Early G, Baker AS and others. 1982. Mass Mortality of Harbor Seals: Pneumonia Associated with Influenza A Virus. Science 215:1129-31.
ABSTRACT: More than 400 harbor seals, most of them immature, died along the New England coast between December 1979 and October 1980 of acute pneumonia associated with influenza virus, A/Seal/Mass/1/80 (H7N7). The virus has avian characteristics, replicates principally in mammals, and causes mild respiratory disease in experimentally infected seals. Concurrent infection with a previously undescribed mycoplasma or adverse environmental conditions may have triggered the epizootic. The similarities between this epizootic and other seal moralities in the past suggest that these events may be linked by common biological and environmental factors.
KEY WORDS: environmental factors, harbor seals, influenza virus, New England coast, pneumonia.

Hall AJ, Law RJ, Wells DE, Harwood J, Ross HM, Kennedy S, Allchin C, Cambell LA, and Pomeroy PP. 1992. Organochlorine Levels in Common Seals *Phoca vitulina* Which Were Victims and Survivors of the 1988 Phocine Distemper Epizootic. Sci. Total Environ. 115:145-62.
ABSTRACT: We compared concentrations of organochlorines in the blubber of

common seals (*Phoca vitulina*) found dead during the 1988 phocine distemper epizootic with levels in animals which survived it. There were highly significant differences between the live and dead animals, and between sample sites. These were not fully accounted for by seasonal and condition-related changes in blubber thickness.
KEY WORDS: DDT, organochlorines, phocid distemper, polychlorinated biphenyls, seals.

Hansen DJ. 1985. The Potential Effects of Oil Spills and Other Chemical Pollutants on Marine Mammals Occurring in Alaskan Waters. OCS Report. Minerals Management Service 85-0031. 22 pp.
ABSTRACT: This report describes and assesses the potential effects of oil spills and other contaminants on marine mammals that occur in Alaskan waters, assuming that a spill or contamination occurs. This current information is used here to more clearly define the potential direct and indirect effects of oil spills and other contaminants on marine mammals than was possible in previous environmental impact statements (EISs) and Alaska Outer Continental Shelf (OCS) Office Technical Paper No. 9 (Cowles et al., 1981), which reviewed earlier information on oil-spill effects on marine mammals. The following discussions address both short-term effects that occur at the time of contact with oil and long-term effects that occur long after contact with oil. Cetacean and noncetacean marine mammals are treated separately in discussions of direct effects. Marine mammals are treated collectively in discussions of oil-spill avoidance, indirect and long-term oil-spill effects, and effects of other contaminants.
KEY WORDS: Alaska, contaminants, marine mammals, oil.

Hansen DJ. 1992. Potential Effects of Oil Spills on Marine Mammals That Occur in Alaskan Waters. OCS Report, MMS 92-0012 :25 pp.
ABSTRACT: Contact with an oil spill can result in direct effects on marine mammals in Alaskan waters, causing mortality of some marine mammals and having no apparent effect on others. If extensive oil-spilled contact occurs, lethal effects on sea otters, polar bears, northern fur seals, and young ice-seal pups are expected from loss of thermal insulation, ingestion, and/or inhalation of toxic hydrocarbons, and from increased physiological stress associated with oiling and hydrocarbon intoxication. Other marine mammals species may suffer less serious or sublethal effects such as eye and skin irritation that might contribute to the death of highly stressed animals. Population-level effects on sea otters and northern fur seals in Alaskan waters could occur if a large spill contacted large concentrations of these species. Indirect effects of oil spills on marine mammals through changes in the availability of food organisms from contamination of habitats are difficult to differentiate from natural changes in the environment and may be inconsequential in comparison to natural variability within the ecosystem. To date no long-term oil-spill effects on marine mammals from bioaccumulation of hydrocarbons have been demonstrated. Marine mammals probably have adapted to the low levels of naturally occurring hydrocarbon components present in crude oil than can accumulate somewhat in the food web.
KEY WORDS: Alaska, contamination, hydrocarbons, marine mammals, oil spill.

Haraguchi K, Athanasiadou M, Bergman A, Hovander L, and Jensen S. 1992. PCB and PCB Methyl Sulfones in Selected Groups of Seals from Swedish Waters. Ambio 21(8):546-9.

ABSTRACT: The concentrations of 7 chlorinated biphenyls (CBs), total PCB, as determined by PCB congener-specific analysis, and of PCB and DDE methyl sulfones in grey seal, harbor seal and ringed seal from different areas of the Swedish coastline, of different age and health status were determined. Total PCB concentrations between 8 $g \cdot g^{1}$ (juvenile harbor seals) and 2100 $g \cdot g^{1}$ (adult female grey seals with serious disease symptoms) were determined. Fifty-five (SD 8.0) of the total PCB concentration was due to three PCB congeners. PCB methyl sulfone concentrations between 0.7 $g \cdot g^{-1}$ (juvenile harbor seals) and 110 $g \cdot g^{-1}$ (adult female grey seals with disease symptoms) were determined. The PCB methyl sulfones were dominated by MeSO2- pentaCBs. Tris-(4-chloro-phenyl)methanol was identified in grey seal blubber.
KEY WORDS: chlorinated biphenyls, grey seal, harbor seal, methyl sulfone, PCB, ringed seal, Sweden.

Harder TC, Whillhaus T, Leibold W, and Liess B. 1992. Investigations on Course and Outcome of Phocine Distemper Virus Infection in Harbour Seals *Phoca vitulina* Exposed to Polychlorinated Biphenyls . Journal of Veterinary Medicine 39:19-31.

ABSTRACT: The influence of polychlorinated biphenyls (PCBs) on phocine distemper virus (PDV) infections in harbour seals (*Phoca vitulina*) was studied. Six out of ten seals had been conditioned with defined mixture of PCB-congeners for several weeks. Following exposure to the cell culture-propagated PDV isolate 2558/Han 88 the complete clinical picture of 1988 seal plague was provoked in all ten seals inoculated. Four out of six PCB-conditioned seals and two out of four seals not loaded with PCBs succumbed to the infection within three weeks post inoculation. With regard to the clinical course, duration of cell-associated viremia, PDV-antigen distribution in tissues of fatally infected seals and the humoral immune response to PDV, no differences between PCB-loaded and unloaded seals were recognized. Evidence was obtained that the pathogenesis of experimental PDV-infection in harbour seals shares some features with those of canine distemper in terrestrial carnivores. In contrast, however, to experimental distemper infection of gnotobiotic dogs, prompt development of high titres of PDV-specific IgG did not correlate with recovery from infection.
KEY WORDS: harbour seals, phocine distemper virus, polychlorinated biphenyls.

Harms U, Drescher HE, and Huschenbeth E. 1977. Further Data on Heavy Metals and Organochlorines in Marine Mammals from German Coastal Waters. Meeresforsch 26:153-61.

ABSTRACT: Studies on heavy metals and organochlorines in harbour seals (*Phoca vitulina*) were continued and extended to other marine mammals, which were found off the German North Sea and Baltic coasts. The results are compared with contamination levels in fish which form the major food source of the marine mammals investigated. Concentrations of copper, zinc, cadmium and lead in muscle and liver tissues of fish did not differ significantly from corresponding organs of the marine mammals. However, considerably higher amounts of mercury were found in the liver of seals and whales than in fish. Higher mercury concentrations in seals are closely related to the age of the animals. The highest amount of 160 mg/kg (ppm) Hg was found in an adult seal. In contrast to fish a high percentage of total mercury occurs in the inorganic form in seal and whale liver.
KEY WORDS: Baltic, bioaccumulation, DDT, heavy metals, marine mammals,

mercury, North Sea, *Phoca vitulina*, pollution effects, polychlorinated biphenyls.

Harwood J, and Reijnders P. 1988. Seals, Sense and Sensibility. New Sci. 120(1634):28-9.
KEY WORDS: mammals, mortality, parasites/diseases, pesticides/pollution, pollution, viral diseases.

Heide-Jorgensen MP, Harkonen T, and Aberg P. 1992. Long-term Effects of Epizootic in Harbor Seals in the Kattegat-Skagerrak and Adjacent Areas. Ambio 21(8):511-6.
ABSTRACT: Results from aerial surveys of hauled-out harbor seals, *Phoca vitulina*, in the entire Kattegat-Skagerrak, the Limfjord and the western part of the Baltic Sea in 1989-1991 are compared with results from surveys conducted soon after the seal epizootic in 1988. The results suggest that an increase in relative abundance of seals occurred between 1988 and 1991 in the Limfjord and in most parts of the Kattegat-Skagerrak. Pup production was assessed at selected localities in the Kattegat-Skagerrak during 1978-1991. Lowered rate of pup production resembled expected values in 1989, the year after the epizootic. However, the pup production resembled expected values in 1990-1991. The decline in 1989 was probably due either to perturbations of the reproductive cycle caused by the morbilli virus infections in 1988, or to the shortage of mature males in the aerial surveys where no increase in relative abundance was detected during 1988-1990. Simulations based on a matrix model of the Kattegat-Skagerrak population suggest that skewed sex and age distributions will persist for decades, but a high rate of increase should enable the population to recover by 1995-1996 to a size similar to that before the epizootic.
KEY WORDS: Baltic Sea, harbor seals, morbilli virus epizootic, *Phoca vitulina*, population density.

Heidmann WA, Deyanes GS, Buthe A, and Russelsinn H. 1992. Correlation Between Concentration and Composition of PCB Mixtures in Seals *Phoca vitulina*. Chemosphere 24(8):1111-8.
ABSTRACT: Two methods for characterizing the composition of PCB mixtures, degree of metabolisation and ring stability values, allow recognition of variations between and within species easily. Blubber of harbour seals from Iceland and the North Sea were analyzed. The degree of metabolisation is presented as a function of the concentration.
KEY WORDS: harbour seals, Iceland, North Sea, PCB.

Helle E, Olsson M, and Jensen S. 1976. PCB Levels Correlated with Pathological Changes in Seal Uteri. Ambio 5:261-3.
ABSTRACT: About 40 percent of a sample of Baltic ringed seal females of reproductive age showed pathological changes of the uterus. The uterine horns were closed by stenosis and occlusions, preventing any passage from the ovary out through the horn. This explains their low reproduction rate. Animals showing these changes had significantly higher levels of DDT and PCB substances than normal, pregnant females. These pathological changes were also found among grey seal from the Baltic area, as well as among harbor seal from the Swedish west coast. It is strongly indicated that PCB is responsible for the reproductive failure of seals in the Baltic area. A significant positive correlation between DDT and PCB levels and age was found in the males but not in the females. The levels of DDT and PCB substances were somewhat lower in fetuses, than

in their mothers.
KEY WORDS: Baltic ringed seal, DDT, PCB, reproductive age.

Hellou J, Stenson G, Ni I-H, and Payne JF. 1990. Polycyclic Aromatic Hydrocarbons in Muscle Tissue of Marine Mammals from the Northwest Atlantic. Mar. Poll. Bull. 21(10):469-73.
ABSTRACT: There are virtually no data available on polycyclic aromatic hydrocarbons (PAH) in marine mammals. Total PAH concentrations were determined in terms of chrysene and petroleum hydrocarbon equivalents in muscle tissues of four species of seals and six species of whales from waters around Newfoundland and Labrador. Values expressed on a dry weight basis ranged from 0.10 to 1.21 ppm in terms of petroleum equivalents. The relatively high levels found in some animals from fishing areas demonstrates a need for more comprehensive information on PAH in marine mammals.
KEY WORDS: mammals, pesticides/ pollution, polycyclic aromatic hydrocarbons.

Himeno S, Watanabe C, Hongo T, Suzuki T, Naganuma A, and Imura N. 1989. Body Size and Organ Accumulation of Mercury and Selenium in Young Harbor Seals (*Phoca vitulina*). Bull. Environ. Contam. Toxicol. 42:503-9.
ABSTRACT: The harbor seal, *Phoca vitulina*, being situated at the top of the marine food chain, consumes a considerable amount of fish which can accumulate a significant concentration of mercury (Hg) and selenium (Se) in its tissues. Tissue samples were examined from harbor seals captured in the Sea of Okhotsk off Monbetsu City, Japan to determine concentrations of Hg and Se. *In vitro* methylmercury (me-Hg) demethylating activity in seal organs were also examined. Total mercury and inorganic mercury showed high correlations with body length in the liver and kidney. An early phase of Hg accumulation with Se in the liver of younger seals, where the molar ration of Hg/Se ratios is approaching towards 1.0 with age, is also present. *In vitro* me-Hg demethylation in both the liver and kidney tissues showed almost twice the activity of that in rats or mice but it is still unknown to what extent harbor seals difference in demethylation contribution to the actual inorganic mercury formation.
KEY WORDS: harbor seal, Japan, mercury, Methylmercury, *Phoca vitulina*, selenium.

Holden AV. 1978. Pollutants and Seals - A Review. Mammal Rev. 8(1,2):53-66.
ABSTRACT: It is evident from the information so far available that high concentrations of several organochlorine compounds can be accumulated in the lipids of seals and other marine mammals in polluted areas. Yet there is still no conclusive evidence that even the highest concentrations are causing adverse effects on any species, although PCBs (rather than DDT) may be linked with the abnormally high abortion rate among Baltic Ringed seals. The PCB concentrations in the extractable fat of the seals affected averaged only 77 mg/kg, but several other populations have been found to contain higher concentrations. Only one of these populations, the California sea lions, has also been found to suffer a high abortion rate. Some heavy metals are present at relatively high concentrations in several organs of seals, but with the possible exception of mercury there is no evidence that any of the concentrations are abnormal. Mercury has been shown to increase with age in liver (but probably not in the brain except in the early years), although the very high concentrations in old seals (over 700 mg/kg in a few specimens) do not necessarily reflect the influence of pollution. Perhaps surprisingly, the mercury is not methylated to any large extent, suggesting that seals can probably demethylate the

mercury in fish. The linear relationship with selenium may also give a protective action against mercury toxication. Few other pollutants have been found in significant concentrations, and even oil, a common marine pollutant particularly in coastal waters, has rarely been associated with any measurable adverse effects. It would seem that a more detailed study of marine mammals might lead to a greater understanding of the mechanisms which appear to give the species some degree of protection from the unusually high concentrations of DDT, PCBs and mercury often found in their tissues. It is recognized, however, that experimental investigations on seals would present considerable practical difficulties.
KEY WORDS: heavy metals, pesticides, Phocidae, pollutants, pollution effects, polychlorinated biphenyls.

Hong C, Calambokidis J, Bush B, Steiger GH, and Shaw S. 1996. Polychlorinated Biphenyls and Organochlorine Pesticides in Harbor Seal Pups from the Inland Waters of Washington State. Env. Sci. Technol. 30(3):837-44.
ABSTRACT: Blubber and liver samples from eight harbor seal (*Phoca vitulina*) pups, found dead at Puget Sound in 1990, have been analyzed for polychlorinated biphenyl (PCB) congeners, including mono-ortho and non-ortho coplanar PCBs, hexachlorobenzene (HCB), p, p-DDE, and mirex. Four of the seals were from Smith Island in the Strait of Juan de Fuca, and four were from southern Puget Sound primary at Gertrude Island. The levels of total PCBs, p, p-DDE, and mirex are significantly higher in the seal samples from Gertrude Island than those from Smith Island. PCB congener 126 was the major contributor to PCB toxic equivalents (TEQs), followed by 156.
KEY WORDS: harbor seal, *Phoca vitulina*, polychlorinated biphenyls, Puget Sound, toxicity.

Hoover-Miller A. 1988. Harbor Seal (*Phoca vitulina*). *In*: Selected Marine Mammals of Alaska: Species Accounts With Research and Management Recommendations. Marine Mammal Commission, Washington, D.C. :125-157.
ABSTRACT: This project is a comprehensive report on the harbor seal (*Phoca vitulina*) population in Alaska. The life history of this animal is discussed, which includes habitat, annual cycle, growth and development, mortality, feeding habits, and energetic and nutritional requirements. Harbor seal distribution in Alaska is from Dixon Entrance to Kuskokwim Bay, throughout the entire coast. Population estimates have been reported in 1973 but the current status is not well understood. The status of harbor seals and evaluation of numbers and trends are discussed in detail. Several present and future conservation issues are also included. During 1964-1966, seal harvests peaked statewide when 40,000-60,000 seals were harvested annually. Today, estimates of subsistence harvest do not exceed 2,500 seals. Marine mammal-fisheries interactions are also a significant concern to scientists. Commercial fisheries are currently expanding without the baseline and monitoring data to detect fishery-related impacts on marine mammals stocks. The importance of both biological and direct interactions with fisheries are discussed. Another factor that can have a direct or indirect effect on harbor seals are the development of offshore oil and gas along with other pollutants such as organochlorines, polychlorinated biphenyls and heavy metals. To date, only a small number of studies have been documented and conclusions can only be based on these reports. Recommendations have been made both for management and research levels. Because an

effective management program for harbor seal in Alaska has not been developed, important management and conservation issues are addressed.
KEY WORDS: Alaska, conservation, harbor seal, life history, management plan, *Phoca vitulina*, research recommendations.

Hoover-Miller A. 1994. Harbor Seal (*Phoca vitulina*) Biology and Management in Alaska. Marine Mammal Commission, Contract Number T75134749 :45 pp.
ABSTRACT: This project is a comprehensive report on the harbor seal (*Phoca vitulina*) population in Alaska. The life history of this animal is discussed, which includes habitat, annual cycle, growth and development, mortality, feeding habits, and energetic and nutritional requirements. Harbor seal distribution in Alaska is from Dixon Entrance to Kuskokwim Bay, throughout the entire coast. Population estimates have been reported in 1973 but the current status is not well understood. The status of harbor seals and evaluation of numbers and trends are discussed in detail. Several present and future conservation issues are also included. During 1964-1966, seal harvests peaked statewide when 40,000-60,000 seals were harvested annually. Today, estimates of subsistence harvest do not exceed 2,500 seals. Marine mammal-fisheries interactions are also a significant concern to scientists. Commercial fisheries are currently expanding without the baseline and monitoring data to detect fishery-related impacts on marine mammals stocks. The importance of both biological and direct interactions with fisheries are discussed. Another factor that can have a direct or indirect effect on harbor seals are the development of offshore oil and gas along with other pollutants such as organochlorines, polychlorinated biphenyls and heavy metals. To date, only a small number of studies have been documented and conclusions can only be based on these reports. Recommendations have been made both for management and research levels. Because an effective management program for harbor seal in Alaska has not been developed, important management and conservation issues are addressed.
KEY WORDS: Alaska, conservation, harbor seal, life history, management plan, *Phoca vitulina*, research recommendations.

Hummert K, Vetter W, and Luckas B. 1995. Levels of Alpha-HCH, Lindane, and Enantiomeric Ratios of Alpha-HCH in Marine Mammals from the Northern Hemisphere. Chemosphere 31(6):3489-500.
ABSTRACT: The enantiomeric ratios of alpha HCH were determined by chiral gas chromatography in blubber of marine mammals from regions of the northern hemisphere (North Sea, Baltic Sea, Arctic, and Iceland). Cetaceans (harbour porpoises and white-beaked dolphins) showed a preferential accumulation of (+)-alpha-HCH. In blubber of harbour seals, grey seals and harp seals (+)-alpha-HCH was also more abundant than (-)-alpha-HCH. Hooded seals formed an exception with a (+/) enantiomeric ratio of alpha-HCH <1.
KEY WORDS: alpha-HCH, chiral gas chromatography, enantiomeric rations, marine mammals.

Huschenbeth E. 1977. Results of Heavy Metal and Organic Halogen Investigation on the Seal *Phoca vitulina* of the German North Sea Coast. Informationen Fur Die Fischwirtschaft 24:18-20.

Hutchinson JD, and Simmonds MP. 1994. Organochlorine Contamination in Pinnipeds. Rev. Environ. Contam. Toxicol. 136:123-67.

ABSTRACT: Organochlorines, such as PCBs and DDT, are ubiquitous contaminants. Most studies reporting concentrations of organochlorines in pinnipeds have investigated ringed, grey, and harbour seals. Very few studies have been carried out on pinnipeds from the southern hemisphere. Pre-1980, the highest mean wet-weight blubber concentrations of DDT and related metabolites (911 +/- 582 micrograms·g^{-1}) were recorded in sea lions from California. The highest pre-1980 blubber concentrations of PCBs (1470 +/- 922 micrograms·g^{-1}) were recorded in harbour seals from the Netherlands. In later studies, the highest blubber concentrations of PCBs have been recorded from grey seals of the Dee estuary, UK [46.79 (10.17-116.68) micrograms·g^{1}]. The highest DDT concentrations measured in individual pinnipeds appear to be in the 1-15 micrograms·g^{-1} range, and such levels have been recorded from ringed, grey, and harbour seals and Australian fur seals. There are problems in identifying trends based on different studies. These include the improvement in analytical methods with time and the lack of uniformity in analytical methodology between laboratories as well as in the biological material analyzed. Insufficient standardized studies have been undertaken for a clear picture of temporal trends in DDT and PCB concentrations in pinniped colonies from different sites, and special reference has been made to comparison of contaminant burdens between the UK colonies. Insufficient standardized information is currently available for patterns of contamination in pinnipeds to be assessed on global scale. Many, although not all, studies have shown evidence for age and sex correlation for organochlorine concentrations in pinnipeds; male seals continuing to accumulate certain organochlorines throughout their lives; female seals accumulating these compounds until maturity when they lose part of their body burdens to their offspring via transplacental transfer and, more importantly, via lactation. The ability of pinnipeds to metabolize organochlorine compounds appears to be less well developed than in terrestrial mammals and seems to vary between seal species. Reported effects on pinnipeds, which have been suggested to result from organochlorine contamination, include skeletal deformities and impacts on reproduction, such as uterine blockages. The evidence of a relationship between recent epizootics in marine mammal populations and organochlorine pollution suggests that viruses and pollution are potential significant contributors to mortalities, but other factors, such as unseasonably warm temperatures and high seal densities, cannot be precluded.

KEY WORDS: contaminants, DDT, epizootics, marine mammals, organochlorines, PCB, pinnipeds, transplacental transfer.

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KEY WORDS: acid precipitation, heavy metals, mammals, mercury, parasites/ diseases, PCDDs, PCDFs, pesticides/ pollution, viral diseases.

Kamrin MA, and Ringer RK. 1994. PCB Residues in Mammals: A Review. Toxic. Environ. Chem. 41:63-84.

ABSTRACT: This article provides a comprehensive review of the results of analytical studies on PCB residues in mammals in the wild, both in the terrestrial and the marine

environments. The data are presented predominantly in terms of total PCBs although some congener-specific studies are also reported. In addition, this report addresses possible geographical and temporal patterns in the data. One conclusion is that while PCBs can be found everywhere, the lowest residue levels are found in mammals in the Antarctic and the highest in hot spots in the Northern hemisphere, e.g. the Baltic sea. Time trends are not as clear although it appears that residue levels in mammals have been decreasing during the past 10-15 years. The results of future studies can be compared with the data presented here to ascertain if this trend is real and continuing.
KEY WORDS: analysis, Dutch Wadden Sea, heavy metals, mammals, marine food chains, polychlorinated biphenyls (PCBs), residues, small cetaceans.

Kendall MD, Safieh B, Harwood J, and Pomeroy PP. 1992. Plasma Thymulin Concentrations, the Thymus and Organochlorine Contaminant Levels in Seals Infected with Phocine Distemper Virus. Sci. Total Environ. 115(1/2):133-44.
ABSTRACT: Blood samples collected from live common seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) around the coast of Scotland and Northern Ireland during, and immediately after, an epizootic caused by phocid distemper virus (PDV) were analysed for thymulin content. Thymulin levels were compared with neutralization titres and concentrations of organochlorine contaminants (DDT and its metabolites, seven chlorinated biphenyl congeners) derived from blood and blubber samples collected from the same animals and analysed independently. Thymulin levels in grey seals (mean 2827 $\pm$ 1355 fg/ml) were negatively correlated with the logarithm of virus neutralization titre. In common seals they varied significantly between age classes. There wan no direct relationship between thymulin levels and contaminant levels in either species. However, when an estimate of time since exposure was included in the regression analysis for common seals, there was a highly significant relationship between thymulin and the two chlorinated biphenyl congeners with the highest concentrations in blubber.
KEY WORDS: organochlorines, phocid distemper virus, seals, thymulin, thymus.

Kennedy S, Smyth JA, McCullogh SJ, Allen GM, McNeilly F, and McQuaid S. 1988. Confirmation of Cause of Recent Seal Deaths. Nature 335:404.
ABSTRACT: The authors have necropsied 17 dead or seriously ill seals (*Phoca vitulina*) found on the coast of Northern Ireland since 3 Aug. 1988. Main necropsy findings were severe pneumonia, encephalitis and ophthalmitis. Histopathological brain lesions were typical of a viral encephalitis and the authors saw many intracytoplasmic and intranuclear acidophilic inclusion bodies characteristic of CDV. Their finding of histopathological lesions and inclusion bodies similar to those of CDV infection in other species, and demonstration of morbillivirus antigen in diseased lung and isolation of a morbillivirus from an affected seal provide very strong evidence for an aetiological role of CDV or a closely related morbillivirus as a primary cause of seal mortality.
KEY WORDS: canine distemper virus, Europe, inclusion bodies, *Phoca vitulina*, viral diseases.

Kerkhoff M, and de Boer J. 1982. Identification Of Chlordane Compounds In Harbour Seals From The Coastal Waters Of The Netherlands . Chemosphere 11(9):841-5.
ABSTRACT: In a study of two unknown compounds in blubber of harbor seals (*Phoca vitulina*) of the Dutch North Sea coast combined capillary gas chromatographic mass

spectrometric data indicated the presence of trans-nonachlor and oxychlordane. These compounds have never been identified in environmental biota in The Netherlands before.
KEY WORDS: blubber, Dutch North Sea, harbour seals, oxychlordane, *Phoca vitulina*, trans-nonachlor.

Kerkhoff M, De Boer J, and Geerdes J. 1981. Heptachlor Epoxide in Marine Mammals. Sci. Total Environ. 19(1):41-50.
ABSTRACT: The presence of heptachlor epoxide in harbour seals (*Phoca vitulina*) and white-beaked dolphins (*Lagenorhynchus albirostris*) has been confirmed by chemical derivatization and mass spectrometric analyses. An unknown compound at a retention time close to that of heptachlor epoxide interfered n the determination by electron capture detector-gas chromatography. On a WCOT CP-Sil 7 column programmed from 85 to 175° two poorly separated peaks could be detected. Heptachlor epoxide contents up to 1.7 mg/kg (on a fat basis) were obtained, which were about 200 times lower than the PCB levels. The same ratio was also observed in fish from the same area.
KEY WORDS: heptachlor, mammals, pesticides/ pollution.

King DP, Robinson I, Hay AWM, and Evans SW. 1993. Identification and Partial Characterization of Common Seal (*Phoca vitulina*) and Grey Seal (*Halichoerus grypus*) Interleukin-6-Like Activities. Dev. Comp. Immunol. 17:449-58.
ABSTRACT: Interleukin-6 (IL-6) is a pleotropic molecule with many important immune modulatory actions. We have investigated the production of biological activity of this cytokine in two species of European seal. IL-6-like activity was detected in supernatants from cultured peripheral blood leucocytes. This IL-6-like activity had an apparent molecular weight of 17-26 kDa, similar to that of human IL-6. IL-6-like activity was also detected in plasma taken from seals with symptoms of systemic infection, but not from apparently healthy seals. Inhibition of this plasma and leucocyte derived activity was accomplished with both rabbit and goat antisera raised against recombinant human IL-6. Further investigation using polymyxin-B showed that this activity was not due to residue LPS present in the supernatants of infected plasmas.
KEY WORDS: common seal, grey seal, interleukin-6, polymyxin-B.

King JE. 1983. Seals of the World. British Museum (Natural History) and Cornell Univ. Press, New York.1983. 240 pp.
ABSTRACT: This book reports the origin and biology of pinnipeds and describes the characteristics of the 2 superfamilies, Phocoidea and Otarioidea. Details of the family characters are given as well as the subfamily and tribe characters. Several chapters included refer to parasites occurring in seals, such as, tapeworms, flukes and roundworms. The pathological conditions of seals are discussed, including information on captive animals as well as the wild populations. References about tumours, wounds from one another or from other marine animals, and crater wounds are included. Pollutants also have an impact on seal populations, such as oil spills, contaminants and pesticides. These topics are briefly discussed along with physiological effects.
KEY WORDS: Otarioidea, parasites, Phocoidea, pinnipeds, pollutants.

Kopec AD, and Harvey JT. 1995. Toxic Pollutants, Health Indices, and Population Dynamics of Harbor Seals in San Francisco Bay, 1989-1992. Moss Marine Laboratories Technical

Publication 96-4. 89 pp.
ABSTRACT: Harbor seals, *Phoca vitulina*, use bays for foraging, resting, and reproduction, and because certain toxic pollutants bioaccumulate, this species is an excellent indicator of the health of estuarine systems. Counts of harbor seals on haul-out sites within San Francisco Bay were conducted from 1989 to 1992. Objectives were to determine the population dynamics and movements of harbor seals within and near San Francisco Bay, to investigate the concentration of pollutants within individuals of the population and to assess the health of the population and potential sources of distress.
KEY WORDS: environmental contaminants, harbor seals, haul-out sites, health indices, organochlorines, *Phoca vitulina*, population dynamics, San Francisco Bay, toxicity, trace metals.

Krahn MM, Becker PR , Tilbury KL , and Stein J.E. 1997. Organochlorine Contaminants in Blubber of Four Seal Species: Integrating Biomonitoring and Specimen Banking. Chemosphere 34(9/10):2109-21.
ABSTRACT: Blubber samples from four Alaska seal species (bearded seal, *Erignathus barbatus*; harbor seal, *Phoca vitulina*; northern fur seal, *Callorhinus ursinus*; ringed seal, *P. hispida*) were collected for inclusion in the US National Biomonitoring Specimen Bank, as well as for immediate analysis as part of the contaminant monitoring component of the US National Marine Fisheries Service's Marine Mammal Health and Stranding Response Program. The blubber samples were analyzed for organochlorine (OC) contaminants (e.g., PCB congeners, pesticides, DDTs). Results for bearded and ringed seals from the Alaska Arctic revealed low blubber concentrations of OC contaminants. Harbor seals from Prince William Sound, Gulf of Alaska had somewhat higher blubber concentrations of OC contaminants. In contrast, northern fur seals sampled from the Pribilof Islands had blubber concentrations of certain OC contaminants that were about an order of magnitude higher than those found in the other seal species. Differences in contaminant concentrations among the Alaska seals may be explained by differences in feeding habits and migratory patterns; age or gender did not appear to account for the differences observed. The highest concentrations of OCs were found in harbor seals stranded along the northwestern US mainland, which is consistent with higher concentrations of anthropogenic contaminants being found in urban coastal areas than in more remote Arctic environments. The integration of real-time contaminant monitoring with specimen banking provides important baseline data that can be used to plan and manage banking activities. This includes identifying appropriate specimens that are useful in assessing temporal trends and increasing the utility of the banked samples in assessing chemical contaminant accumulation relationships to biological effects.
KEY WORDS: Alaska, Arctic, bearded seals, Bering Sea, *Callorhinus ursinus,* DDT, *Erignathus barbatus,* Gulf of Alaska, harbor seals, northern fur seals, organochlorine contaminants, PCB, pesticides, *Phoca hispida*, *Phoca vitulina*, Pribilof Islands, Prince William Sound, ringed seals, specimen banking.

Kuiken T, Bennett PM, Allchin CR, Kirkwood JK, Baker JR, Lockyer CH, Walton MJ, and Sheldrick MC. 1994. PCBs, Cause of Death and Body Condition in Harbour Porpoises (*Phocoena phocoena*) from British Waters. Aquatic Toxicology 28:13-28.
ABSTRACT: Polychlorinated biphenyls (PCBs) suppress immunity, and may have exacerbated the effects of recent morbillivirus epizootics in harbour seals (*Phoca*

vitulina) and striped dolphins (*Stenella coeruleoalba*). To test the hypothesis that PCBs cause immunosuppression in harbour porpoises (*Phocoena phocoena*) and increase their risk of dying from an infectious or parasitic disease, we compared the levels of PCBs in the blubber between animals that died from these causes and those that died from physical trauma. We established the cause of death and measured the blubber levels of HCB, alpha-HCH, gamma-HCH, *p,p'*-DDE, *p,p'*-DDT, *p,p'*-TDE, dieldrin and 25 individual chlorobiphenyls in 94 harbour porpoise carcasses, found in Great Britain between 1989 and 1992. After correcting for the effect of region, there were no significant differences between disease groups in the levels of any of these contaminants. Thus, our results provide no support for the hypothesis. However, there were significant differences in body condition between animals that died from an infectious or parasitic disease, physical trauma, or starvation. Therefore, we suggest that a quantitative measure of body condition such as relative body girth, could be used as a diagnostic aid in the pathological examination of harbour porpoises.
KEY WORDS: body condition, harbour porpoise, immunosuppression, pathology, *Phocoena phocoena*, polychlorinated biphenyl.

Lake CA, Lake JL, Haebler R, McKinney R, Boothman WS, and Sadove SS. 1995. Contaminant Levels in Harbor Seals from the Northeastern United States. Arch. Environ.Contam.Toxicol. 29:128-34.

ABSTRACT: The concentrations of polychlorinated biphenyls (PCBs), organochlorine pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzofurans (PCDF), polychlorinated dibenzo-*p*-dioxins (PCDD), and mercury (Hg) were determined in blubber and liver tissues of harbor seals (*Phoca vitulina*) collected along the northeastern coast of the U.S. Average PCB concentrations in seal blubber (sum of congeners) were 12.0 µg/g (wet weight) with a range of 7.30 to 24.3 µg/g in 1980 and 6.66 µg/g (wet weight) with a range of 2.61 to 11.3 µg/g in 1990-1992. Comparisons between blubber data from this study and previous work indicated that the concentration of PCBs along the northeast coast of the U.S. may have decreased over the past twenty years. The average p,p' -DDE concentrations in seal blubber were 10.9 µg/g (wet weight) in 1980 with a range of 6.95 to 21.9 µg/g and 4.12 µg/g (wet weight) with a range of 1.83 to 7.84 µg/g in 1990-1992. Only trace amounts of PCDFs and PCDDs were found in a few blubber samples; levels in most tissues were below detection (3-5 pg/g)(wet weight). Trace amounts (<30 ng/g) of phenanthracene, anthracene, and alkylated MW-178 compounds were found in some seal samples, all other PAH compounds were below the detection level (5-15 ng/g). Toxic equivalents (TEQ) of selected coplanar and mono-*ortho* PCB congeners and relative toxic equivalents (RTE) (pg total TEQ/µg total PCB) were calculated, using recently proposed dioxin toxic equivalent factors (Ahlborg *et al.* 1994). The TEQs ranged from 41 to 315, and the RTEs ranged from 2.25 to 16.3 The RTEs for seal blubber indicated that the present values were in the midrange of those reported in the literature. Toxic equivalents calculated on the basis of the concentrations of the coplanar PCBs, PCDDs, and PCDFs indicated that coplanar PCBs, rather than PCDDs and PCDFs, may pose a more important toxic threat to harbour seals. Mercury levels in liver tissue averaged 70.0 µg/g (wet weight) and 44.1 µg/g (wet weight) in the 1991 and 1980 samples, respectively, and are similar to those found in relatively polluted waters of the British Isles.
KEY WORDS: harbor seals, mercury, Northeastern U.S., organochlorine pesticides,

Phoca vitulina, polychlorinated biphenyls.

Law RJ. 1994. Collaborative UK Marine Mammal Project: Summary of Data Produced 1988-1992. Fisheries Research Technical Report No. 97. Directorate of Fisheries Research, Lowestoft, 1994.
ABSTRACT: This project, coordinated by the Department of the Environment, began in 1990 and combines information on strandings with the provision of samples for pathological and chemical analyses. The aim of this report is to make the contaminant dataset and biological information available to other researchers. Included in the report are details of methodology used and procedures of the associated analytical quality control (AQC) for the determination of trace metals and organochlorines. The data includes metals and/or organochlorines in tissues from 275 marine mammals; 205 cetaceans of 9 species and 70 seals. Altogether, detailed postmortem examinations were performed on over 300 marine mammals carcasses along the coast of the United Kingdom. This examination can determine the presence of diseases and if possible, establishes the cause of death of the animal. Tissues samples are also collected for a number of laboratory analyses. Written guidelines are provided in the report so that the methodology can be standardized and to ensure that all steps of the examination are complete. It was possible to attribute the cause of a mass mortality of common dolphins around the south-west coast of England from a number of institutes working together. The morbillivirus infection was also first diagnosed in harbor porpoises in Great Britain as well as several other marine mammal species because of these examinations.
KEY WORDS: Associated Analytical Quality Control, heavy metals, marine mammals, morbillivirus, organochlorines, postmortem examination.

Law RJ, Allchin CR, and Harwood JH. 1989. Concentrations of Organochlorine Compounds in the Blubber of Seals from Eastern and North-eastern England, 1988. Mar. Poll. Bull. 20(3):110-5.
ABSTRACT: Samples of blubber from common seals (*Phoca vitulina*) found dead in eastern England and grey seals (*Halichoerus grypus*) found dead on the Farne Islands have been analyzed for a range of organochlorine pesticides, individual chlorobiphenyl congeners and total polychlorinated biphenyls (PCB). No significant differences were seen between results for the two seal species. HCB and HCH concentrations were low, and total DDT and PCB concentrations (ranging from 0.00-8.0 and 5.7-33 g g-1 wet wt respectively) were at the lower end of the reported range for seals from the North and Baltic Seas. PCB profiles were dominated by congeners 138 and 153, and amongst the DDT group of compounds the pattern of abundance was DDE>DDT>>TDE.
KEY WORDS: chlorobiphenyl congeners, common seals, Farne Islands, grey seals, *Halichoerus grypus*, low fertility, organochlorine pesticides, *Phoca vitulina*.

Law RJ, Fileman CF, Hopkins AD, Baker JR, Harwood J, Jackson DB, Kennedy S, Martin AR, and Morris RJ. 1991. Concentrations of Trace Metals in the Livers of Marine Mammals (Seals, Porpoises and Dolphins) from Waters Around the British Isles. Mar. Poll. Bull. 22(4):183-91.
KEY WORDS: heavy metals, mammals, pesticides/ pollution.

Lewis JP. 1995. Investigations of Harbor Seals in Alaska. NOAA Award NA37FX0142, Final

Report, Alaska Department of Fish and Game :115 pp.
ABSTRACT: In response to a continuing and severe decline in harbor seal stocks in the Gulf of Alaska, the National Marine Fisheries Service provided annual grants of $450,000 to the Alaska Department of Fish and Game to investigate the causes of the decline and to monitor current trends in the population. Results obtained in the area of decline were compared to results obtained from seals in the southeastern Alaska where seals have remained abundant. Aerial surveys of trend sited in the Kodiak and Ketchikan areas suggest seal numbers are increasing in both areas. Seals along the Ketchikan route increased between 1 and 8 % annually since 1983 and in the Kodiak area between 31 and 44% annually. The actual magnitude of the increase in the Kodiak area is almost certainly less than 31%. Composition counts of the seals at Tugidak Island suggest a decrease in yearling presence from approximately 15% in the 1970s to 3.5% in the 1994. Indices of the health status of seals such as growth blood chemistries, and body condition have detected no differences between seals in the Gulf of Alaska and in southeastern Alaska. Overall disease prevalence indicate exposure rates of 71% to phocine herpes virus, 5% to canine distemper virus, 40% to phocine distemper virus, 48% to *Chlamydia sp.*, and 0% to caliciviruses. Bacterial isolation identified mostly normal bacteria, with the exception of *Moraxella sp.* found in three seals in southeastern Alaska. No clinical symptoms of exposure to any of these pathogens were observed. Chromatographic analyses of blubber samples identified low levels of organochlorine pesticides in all seals sampled. No PCBs were detected using this method. Satellite-linked time depth recorders were attached to 376 seals to monitor their locations and diving behavior. Seals generally remained in the area of their capture with most traveling less than 50 kilometers. Some individuals were relocated up to 160 kilometers from their capture site, but all eventually returned to their resident haulout. Support was provided to other research projects studying genetic stock identity, food habits from fatty acids analyses, food habits from stable isotope analyses, and alternative methods of viral screening.
KEY WORDS: food habits, genetic stock identity, Gulf of Alaska, harbor seal, health status, organochlorine pesticides, *Phoca vitulina*, population density.

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KEY WORDS: California sea lion, DDT, dolphins, harbor seal, mercury, organs and systems, residual effects, sea otter, seal.

Lowry LF, and Frost KJ. 1993. Harbor Seals: Were They Injured and Will They Recover. Alaska Wildlife January/February:20-1.

Marine Mammals Committee. 1997. Report of the Working Group On Seals and Small Cetaceans in European Seas, Stockholm, Sweden. ICES CM 1997/N:1; Ref.: Asses, Env. 25 pp.
ABSTRACT: The report from the Working Group on Seals and Small Cetaceans in European Seas (WGSEAL) discusses population status of several marine mammals, including the harbour porpoise in the Baltic Sea as well as Baltic seals. Population trends, distribution and abundance are also included along with by-catch information on all species in the area. Effects of acoustic disturbance and contaminant concentrations on marine mammals are also discussed. Future activities and general recommendations are

given including monitoring programmes and fundamental research on specific areas of concern. The meetings agenda, papers, list of participants and tables are provided in the report.
KEY WORDS: Baltic Sea, by-catch, contaminant concentrations, harbour porpoise, marine mammals, population status, seals.

Mees J, and Reijnders PJH. 1994. The Harbour Seal, *Phoca vitulina*, in the Oosterschelde: Decline and Possibilities for Recovery. Hydrobiologica 282/283:547-55.
ABSTRACT: Within a time span of a few decades, the harbour seal almost completely disappeared from the estuaries in the south-west of the Netherlands. In 1960 a population of around 350 animals still lived in the Oosterschelde and Westerschelde area. About a quarter of this population lived in the Oosterschelde. At present less than 17 animals can be regularly observed in the whole area. Human influences are responsible for the rapid decline of the population. Initially a high hunting pressure and later environmental pollution are the main causes. Loss of habitat and disturbance at the resting places are additional important factors. The Oosterschelde still is a suitable habitat for seals. A short term natural development of a viable population in the area is not to be expected. Only with human help through active management, i.e. reintroduction of rehabilitated seals (preferably originating from that area) and strict conservation of the extant Oosterschelde seal population, accompanied by environmental sanitation of the neighboring waters, can the current southern Dutch harbour seal population increase.
KEY WORDS: aquatic animals, coastal engineering, ecological effects, ecosystem disturbance, estuarine environment, habitats, marine mammals, Netherlands, Oosterschelde, *Phoca vitulina*, population dynamics, population number, seals.

Miles AK, Calkins DG, and Coon NC. 1992. Toxic Elements and Organochlorines in Harbor Seals (*Phoca vitulina* Richardsi), Kodiak, Alaska, USA. Bull. Environ. Contam. Toxicol. 48:727-32.
ABSTRACT: Marine and estuarine habitats near urban or industrialized regions are vulnerable to contaminated runoff. Harbor seals (*Phoca vitulina richardsi*), which occur throughout much of the northern hemisphere, are useful mammalian biomonitors because they feed, reproduce, and rest near or on shore and are high-level trophic consumers. They have often been monitored for contaminants in Europe (Wagemann and Muir 1984). To date, no studies have been reported on contaminants in harbor seals from industrialized areas of Alaska. In the vicinity of Anchorage, Alaskas largest urban and industrial city, harbor seals are sedentary and limited to coastal waters some movements have been documented but there is no evidence of extensive migrations. Although some harbor seals in the Kodiak Archipelago move up to 100 km along the shore, strong fidelity to specific haulout sites is more common (Pitcher and Calkins 1979). These seals eat mainly non-migratory fishes and octopi. Harbor seal numbers have declined substantially from unknown causes in the southern part of the Kodiak Archipelago. The Alaska Department of Fish and Game (ADF&G) suggested that the decline is a trend for the entire Kodiak region and other Alaskan waters. Contaminants have been suggested as a possible reason for the precipitous decline of Steller sea lions (*Eumetopias jubatus*) in the region (Braham et al. 1980), and were suspected in the decline of harbor seals. In this study, harbor seals were sampled from throughout the Kodiak Archipelago to determine concentrations of certain metals, metalloids, polychlorinated biphenyls (PCBs), and

organochlorine pesticides, and to determine if these concentrations varied by sex or accumulated with age. All seals were collected within 75 km of Cook Inlet, an estuary next to Anchorage. The targeted elements or compounds were known to be toxic to a wide spectrum of organisms.

KEY WORDS: Alaska, harbor seals, heavy metals, Kodiak Island, organochlorines, *Phoca vitulina*, toxic elements.

Mitchell SH, and Kennedy S. 1992. Tissue Concentrations of Organochlorine Compounds in Common Seals from the Coast of Northern Ireland. Sci. Total Environ. 115(1/2):163-77.

ABSTRACT: An epizootic of morbillivirus infection killed several hundred common seals (*Phoca vitulina*) along the coast of Northern Ireland in 1988. Many dead and moribund seals were submitted to the Department of Agriculture for Northern Ireland, Veterinary Research Laboratories for necropsy. Samples of blubber, liver and kidney were collected from these animals (n = 55) for analysis for a wide range of organochlorine pesticides and also total polychlorinated biphenyls (PCBs). The organochlorines found in highest concentrations in blubber were PCBs which were detected in all samples (mean, 26 $\mu g\ g^{-1}$ wet wt). Sum DDT (mean, 2.63 $\mu g\ g^{-1}$ wet wt) and chlordane (mean, 0.22 $\mu g\ g^{-1}$ wet wt) were also present in all samples. Heptachlor including heptachlor epoxide (mean, 0.13 $\mu g\ g^{-1}$ wet wt) was present in over 93% of samples. Seventy-four percent of samples contained alpha-HCE (mean, 0.035 $\mu g\ g^{-1}$ wet wt), 50% contained beta-HCH (mean, 0.026 $\mu g\ g^{-1}$ wet wt) while gamma-HCH (mean, 0.012 $\mu g\ g^{-1}$ wet wt) was detected in 46% of samples. The organochlorine concentrations found in this study are at the lower end of the range previously reported for European common seals.

KEY WORDS: organochlorine, *Phoca vitulina*, polychlorinated biphenyls, seal.

Mortensen P, Bergman A, Bignert A, Hansen H, Härkönen T, and Olsson M. 1992. Prevalence of Skull Lesions in Harbor Seals (*Phoca vitulina*) in Swedish and Danish Museum Collections: 1835-1988. Ambio 21(8):520-4.

ABSTRACT: Earlier studies of skulls and mandibles in Baltic grey seals *Halichoerus grypus* indicate that bone lesions are most probably part of a disease complex. The different organ changes show similarities to those present in hyperadrenocorticism which is thought to be caused by exposure to environmental pollutants. The lesion in grey seals mainly resemble those of parodontitis, with a more or less pronounced loss of bone tissue in the jaw bones. The present study on harbor seals *Phoca vitulina* along the Swedish west coast, and in the Danish and Swedish waters of the southern Baltic, are based on museum collections and shows that the prevalence of pathological changes in skulls of this species has increased since the 19th century. However, these changes do not appear to be of the same magnitude as those found in grey seals from the Baltic. A lesion not earlier described in seals was found in the material of harbor seals. This lesion is characterized by a deposition of bone tissue (exostosis of the alveolar bone) predominantly occurring in the lateral part of the mandible, in particular in the area of the premolars.

KEY WORDS: Baltic, exostosis of the alveolar bone, harbor seals, *Phoca vitulina*, skull lesions, Swedish west coast.

Mossner S, and Ballschmiter K. 1997. Marine Mammals as Global Pollution Indicators for

Organochlorines. Chemosphere 34(5-7):1285-96.
ABSTRACT: Blubber tissues of the following marine mammals differing in their geographic distribution (North Atlantic, North Pacific, Bering Sea/Arctic Ocean), trophic level, and feeding habits were analyzed for their organochlorine contents: two seal species (harbor seals *Phoca vitulina*, northern fur seals *Callorhinus ursinus*), three toothed whale species (beluga whales *Delphinapterus leucas*, one common dolphin *Delphinus delphis*, one pilot whale *Globicephala melaena*), and one baleen whale species (a bowhead whale *Balaena mysticetus*). As xenobiotics were quantified the seven indicator congeners of the polychlorinated biphenyls (PCB 28, 52, 101, 118, 138, 153, and 180), three isomers of the hexachlorocyclohexanes (alpha , beta and gamma HCH) as well as six components of the DDT group (4,4' DDT, 4,4' DDD, 4,4' DDE, 2,4' DDT, 2,4' DDD, and 2,4' DDE). When comparing the xenobiotic levels of these marine mammals, it showed that the animals from the western North Atlantic were contaminated about 15 times more with organochlorines than the animals from the eastern North Pacific and the Bering Sea/Arctic Ocean. The total organochlorine burden, the 4,4' DDE percentage as well as the metabolic PCB patterns correlate with the trophic levels of the marine mammals studied. The quantitative analyses were done by high resolution capillary gas chromatography with electron capture detection (HRGC/ECD) whereas the analyses of the metabolic PCB patterns were done by high resolution capillary gas chromatography and mass selective detection (HRGC/MSD).
KEY WORDS: HRGC/ECD, HRGC/MSD, marine mammals, North Atlantic, North Pacific, organochlorine levels, xenobiotic patterns and metabolism.

Murk A, Morse D, Boon J, and Brouwer A. 1994. In Vitro Metabolism of 3,3',4,4'-Tetrachlorobiphenyl in Relation To Ethoxyresorufin-O-Demethylase Activity in Liver Microsomes of Some Wildlife Species and Rat. Eur. J. Pharmacol. 270(2-3):253-61.
KEY WORDS: birds, mammals, pesticides/ pollution, polychlorinated biphenyls.

Nakano M, Shukunobe T, Fukushima M, Kobayashi S, and Negishi T. 1992. Heavy Metals in Kuril Seal *Phoca vitulina stejnegeri* from the East Coast of Hokkaido. Res. Bull. Obihiro Univ. Ser. I. 17:437-42.

Northrup MA. 1981. Evidence for the Detoxification of Methylmercury by Harbor Seals, *Phoca vitulina*. Abstract. Thesis, M.A., Humboldt State Univ. 1 p.

Olsson M, Andersson O, Bergman A., Blomkvist G, Frank A, and Rappe C. 1992. Contaminants and Diseases in Seals from Swedish Waters. Ambio 21(8):561-2.
ABSTRACT: A compilation of analytical results from the project Seals and Seal Protection based on data on metal and organohalogen compound concentrations in tissue samples from harbor (*Phoca vitulina*), grey (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) collected in Swedish waters are evaluated. With the exception of the dioxins (PCDDs, PCDFs) and polychlorinated camphenes (PCC) the concentrations of organohalogens covariate. The concentrations of polybrominated diphenyl ethers (PBDE), PCC and chlordane compounds (CHLs) are all much lower than the concentrations of PCB and sDDT. The highest concentrations of organohalogen compounds were found in Baltic seals. The presence of diseases in relation to toxic contaminants is discussed.

KEY WORDS: contaminants, diseases, marine mammals, seals, summary.

Olsson M, Bignert A, Bergqvist P-A, Bergek S, Rappe C, de Wit C, and Jansson B. 1989. Polychlorinated Dibenzo-p-Dioxins (PCDD) and Dibenzo-Furans (PCDF) In Seal Blubber. Chemosphere 19(1-6):551-6.
ABSTRACT: Blubber samples from seals collected in waters around the Scandinavian peninsula and from the Antarctic have been analyzed for the presence of PCDD and PCDF. The results do not indicate any substantial species or spatial differences in levels for animals representing the northern hemisphere, but in marine mammals highly persistent organochlorines normally increase with increasing age. In our study no clear age or sex dependence in levels of PCDD and PCDF was found. The levels of PCDD and PCDF in seal blubber are of the same magnitude as the levels found in humans.
KEY WORDS: Antarctic, Arctic, Baltic, PCDD, PCDF, seals.

Olsson M, Karlsson B, and Ahnland E. 1994. Diseases and Environmental Contaminants in Seals from the Baltic and the Swedish West Coast. Sci. Total Environ. 154(2-3):217-27.
ABSTRACT: Investigations have shown that Baltic grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) suffer from a disease complex described as a primary lesion in the adrenals causing secondary reactions in various other organs. Studies on historical Baltic grey seal skull bone material show that the prevalence of affected animals started to increase after World War II. The disease complex explains the dramatic decrease in the Baltic grey and ringed seal population during the 1960s and 1970s and is believed to be caused by environmental pollutants. In 1988, about 60% of the harbor seal population (*Phoca vitulina*) along the Swedish west coast and in the southwestern part of the Baltic died in the PDV epizootic (Phocine Distemper Virus). Whether the course of the epizootic was altered by environmental pollutants is still an open question. Studies on historical harbor seal skull bone material from both the Baltic and the Swedish west coast show that the incidence of skull bone lesions has also increased in these populations since World War II, indicating the presence of unnatural stress factors. After the epizootic, the harbor seal populations both in the Baltic and along the Swedish west coast have increased in number. Chemical analysis of tissues has been performed on the three seal species collected in various areas of the Baltic and the Swedish west coast. The concentrations of 17 metals and non-metal elements, sDDT and PCBs, DDE and PCB methylsulfones, toxaphene, chlordanes, polybrominated diphenyl ethers, TCDDs and PCDFs have been determined in selected groups of seals in order to determine spatial, species and age variations in concentrations. Furthermore, healthy animals have been compared to diseased animals. Spatial variation was found mostly within the group of organohalogenated compounds, a group of contaminants where a strong covariation between the various compounds was also found. On the basis of the analytical results as well as the pathological findings on Baltic seals, the group of DDE and PCB methylsulfones is tentatively suggested to be more important in explaining the disease complex than coplanar structures including dioxins.
KEY WORDS: diseases, environmental contaminants, metals, organohalogens, seals.

Olsson M, Karlsson B, and Ahnland E. 1992. Seals and Seal Protection: A Presentation of a Swedish Research Project. Ambio 21:494-6.
ABSTRACT: A 4-year research project, Seals and Seal Protection, is presented. The

background and the organization of the multidisciplinary project is summarized. The study aim was to investigate the possible effects of contaminants on seal populations in Swedish waters. Contaminants in Swedish waters are similar to those found in waters all over the world and the contaminant problems are thus of international concern. The project included population studies on three different species, namely harbor seal (*Phoca vitulina*), gray seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*). Studies on seal-skull collections have been carried out in order to study changes over time in the prevalence of skull-bone lesions. Tissue concentrations of 17 metals and non-metal elements and various organohalogen compounds have been determined to disclose differences in contaminant concentrations related to species, geographical areas, age, sex, and health status. Experimental studies have been carried investigating biological effects in mink (*Mustela vison*) exposed to commercial PCB and PCB fractions. Fractions have been selected on the basis of number of chlorine atoms in ortho-position of the biphenyl bond and contaminants in the mixture such as polychlorinated dibenzofurans and napthalenes. Comparative studies on various species studying the toxicity of methylsulfonyl metabolites of DDT have also been carried out.
KEY WORDS: contaminants, marine mammals, metals, non-metal elements, seal populations, skull-bone lesions, Swedish waters.

Osterhaus ADME, Groen J, DeVries P, YttdeHaage PGCM, Klingeborn B, and Zarnke R. 1988. Canine Distemper Virus in Seals. Nature 335:403-4.
ABSTRACT: This report discusses the primary cause of an outbreak among harbour seals (*Phoca vitulina*) in the seas of north-west Europe. Serological studies were performed on specified pathogen-free (SPF) beagle dogs which indicated that canine distemper virus (CDV), or a related virus, had been present in the suspension of pooled seal cells and was also directly isolated from tissues of a harbour seal that died during the outbreak. Other studies were performed on marine mammals prior to the outbreak and concluded no CDV antibodies were detected. Further studies among pinniped species need to be implemented to help detect the origin of the outbreak of CDV infection in seals.
KEY WORDS: canine distemper virus, harbour seals, marine mammals, *Phoca vitulina*, specified pathogen-free beagle dogs.

Osterhaus A, De Swart RL, Vos HW, Ross PR, Kenter MJH, and Barett T. 1995. Morbillivirus Infections of Aquatic Mammals: Newly Identified Members of the Genus. Vet. Microbiology 44(2-4):219-27.
ABSTRACT: Several disease outbreaks, which have caused the deaths of many thousands of seals and dolphins during the last decade, have now been attributed to infections with newly identified Morbilliviruses. Outbreaks in the late eighties amongst harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in northwestern Europe and amongst baikal seals (*Phoca sibirica*) in Siberia were caused by the newly discovered phocine distemper virus and by a strain of canine distemper virus, respectively. Although closely related these two viruses were not identical. They were more distantly related to the viruses which caused mass mortality amongst striped dolphins (*Stenella coeruleoalba*) in the Mediterranean sea in the early nineties. This dolphin morbillivirus was shown to be closely related to a virus that was found in harbour porpoises (*Phocoena phocoena*) which had stranded at the coasts of northwestern Europe

in the late knowledge of the genetic and antigenic relationships of these apparently new members of the genus Morbillivirus with the established members of the genus is presented. In addition, the origin and epizootiological aspects of these newly discovered viruses are discussed. Finally experimental evidence that environmental pollution may have contributed to the severity and the extent of these infections in recent years is presented.

KEY WORDS: antibodies, aquatic, dolphins, Europe, mammal, morbillivirus, nucleotide sequence, *Phoca vitulina*, pollution, porpoises, protein, vaccination.

Page DS, Boehm PD, Douglas GS, Bence AS, Burns WA, and Mankiewicz PJ. 1997. An Estimate of the Annual Input of Natural Petroleum Hydrocarbons to Seafloor Sediments in Prince William Sound, Alaska. Mar. Poll. Bull. 34(9):744-9.

ABSTRACT: The widespread occurrence of oil seepage along the coast of the eastern Gulf of Alaska makes this a potentially important source of background petrogenic hydrocarbons on suspended sediment matter in Alaskan coastal waters. This study provided sufficient data over a geographic area and over time to estimate the annual flux of natural petroleum hydrocarbons from oil seeps to PWS deep subtidal sediments. The overall regional annual input of seep-derived PAHs is distributed over tens of thousands of square kilometers of seafloor in PWS and in the Gulf of Alaska coast, extending at least 500 km from Icy Bay in the east to Kenai in the west.

KEY WORDS: annual input, natural seepage, PAHs, petroleum hydrocarbons, Prince William Sound.

Ponce RA, Egeland GM, Becker PR, and Middaugh JP. 1996. Twenty Years of Trace Metal Analyses of Marine Mammals: Evaluation and Summation of Data From Alaska and Other Arctic Regions. State of Alaska Epidemiology: Bulletin-Recommendation and Reports :18 pp.

ABSTRACT: Trace metals are ubiquitous in the environment, originating from natural and anthropogenic sources. Existing data on trace metals in the Arctic marine food chain were compiled to help assess the magnitude of exposures to wildlife and to humans consuming subsistence species. This paper presents a summary of studies on trace metals in tissues of Alaskan and other Arctic and subarctic marine mammals from the 1970s to the present along with summary statistics on tissue trace metal concentrations. With few exceptions, tissue trace metal concentrations are comparable within species. The data provide a range of reference trace metal levels that may be used to compare future monitoring results, and to estimate human exposure to trace metals through the consumption of marine mammals. Despite considerable efforts to monitor marine mammal species, significant gaps remain. Few published reports are available for any given species, sample sizes are small, and age estimates and sex information are rarely reported. Because age is a significant predictor of trace metal concentrations in organ tissues in marine mammals, age data are needed to help compare study populations over time and by geographic region. Tissue concentrations of methylmercury, particularly for muscle tissue, and measurement of the ratio of methylmercury to total mercury in marine mammal organ tissues are lacking. Additional research to obtain these data, essential to developing an assessment of potential changing patterns in trace metal concentrations and in evaluating the safety of subsistence food consumption, should be undertaken as a high priority.

KEY WORDS: Arctic marine food chain, marine mammals, trace metals.

Reijnders PJ. 1988. Ecotoxicological Perspectives in Marine Mammalogy: Research Principles and Goals for a Conservation Policy. Marine Mammal Science 4(2):91-102.
ABSTRACT: In integrating ecotoxicology and marine mammalogy two principal themes are conceivable: (1) the impact of contaminants on marine mammals and (2) the feasibility of monitoring marine pollution with marine mammals. Monitoring should be an alert procedure, carried out with a sensitive sensor. Uncertainties in interpreting analyses and the low susceptibility of marine mammals to short-term changes in pollution, make them inappropriate for pollution monitoring at present. To answer the question whether pollutants affect marine mammals, the occurrence of contaminants and the response of the animals to those chemicals have to be assessed. In studying the occurrence of contaminants it is essential that atmospheric and riverine input, geochemical processes, and processes involved with the occurrence of natural compounds are considered. To investigate the mechanisms by which pollutants affect physiological processes the kinetics of contaminants in the animals and their clinical toxicity effects have to be studied. Comparative reference data on physical and chemical blood parameters facilitates checking for hematological disorders, electrolyte imbalance, serum biochemistry and hormonal changes. Following such a concept the retrospective study of pollution effects on marine mammals might be turned into a predictive approach.
KEY WORDS: conservation, ecotoxicology, marine mammalogy, monitoring, pollution impact.

Reijnders PJH. 1984. Man-induced Environmental Factors in Relation to Fertility Changes in Pinnipeds. Environmental Conservation 11(1):61-5.
ABSTRACT: The possible effects of human activities (such as the release of pollutants, exploitation, and disturbance) on the reproductive performance of pinniped populations (especially of certain seals) are discussed. While there are documented cases of reproductive rates increasing in exploited seal populations, the effects of disturbance on reproduction have only been suggested on the basis of rather incidental observations. In a number of cases the decline of a pinniped population has coincided with an elevation in the level of various contaminants. In some animals, reproductive failure has been associated with high levels of contaminants in their tissues; but even in these cases, no cause and effect relation between pollutants and altered physiological processes has been established. Clearly, far more research will be needed to elucidate these problems.
KEY WORDS: exploitation, physiological processes, pinnipeds, pollutants, reproduction.

Reijnders PJH. 1982. On the Ecology of the Harbor Seal *Phoca vitulina* in the Wadden Sea: Population Dynamics, Residue Levels, and Management. Vet. Q. 4:36-42.

Reijnders PJH. 1980. Organochlorine and Heavy Metal Residues in Harbour Seals from the Wadden Sea and Their Possible Effects on Reproduction. Netherland Journal of Sea Research 14(1):30-65.
ABSTRACT: As the harbour seal population in the Dutch Wadden Sea has decreased significantly and its pup production is low compared to the more stable population in Schleswig-Holstein, Germany, an attempt has been made to correlate this with an

assumed inverse trend of contaminants residue levels in seal tissues. Blubber, liver, brain and kidney were analyzed for PCB, o,p'-DDT, p,p'-(DDT + DDE + TDE), dieldrin, aldrin, endrin, endosulfan, alpha-HCH, beta-HCH, gamma-HCH, HCB, QCB (pentachlorobenzene), HEPO, total mercury and methylmercury, selenium and bromium. High levels of all contaminants except bromium occurred together in the seals. An equimolecular relationship is found for mercury and selenium but not for bromium. A clear cut correlation is also demonstrated for PCB and total DDT in blubber and kidney. The main metabolite present in the DDT family is DDE. Deposition of contaminants is generally lower in juvenile seals reaching a plateau in older ones. The highest ratios of methyl mercury to total mercury are found in juveniles. The residue levels already present in stillborn pups indicate transplacental transport of all organochlorines and metals analyzed. Differences in residue levels, between Schleswig-Holstein and Denmark on one hand and the Netherlands on the other revealed higher values for the latter, especially PCB levels which in Dutch adult seals are tenfold higher. Increase of PCB and total DDT residue levels with age is present in Dutch seals but absent in the Schleswig-Holstein and Danish specimens. It is concluded that the observed decrease in the reproductive success of the Dutch seal population correlates strongly with the high concentrations of PCB's in the tissues.
KEY WORDS: chemical pollutants, *Phoca vitulina,* pollution effects, polychlorinated biphenyls, reproduction (biology), Wadden Sea .

Reijnders PJH. 1986. Reproductive Failure in Common Seals Feeding on Fish from Polluted Coastal Waters. Nature 324(4):456-7.
ABSTRACT: The population of common seal *Phoca vitulina* in the westernmost part of the Wadden Sea, The Netherlands, has collapsed during the past few decades. Between 1950 and 1975 the population dropped from more than 3,000 to less than 500 animals. Comparative studies of common seal populations from different parts of the Wadden Sea reveal that pup production has declined sharply only in the western (Dutch) part. A comparative toxicological study on the levels of heavy metals and organochlorines in tissues of seals from the western and northern parts of the Wadden Sea shows that only the polychlorinated biphenyl (PCB) levels differ significantly. This is predominantly a result of PCB pollution from the river Rhine, which mainly affects the western (Dutch) part. PCBs are thought to be responsible for the low rate of reproduction in Dutch common seals on the basis of epidemiological and experimental data on the ability of PCBs to interfere with mammalian reproduction. Here I report that reproductive failure in common seals from the Dutch Wadden Sea is related to feeding in fish from that polluted area. This is the first demonstration of a causal relationship between naturally occurring levels of pollutants and a physiological response in marine mammals.
KEY WORDS: common seal, fish, heavy metals, organochlorines, *Phoca vitulina*, reproductive failure.

Reijnders PJH, and de Ruiter-Dijkman EM. 1995. Toxicological and Epidemiological Significance of Pollutants in Marine Mammals. In: Whales, Seals, Fish and Man: Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic, Tromso, Norway. 575-87.
ABSTRACT: There is accumulation evidence from epidemiological and experimental research that the resilience of marine mammals can be affected by contaminants. The

expected prolonged existence of persistent pollutants already present in oceans and seas warrants intensified research on the impact of pollution on marine mammals. The establishment of a monitoring scheme based on multiple response assessment, investigations on synergistic effects of contaminants and toxic significance of new contaminants of concern are important elements in this research. It should be integrated in an assessment of general habitat degradation of marine mammal species, in which marine pollution in an important contributing factor.
KEY WORDS: cetaceans, impact assessment, pinnipeds, pollutants, trends.

Ridgway SH, Geraci JR, and Medway W. 1975. Diseases of Pinnipeds. Conseil International Pour L'Exploration De La Mer. Rapports Et Proces-Verbaux Des Reunions 169:327-37.

Rimkus G, Rexillus L, Heidemann G, Vagts A, and Hedderich J. 1993. Results of an Interlaboratory Study on Organochlorine Compounds (PCB, DDT, DDE) in Seal Blubber *Phoca vitulina*. Chemosphere 26(6):1099-108.
ABSTRACT: In an interlaboratory study, initiated by the German Study Group on Seal Pathology, an extract of genuine (unspiked) seal blubber (*Phoca vitulina*) was analysed by 14 laboratories (15 participants) for six PCB congeners (Nos. 28, 52, 101, 138, 153, 180), 4,4'-DDT, and 4,4'-DDE. The choice of the analytical method (clean-up, GC) was left to the laboratories. From the data which were subjected to a statistical analysis, an interlaboratory comparison (R-values) was assessed. On the basis of the R-values (except PCB Nos. 28 and 52) which ranged from 1.29 to 1.89 for the analysed compounds, the overall comparability of the participating laboratories can be considered as satisfactory. From these results the conclusion has to be drawn that any comparison of residue data, produced by different laboratories, can only be justified under the assumption that the corresponding range of variation are observed and that data of the same distinct congeners are compared.
KEY WORDS: interlaboratory, marine mammals, organochlorine compounds, PCB congeners, *Phoca vitulina*.

Risebrough RW, Alcron D, Allen S, Anderlini VC, Booren L, DeLong RL, Fancher L, Jones RE, McGinnis SM, and Schmidt TT. 1977. Population Biology of Harbor Seals in San Francisco Bay, California. Report of the Bodega Bay Institute of Pollution Ecology to the Marine Mammals Commission, Wash., D.C.

Roberts TM, Heppleston PB, and Roberts RD. 1976. Distribution of Heavy Metals in Tissues of the Common Seal. Mar. Poll. Bull. 7(10):194-6.
ABSTRACT: The lead, cadmium and mercury content of soft tissues and bone were determined for the common seal (*Phoca vitulina*) collected from off the coast of East Anglia and the West of Scotland. Lead levels were low in all tissues, cadmium accumulated with age in the kidney of West Scotland seals and mercury accumulated to high levels in the liver of seals from both areas. Comparison of our results with those of other workers, suggests that the rate of mercury accumulation in the liver of seals increases in the order: Canadian Arctic and Atlantic coast < West Scotland < East Anglia < Netherlands coast. Accumulation of mercury in the kidney and spleen of older seals, lends tentative support to the hypothesis that a protective demethylation and retention process in the liver may begin to leak mercury to other tissues at the high concentrations

which have been recorded in the liver of older seals, and at the high dose rates which have been used in toxicological experiments.
KEY WORDS: bioaccumulation, common seal, heavy metals, *Phoca vitulina.*

Roos A, Blomkvist G, Jensen S, Olsson M, Bergman A, and Harkonen T. 1992. Sample Selection and Preparation Procedures for Analyses of Metals and Organohalogen Compounds in Swedish Seals. Ambio 21(8):525-8.
ABSTRACT: This paper is a background presentation of seal material that has been analyzed for a number of elements and organohalogen compounds and presented elsewhere in this issue of Ambio. Altogether 13 groups of seals representing three species were studied: harbor seals (*Phoca vitulina vitulina*), grey seals (*Halichoerus grypus*) and ringed seals (*Phoca hispida botnica*). The material was further divided into collection areas, age classes and health status. Biological parameters such as age, sex, weight, length, collection area, etc. are presented. Preparation procedures are described as well as the extraction of organohalogen compounds.
KEY WORDS: marine mammals, organohalogen compounds, preparation procedures.

Ross PS. Seals, Pollution and Disease: Environmental Contaminant-induced Immunosuppression. Thesis Universiteit Utrecht.1963. 176 pp.
ABSTRACT: In this thesis, the effects of environmental contaminants on immune function in harbour seals were studied. We initially established that PDV or a very similar virus had infected relatively uncontaminated harbour seals on Sable Island, Canada, without leading to any evident mass mortality. Since little information existed on immune function in the harbour seal, we undertook preliminary studies on Sable Island in order to apply and adapt existing immunological techniques to a carefully controlled group of free-ranging seals. We were able to demonstrate that existing methods can provide valuable information on the developing immune system of harbour seals. A broad approach was used to evaluated both functional aspects and maternal transfer of immunity in the newborn harbour seal pup. We subsequently initiated a captive feeding project in The Netherlands in which two groups of 11 harbour seals each were fed either herring from the relatively uncontaminated Atlantic Ocean or herring from the contaminated Baltic Sea. We routinely monitored immune function parameters in these animals by studying NK cell activity, specific T-lymphocyte function, *in vitro*, and delayed-type hypersensitivity (DTH) responses *in vivo*. Since obvious legal and ethical constraints limited us from carrying out challenge tests in seals, we carried out two parallel feeding experiments using laboratory rats. In the first of these, recently weaned rats were fed a freeze-dried diet of the same Atlantic and Baltic herring used in the seal study for a period of 130 days, at which point immune function and host resistance to rat cytomegalovirus (RCMV) were assessed. Rats were exposed to the same contaminant profile and a similar contaminant levels as the seals, with a correction for body weight. The availability of specific reagents enable the evaluation of thymus and spleen lymphocyte subpopulations. Since the developing immune system has been shown to be particularly sensitive to the toxic actions of PHAHs, and seals inhabiting contaminated areas are also exposed perinatally, we carried out a second experiment in which pregnant rats were given oil extracted from the two herring diets between day 6 of gestation and the weaning of the rat pups. During this time, the developing rat fetuses, and subsequently, the nursing pups, were exposed to the mixture of contaminants present in

the Baltic Sea herring and, to a lesser extent, the Atlantic Ocean herring. While attention has been paid to the presence of a complex mixture of environmental contaminants in the Baltic Sea herring, we have largely concentrated on the *Ah*-related PHAH components because of the unequivocal evidence of their immunotoxic potential and their presence in high concentrations in marine mammals.

KEY WORDS: contaminants, harbour seals, immune response, immunocompetence, immunotoxicology, marine mammals, PHAHs, pinnipeds.

Ross PS, De Swart RL, Reijnders PJH, Loveren HV, Vos JG, and Osterhaus ADME. 1995. Contaminant-related Suppression of Delayed-type Hypersensitivity and Antibody Responses in Harbor Seals Fed Herring From the Baltic Sea. National Institute of Environmental Health Services 103:162-7.

ABSTRACT: Recent mass mortalities among several marine mammal populations have led to speculations about increased susceptibility to viral infections as a result of contaminant-induced immunosuppression. In a 2.5 year study, we fed herring from either the relatively uncontaminated Atlantic Ocean or the contaminated Baltic Sea to two groups of captive harbor seals and monitored immune function in the seals. Seals fed the contaminated fish were less able to mount a specific immunological response to ovalbumin, as measured by in vivo delayed-type hypersensitivity (DTH) reactions and antibody responses. The skin reaction to this protein antigen was characterized by the appearance of mononuclear cells which peaked at 24 hr after intradermal administration, characteristic of DTH reactions in other animals studied. These DTH responses correlated well with in vitro tests of T-lymphocyte function, implicating this cell type in the reaction. Aryl-hydrocarbon (Ah) receptor-dependent toxic equivalent (TEQ) profiles in blubber biopsies taken from the seals implicated polychlorinated biphenyls rather than dioxins or furans in the observed immunosuppression. Marine mammal populations currently inhabiting polluted coastal environments in Europe and North America may therefore have an increased susceptibility to infections, and pollution may have played a role in recent virus-induced mass mortalities.

KEY WORDS: delayed-type hypersensitivity, harbor seals, immunosuppression, organochlorines.

Ross PS, De Swart RL, Timmerman HH, Reijnders PJH, Vos JG, Van Loveren H, and Osterhaus ADME. 1996. Suppression of Natural Killer Cell Activity in Harbour Seals (*Phoca vitulina*) Fed Baltic Sea Herring. Aquatic Toxicology 34:71-84.

ABSTRACT: Mass mortalities among marine mammal populations in recent years have raised questions about a possible contributory role of contaminants accumulated through the marine food chain. While viruses were shown to be the primary cause of the outbreaks, an immunotoxic action by organochlorine chemicals in affected animals could not be ruled out. We carried out a 2½-year immunotoxicological experiment in which two groups of 11 harbour seals each were fed herring from either the relatively contaminated Baltic Sea or the relatively uncontaminated Atlantic Ocean. Seals in the Baltic Sea group accumulated 3-4 times higher levels of *Ah*-receptor-mediated 2,3,7,8-TCDD toxic equivalents in blubber than did their Atlantic counterparts following 2 years on the respective diets. Blood was sampled a total of 17 times during the course of the experiment for immunological evaluation, during which time the natural cytotoxic activity of peripheral blood mononuclear cells isolated from seals fed Baltic Sea herring

declined to a level approximately 25% lower than that observed in seals fed Atlantic herring ($P<0.01$). Natural killer (NK) cell activity has not been previously described for a marine mammal species. We characterized the natural cytotoxic activity of harbour seal peripheral blood mononuclear cells (PBMC), and found this to be interleukin-2 (IL-2) responsive, sensitive to antibody anti-asialo GMI, and it was higher against a virus-infected target cell, like NK cells described for other mammals. As NK cells are leukocytes which play an important role in the first line of defense against viruses, the observed impairment of NK cell activity in the seals feeding on the Baltic Sea herring suggests that exposure to contaminants may have an adverse effect on the defense against virus infections in seals inhabiting polluted waters in Europe. This may therefore have affected the severity of the infections, the survival rates and the spread of infections during recent epizootics.
KEY WORDS: contaminants, immunosuppression, morbillivirus, Natural killer cells, organochlorines, *Phoca vitulina* (harbour seal), season.

Ross PS, De Swart RL, Visser IKG, Vedder LJ, Murk W, Bowen WD, and Osterhaus ADME. 1994. Relative Immunocompetence of the Newborn Harbour Seal, *Phoca vitulina*. Vet Immunol Immunopathol 42:331-48.

Ross P, de Swart R., Addison R, Van Loveren H, Vos J, and Osterhaus A. 1996. Contaminant-induced Immunotoxicity in Harbour Seals: Wildlife at Risk? Toxicology 112:157-69.
ABSTRACT: Persistent, lipophilic polyhalogenated aromatic hydrocarbons (PHAHs) accumulate readily in aquatic food chain are found in high concentrations in seals and other marine mammals. Recent mass mortalities among several marine mammal populations have been attributed to infection by morbilliviruses but a contributing role for immunotoxic PHAHs, including the polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) was not ruled out. We addressed this issue by carrying out a semi-field study in which captive harbour seals were fed herring from either the relatively uncontaminated Atlantic Ocean or the contaminated Baltic Sea for 2 years. We present here an overview of results obtained during this study. An impairment of natural killer (NK) cell activity, in vitro T-lymphocyte function, antigen-specific in vitro lymphocyte proliferative responses, an in vivo delayed-type hypersensitivity and antibody responses to ovalbumin was observed in the seals fed the contaminated Baltic herring. Additional feeding studies in PVG rats using the same herring batches suggested that an effect at the level of the thymus may be responsible for changes in cellular immunity, that virus-specific immune responses may be impaired, and that perinatal exposure to environmental contaminants represents a greater immunotoxic threat than exposure as a juvenile or adult. Together with the pattern of TCDD toxic equivalents of different PHAHs in the herring, these data indicate that present levels of PCBs in the aquatic food chain are immunotoxic to mammals. A review of contaminant levels in free-ranging harbour seals inhabiting polluted areas of Europe and North America suggested that many populations may be at risk to immunotoxicity. This could result in diminished but resistance and an increased incidence and severity of infectious disease.
KEY WORDS: immunotoxicology, morbillivirus, PCBs, PCDDs, PCDFs, seals.

Schandorff S. 1997. Developmental Stability and the Harbour Seal Epizootic in 1988. Annales-

Zoologici-Fennici 34(3):167-75.
ABSTRACT: Developmental instability of harbour seals (*Phoca vitulina*) that died during the epizootic in 1988 in the Kattegat was compared with that of the population prior to the epizootic to investigate whether animals that died were the developmentally less stable individuals in the population. As an assessment of developmental instability the fractal dimension of the paired maxillo palatinae suture was calculated and the degree of fluctuating asymmetry in teeth, foramina and the paired suture was estimated in a total of 240 skulls. Moreover, prevalences of three pathological changes of the skull were compared. No difference was found in developmental instability or prevalence of skull lesions between animals that died in the epizootic and estimates from the population prior to the epizootic. The lack of difference could be in accordance with the suggestion that organochlorines had an influence on mortality during the epizootic. Levels of organochlorines have decreased in the last decade before the epizootic, and thereby could have equalized differences in levels of developmental stability.
KEY WORDS: epizootic, harbour seals, Kettegat, organochlorines, pathological changes.

Schumacher U, Zahler S, Heidemann G, Skirnisson K, and Welsch U. 1993. Histological Investigations on the Thyroid Glands of Marine Mammals (*Phoca vitulina*) (*Phocoena phocoena*) and the Possible Implications of Marine Pollution. J. Wildl. Dis. 29:103-9.
ABSTRACT: In 1988 and 1989, thousands of harbor seals (*Phoca vitulina*) died in the North Sea from phocine distemper infection. The morphology of thyroid glands from 40 harbor seals found dead on the North Sea coastlines of Schleswig-Holstein, Federal Republic of Germany, during an epizootic of phocine distemper, was compared with the morphology of thyroid glands from five healthy harbor seals collected in Iceland. Thyroid glands from seven harbor porpoises (*Phocoena phocoena*) found dead in 1990 on the North Sea coastlines also were evaluated. Colloid depletion and fibrosis were found in the thyroid glands of harbor seals which died during the epizootic, but not in animals from Iceland. Thyroid glands of the porpoises showed similar lesions, but to a lesser degree, than those observed in the North Sea seals. The seal epizootic had a particularly high mortality in those areas where environmental pollution was high; in contrast, no seal deaths were observed around Iceland, where there is little environmental pollution.
KEY WORDS: histology, marine mammals, North Sea, *Phoca vitulina*, phocine distemper virus, *Phocoena phocoena*, pollution effects, thyroid, viral diseases, water pollution.

Shaw SB. 1971. Chlorinated Hydrocarbon Pesticides in California Sea Otters and Harbor Seals. Calif. Fish and Game 57:290-4.

Skaare JU. 1996. Environmental Pollutants in Marine Mammals from the Norwegian Coast and Arctic. Sci. Total Environ. 186(1-2):25-7.
ABSTRACT: The synthetic organochlorine (OC) compounds, including pesticides such as DDT, as well as industrial pollutants, such as polychlorinated biphenyls (PCBs) together with several metals, especially mercury, have for many years been of great concern as environmental pollutants in marine ecosystems. OCs are lipophilic and persistent and may be stored in body fats and increasingly concentrated along food webs. Environmental pollutants are known to be transferred to the Arctic by air (and water)

currents, and the OC levels in marine mammals, polar bears, sea birds, etc. which occupy high trophic levels are orders of magnitude greater than levels found in terrestrial wild life. Toxic effects related to exposure to such compounds have been found in marine mammals living in particularly polluted waters. However, little is known about sublethal effects. Thus, monitoring of environmental pollutants is of great importance. In the period 1987-1994, the occurrence and levels of selected OCs (PCBs, DDTs, chlordanes, HCB, HCHs) and some heavy metals (Hg, Cd) were studied in harbour seals (*Phoca vitulina*) and harbour porpoises (*Phocoena phocoena*) caught along the coast of Norway; harbour seals, grey seals (*Halichoerus grypus*), harp seals (*Phoca groenlandica*) and ringed seals (*Phoca hispida*) caught along the northern coast of Norway; harp seals and hooded seals (*Cystophora cristata*) from the West Ice area; harp seals from the Barents Sea; polar bears (*Ursus maritimus*), polar foxes (*Alopex lagopus*), harp seals, harbour seals and ringed seals from Svalbard and minke whale (*Balaenoptera acutorostrata*) from the northern coast of Norway and the Barents Sea area. Altogether samples from more than 900 individual animals have been analyzed.
KEY WORDS: Arctic, marine mammals, monitoring, Norwegian coast, organochlorines.

Skaare JU, Degre E, Aspholm PE, Ugland KI, Frank A, Galgan V, Olsson M, Petersson LR, and Bignert A. 1994. Mercury and Selenium in Arctic and Coastal Seals Off The Coast of Norway Metal Concentrations in Seals from Swedish Waters. Env. Poll. 85:153-60.
ABSTRACT: Mercury and selenium concentrations (wet weight) have been determined in samples of liver, kidney and brain of grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*), harp seal (*Phoca groenlandica*) and ringed seal (*Phoca hispida*) caught along the Norwegian coast, 114 individuals in all. Significant differences have been found in mercury contamination between the 4 species caught in the same coastal area, Jarfjord, located at the north-east of the Norwegian coast close to the Russian border. Very low hepatic mercury levels were found in the arctic species, ringed and harp seals, ranging from 0.20 to 0.67 and 0.04 to 1.0 $\mu g \cdot g^{-1}$, respectively, while in the coastal seal species the concentrations were 10 to 40 times higher. The corresponding ranges were 0.7 to 48.3 $\mu g \cdot g^{-1}$ in grey seals and 0·2 to 19·0 $\mu g \cdot g^{-1}$ in harbour seals. The median values were 13.5 and 0.7 $\mu g \cdot g^{-1}$, respectively. The highest levels were found in grey seals, indication that particularly the stock frequenting the waters of the north-east of Norway and north-west coast of Russia had received a substantial mercury exposure. Fifty-five percent of these grey seals from Jarfjord had hepatic mercury levels above 10 $\mu g \cdot g^{-1}$ and 21% had levels above 20 $\mu g \cdot g^{-1}$. By a one-way analysis of covariance, sex and age were found to explain 28 and 30%, respectively, of the total variability in the mercury concentration in grey seal from Jarfjord. Significant differences in mercury concentrations were also found between stocks of harbour seals caught at different sites along the Norwegian coast, and decreasing concentration from the south to the north-east coast of Norway was revealed. The renal mercury levels in the arctic seals ranged from 0.08 to 0.45 $\mu g \cdot g^{-1}$, and about five times higher levels were found in grey seals and harbour seals. The mercury levels in the brain ranged from the detection level 0.01 $\mu g \cdot g^{-1}$ to about 0.1 $\mu g \cdot g^{-1}$. The hepatic selenium levels in the arctic seal species ranged from 0.08 to 3.7 $\mu g \cdot g^{-1}$. The corresponding ranges in grey seals and harbour seals were 1.0 to 23.3 $\mu g \cdot g^{-1}$. The renal selenium levels were lower, and the levels in the brain were below the detection level (0.01 $\mu g \cdot g^{-1}$). The mercury /selenium ratio was close to unity for mercury concentrations greater than 15 $\mu g \cdot g^{-1}$, and a nonlinear, concave relationship was

found between the ratio of the hepatic mol concentrations of mercury and selenium and the hepatic mol concentrations of mercury.
KEY WORDS: grey seal, harbour seal, harp seal, mercury, ringed seal, selenium.

Skaare JU, Markussen NH, Norheim G, Haugen S, and Holt G. 1990. Levels of Polychlorinated Biphenyls, Organochlorine Pesticides, Mercury, Cadmium, Copper, Selenium, Arsenic, and Zinc in the Harbour Seal, *Phoca vitulina*, in Norwegian Waters. Env. Poll. 66:309-24.
ABSTRACT: Residue levels of the chlorinated hydrocarbons polychlorinated biphenyls (PCBs), total DDT, alpha-, gamma-, and -hexachlorocyclohexane (HCH), hexachlorobenzene (HCB), and oxychlordane in blubber, and the elements mercury , cadmium, copper, selenium, arsenic, and zinc in liver, of 82 harbour seals, *Phoca vitulina*, were determined. The seals were found dead or dying in Norwegian waters during the disease outbreak caused by a morbilli virus in 1988. Of the chlorinated hydrocarbons, the highest concentrations were found of PCBs, which were 2-4 times higher than the total DDT concentrations. p,p'-DDE was the main contributor to the total DDT, and constituted about 80%. The PCB and total DDT concentrations ranged from 04-38 and 01-88 $mg \cdot kg^{-1}$, respectively. The mercury concentrations ranged from 01-89 $mg \cdot kg^{-1}$. Significantly higher mean levels of PCBs (13 $mg \cdot kg^{-1}$) and mercury (16 $mg \cdot kg^{-1}$) were found in blubber and liver, respectively, of seals from the Southern coast of Norway, as compared to the corresponding mean levels in seals from the Oslofjord (88 and 41 $mg \cdot kg^{-1}$), and at the Northwestern coast (58 and 79 $mg \cdot kg^{-1}$), respectively. A significant positive correlation was found between the concentrations of selenium and mercury. When the seals were grouped according to sex and age, females of age class >1 and pups of both sexes had significantly lower PCB and total DDT levels than males age class >1. Significantly higher hepatic mercury levels were found in seals age class >1 as compared to pups. Only low levels of the other organochlorines, cadmium and arsenic, were found. Copper and zinc were considered to be present at normal physiological levels. The present organochlorine and heavy metal concentrations gave no support to suggestions that organochlorines and heavy metal pollution may be directly involved in the observed seal deaths.
KEY WORDS: intoxication, marine mammals, mercury, polychlorinated biphenyls, zinc toxicity.

Small RJ, and DeMaster DP. 1995. Alaska Marine Mammal Stock Assessments 1995. U.S. Dept.Commer., NOAA Tech. Memo. NMFS-AFSC-57 :93 pp.
ABSTRACT: The Alaskan Marine Mammal Stock Assessment Report for 1995 recognized 3 separate stocks in Alaskan waters; Gulf of Alaska, Southeast Alaska and Bering Sea. Stock definition and geographic ranges were described for each of the 3 locations based on a phylogeographic approach. Photographic aerial surveys were conducted for each area between the years of 1991 and 1994 to determine population size. An estimate of minimum population and the current population trend were also determined where data was available. Information on the number of harbor seals that were killed or injured in association with fisheries interactions, subsistence Native Harvest and other mortality information were also described.
KEY WORDS: Alaska, fisheries, harbor seals, *Phoca vitulina*, population size, stock assessment.

Spencer DL. 1994. Analytical Laboratory Report. Department of Fish and Game, State of Alaska, Division of Wildlife Conservation .
ABSTRACT: An analytical report on Harbor Seals was conducted, performing a GC screen for both organochlorines and PCBs.
KEY WORDS: analytical report, harbor seals, organochlorines, PCBs, *Phoca vitulina*.

Stewart BS, and Yochem PK. 1985. Entanglement of Pinnipeds in Net and Line Fragments and Other Debris in the Southern California Bight. NOAA Tech. Memo. NMFS, SWFC-54 :315-25.
KEY WORDS: fish nets, fishing line, mammals, mortality, pesticides/ pollution, plastics.

Storr-Hansen E, and Spliid H. 1993. Coplaner Polychlorinated Biphenyl Congener Levels and Patterns and the Identification of Separate Populations of Harbor Seals (*Phoca vitulina*) in Denmark. Arch. Environ.Contam.Toxicol. 24:44-58.
ABSTRACT: Blubber samples from 21 harbor seals (*Phoca vitulina*), found dead on Danish beaches during the morbillivirus epidemic in 1988, have been analyzed for toxic coplanar chlorinated biphenyl (CB) congeners. The 21 samples consist of seven samples from 1-2-year-old animals (both males and females) from each of three geographical separate locations: The Limfjord, the Kattegat, and the Wadden Sea. The level of the CBs, defined as the sum of all the measured CB congeners, were highest in the samples from the Wadden Sea and the lowest in the Limfjord samples. The quotient between highest level and lowest level was 4. Toxic equivalency factors given by Safe (1990) was used for calculation of the contribution to dioxin-like toxicity from the coplanar CB congeners, and the result was compared to literature data on polychlorinated dibenzo-p-dioxins and -dibenzofurans in harbor seal. CB congeners CB-118, CB-156, CB-157, and CB-105 were major contributors to sTEQ in all samples. The patterns of polychlorinated biphenyl congeners in harbor seals from the three locations were compared by principal component analysis. The two first principal components could separate the samples in groups corresponding to each of the three geographical locations. The geographical and biological variations were estimated from the data. It was shown, that the geographical variation was the largest. Possible reasons behind the geographical variation in CB congener patterns are discussed.
KEY WORDS: Denmark, harbor seal, morbilli virus epidemic, *Phoca vitulina*, polychlorinated biphenyl congeners, toxic coplanar chlorinated biphenyl congeners.

Storr-Hansen E, and Spliid H. 1993. Distribution Patterns of Polychlorinated Biphenyl Congeners in Harbor Seal (*Phoca vitulina*) Tissues: Statistical Analysis. Arch. Environ.Contam.Toxicol. 25:328-45.
ABSTRACT: Tissue samples from five harbor seals (*Phoca vitulina*) have been analyzed for coplanar and other polychlorinated biphenyl (CB) congeners, in order to measure variations in levels and patterns of the CBs. Blubber samples contained the highest level of CBs in all animals; kidney and liver were relatively high-level tissues. CB-153 and CB-138 were the most abundant CB congeners in all samples analyzed. Variations in the patterns of CB congeners in tissues were studied by principal component analyses and multivariate analysis of variance. The CB congener patterns in seals from different geographical regions had distinctly different patterns, whereas the patterns

appeared quite similar in tissues within each seal. Based on multivariate analysis of variance, it was, however, possible to detect some systematic variation of the principal components with individual seals and with tissue type within seals. The assessment of differences in CB congener patterns was possible by comparison to results obtained by repeated analyses of a quality control sample. The calculated dioxin toxic equivalents of the CB congeners followed the levels of the CB congeners, with the highest levels being found in the blubber samples.
KEY WORDS: bioaccumulation, congeners, distribution patterns, PCB, *Phoca vitulina*.

Storr-Hansen E, Spliid H, and Boon JP. 1995. Patterns of Chlorinated Biphenyl Congeners in Harbor Seals (*Phoca vitulina*) and in their Food: Statistical Analysis. Arch. Environ.Contam.Toxicol. 28:48-54.
ABSTRACT: Patterns of chlorinated biphenyl (CB) congeners have been compared in two groups of samples, namely blood samples from harbor seals (*Phoca vitulina*) and muscle tissue samples in the fish with which the seals were fed. The data originate from a Dutch controlled feeding study, performed in 1981 and 1983. The seals were living in captivity in two separate groups, and the fish samples were plaice (*Pleuronectes platessa*) from the Dutch part of the Wadden sea and mackerel (*Scomber scombrus*) from the Atlantic ocean. The levels of CB congeners were different in the two types of fish. The CB congener patterns of these four matrices were compared by analysis of principal components, and were found to be different in the two groups of harbor seals, which were fed the different types of fish. The corresponding CB congener patterns of the two groups of fish were also different. There was no indication for a relatively larger impact of biotransformation due to induction of isoforms of the cytochrome P450-system at the higher absolute CB congener levels in the Wadden sea group of seals compared to the Atlantic group of seals. The differentiation between the CB congener patterns in the two groups of seals in the Dutch study can be ascribed solely to different CB congener patterns in their food. The difference between CB congener patterns in the seals and in their diet can be explained by the structure-related biotransformation of the CB congeners in the harbor seal.
KEY WORDS: biotransformation, captivity, chlorinated biphenyl congeners, harbor seals, *Phoca vitulina*, principal component analysis.

Tohyama C, Himeno S, Watanabe C, Suziki T, and Morita M. 1986. The Relationship of the Increased Level of Metallothionein with Heavy Metal Levels in the Tissue of the Harbor Seal *Phoca vitulina*. Ecotoxicol Environ Safety 12:85-94.
ABSTRACT: The relationship between age, heavy metal levels, and a heavy-metal binding protein, metallothionein (MT), in the liver and kidney of the harbor seal (*Phoca vitulina*) was studied. The cadmium (Cd) level in the liver and the Cd, inorganic mercury (I-Hg), and zinc (Zn) levels in the kidney were increased with body length, suggesting an age-related accumulation of these metals. The MT levels determined by an MT radioimmunoassay showed concentrations of 240 plus or minus 139 mu g/g in the liver and 343 plus or minus 219 mu g/g in the kidney. These MT levels were shown to be correlated with age. The statistically significant relationship of the MT levels with the levels of Cd and Zn in the liver and those of Cd, Zn, and I-Hg in the kidney suggested that the protein is responsible for the sequestration of these metals as already observed in terrestrial animals.

KEY WORDS: age, bioaccumulation, cadmium, correlation analysis, heavy metals, kidney, liver, marine mammals, metallothionein, *Phoca vitulina*, proteins.

Troisi GM, and Mason CF. 1997. Cytochromes P450, P420 and Mixed-function Oxidases as Biomarkers of Polychlorinated Biphenyl (PCB) Exposure in Harbour Seals. Chemosphere 35(9):1933-46.

ABSTRACT: Hepatic microsomal cytochrome P450, EROD and ECOD activity were investigated as biomarkers of PCB exposure in harbour seals (*Phoca vitulina*). Due to the difficulty of obtaining undegraded seal liver samples, standard spectrophotometric methodology was adapted to investigate P420 (degraded P450) as a PCB biomarker with partially degraded samples. Total PCB burdens in both blubber and liver had positive correlations with P450, P420 and MFO activity levels. The use of P420 biomarkers in this study supports the inclusion of samples from by-caught marine mammals for future biomonitoring studies. P450 isozymes CYP1A (P4501A) and CYP2B (P4502B) in conjunction with MFO activity were investigated as specific biomarkers of PCB exposure. They were found to reliably reflect levels of [MC] and [PB]-type PCB exposure in harbour seal liver.

KEY WORDS: biomarkers, cytochrome P420, cytochrome P450, harbour seals, marine mammals, MFO activity.

Van der Zande T, and de Buiter E. 1983. The Quantification of Technical Mixtures of Polychlorinated Biphenyls by Microwave Plasma Detection, and the Analysis of Polychlorinated Biphenyls in the Blubber Lipid from Harbor Seals *Phoca vitulina*. Sci. Total Environ. 27:133-48.

ABSTRACT: Several technical mixtures of polychlorinated biphenyls (PCBs) were quantified with gas-liquid chromatography-microwave plasma detection (g.l.c.-m.p.d.). These mixtures were then used to determine individual peak response factors for g.l.c.-electron capture detection (e.c.d.), which is used for the routine analysis of PCBs. PCB residues in the blubber lipid from harbour seals, found dead on the Dutch coast from 1972 to 1981 were analysed, 175 samples showed a log-normal distribution with a large coefficient of variation, which makes it difficult to detect differences between groups of harbour seals. Regression analysis showed a significant decrease of PCB content with increasing blubber thickness (BT). Relations between PCB content and age of the seal, and between PCB content and the year in which the seal was found are uncertain.

KEY WORDS: harbour seals, microwave plasma detection, PCBs, *Phoca vitulina.*

Van Forest AW, and Van Haaften JL. 1981. A Preliminary Report on Contrast Radiography of the Genital Tract in the Harbour Seal *Phoca vitulina*. Aquatic Mammals 8:77-8.

Van Loveren H, Vos JG, Reijnders PJH, and Osterhaus ADME. 1994. Impairment of Immune Function in Harbor Seals (*Phoca vitulina*) Feeding on Fish from Polluted Waters. Ambio 23(2):155-9.

ABSTRACT: Disease outbreaks with high mortality rates among seals and dolphins have recently attracted considerable public and scientific interest. Although in most cases morbillivirus infections were shown to be the primary cause of the disease outbreaks, it was speculated that pollution-induced immunosuppression had played a contributory role. Here we present results of a prospective study under semifield conditions, in which two

groups of harbor seals (*Phoca vitulina*) were fed herring from marine regions with different contamination levels; the highly polluted Baltic Sea and the relatively unpolluted Atlantic Ocean. During a period of 93 weeks, parameters related to immune function were monitored and compared between the two groups. We found that natural killer-cell activity and mitogen-induced proliferative T-cell responses from the seals feeding on herring from the Baltic Sea were significantly lower. In addition, we observed higher levels of circulation polymorphonuclear granulocytes in these animals which may indicate an increase in the occurrence of bacterial infections. This is the first demonstration of impaired immunological functions in mammals associated with chronic exposure to environmental contaminants accumulated through the marine food chain.
KEY WORDS: harbor seals, herring, mitogen-induced proliferative T-cell, natural killer-cell activity, *Phoca vitulina*, pollution-induced immunosuppression.

Vanek V, and Wynne K. Undated. Harbor Seal Sampling Manual. Alaska Department of Fish and Game, National Marine Fisheries Service, University of Alaska Sea Grant .
ABSTRACT: This manual provides information on how to correctly and safely collect harbor seal samples. Dataforms are provided along with weighing and measuring procedures. Correct procedures on how to sample organs and tissues are also given as well as what the samples are used for. The information provided should be standard procedure for all researchers studying harbor seals so that analysis and results can be compared among scientists.
KEY WORDS: data forms, harbor seals, *Phoca vitulina*, sampling procedures.

Varanasi U, Brown DW, Hom T, Burrows DG, Sloan CA, Field LJ, Stein JE, Tilbury KL, McCain BB, and Chan S. 1993. Volume I: Survey of Alaskan Subsistence Fish, Marine Mammal, and Invertebrate Samples Collected 1989-91 for Exposure to Oil Spilled from the *Exxon Valdez*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-12 :110 pp.
ABSTRACT: The *Exxon Valdez* ran aground on Bligh Reef, Prince William Sound, Alaska on March 24, 1989, spilling millions of gallons of Prudhoe Bay crude oil (PBCO). During the weeks following the spill, large amount of oil flowed towards southwestern Prince William Sound, and as a result, many shorelines were oiled. The spreading of spilled oil raised concerns of native Alaskans that their subsistence seafoods (fish, marine mammals, and invertebrate organisms) were contaminated by the spilled petroleum. At the request of native Alaskans, a study was conducted as a cooperative effort among NOAA, Exxon, and the Alaska Department of Fish and Game to assess the degree of contamination of subsistence organisms by PBCO. In this study, edible flesh of fish, marine mammals, and shellfish from 22 native subsistence food collection areas and from two reference areas (Angoon and Yakutat) were analyzed for aromatic compounds (ACs). As expected, most fish muscle samples were not contaminated with ACs (<10 ng/g). In fact, the highest concentration of ACs found in muscle samples of fish caught during this study was 100ng/g in a pink salmon caught near Kodiak (city) in 1989. In contrast, two samples of smoked salmon obtained from Tatitlek and Old Harbor contained 23,000 and 8,100 ng/g ACs, respectively. Bile and tissue samples were collected from 33 harbor seals and 10 sea lions in 1989 and 1990. As with fish, the concentrations of FACs in bile of harbor seals varied considerably. Nine of the 12 bile samples with the highest concentrations of FACs were from animals collected in 1989 that were visibly oiled. With two minor exceptions, samples of muscle, liver, and kidney from harbor seals and

sea lions, as well as blubber from sea lions, were not contaminated (<10 ng/g) with ACs. Samples of blubber from 12 of the harbor seals were minimally contaminated (10 to 99 ng/g), and samples of blubber from 4 harbor seals were moderately contaminated with ACs (100 to 1,000 ng/g). Invertebrates from most of the sampling areas were not contaminated or were minimally contaminated by ACs (<100 ng/g). Therefore, results are presented for only those few stations where higher concentrations of ACs were found. Aromatic compounds were present in molluscs at concentrations high enough to evaluate in terms of temporal trends only at some stations. In conclusion, the finding of elevated concentrations of FACs in some bile samples from fish and marine mammals was clear evidence of their exposure to petroleum. Generally, ACs were not found in muscle tissue of fish, harbor seals, and sea lions. Some harbor seal blubber samples did contain ACs; however, the concentrations of ACs in most blubber samples was less than 100ng/g. Smoked salmon contained higher concentrations of ACs (8,000 to 20,000 ng/g) than any of the untreated subsistence samples. The concentrations of ACs were less than 100ng/g in approximately 90% of the more than 1,000 mollusc samples from 80 sampling beaches. The concentrations of ACs were elevated in some mollusc samples (as high as 18,000 ng/g), and the concentration of ACs exceeded 1,000 ng/g in 24 samples. The results to date provide important information on the level of contamination of subsistence fish, shellfish, and marine mammals from fishing areas of native Alaskan villages in and near Prince William Sound. In an advisory opinion, the Food and Drug Administration has indicated that little risk is involved in the consumption of the nonsmoked subsistence foods studied. Subsistence food gatherers were advised not to collect or consume food if oil was observed to be present. The results also show that in future oil spills, shellfish tissues should be given the highest priority for analysis, whereas rapid screening of bile from fish and marine mammals should be sufficient to provide information on level of exposure.

KEY WORDS: aromatic compounds, crude oil, *Exxon Valdez*, marine mammals, marine organisms, Prince William Sound.

Varanasi U, Stein JE, Tilbury KL, Brown DW, Meador JP, Krahn MM, and Chan S. 1993. Contaminant Monitoring for NMFS Marine Mammal Health and Stranding Response Program. In: Coastal Zone 93 Proceedings, The Eighth Symposium on Coastal and Ocean Management, New Orleans, LA, July 19-23, 1993. 3:2516-30.

ABSTRACT: Because of increasing concern that chemical contamination may impair the health of marine mammals, a better understanding of the extent of contamination and types of toxic effects in these ecologically important animals is needed. The National Marine Fisheries Service has initiated a broadly based and systematic study of several species of marine mammals to better define the environmental hazards encountered by these species. To date, samples from a number of species including harbor seals (*Phoca vitulina*), Northern fur seals (*Callorhinus ursinus*), Steller sea lions (*Eumetopias jubatus*) and bowhead whales (*Balaena mysticetus*) from Alaska; harbor seals, harbor porpoises (*Phocoena phocoena*), minke whale (*Balaenoptera acutorostrata*) and gray whales (*Eschrichtius robustus*) from the Pacific coast; bottlenose dolphins (*Tursiops truncatus*) from the Gulf of Mexico; and pilot whales (*Globicephala malaena*) and harbor porpoises from the Northeast coast of the USA have been analyzed for a broad spectrum of chemical contaminants including trace and essential elements, chlorinated hydrocarbons, aromatic hydrocarbons and their metabolites. Although for most species the number of

samples available is limited at present, the database has begun to yield useful information. For example, contrary to popular belief, gray whales that strand in urban areas of Puget Sound have much lower levels of toxic contaminants in their tissues than do Stellar sea lions sampled from environmentally pristine areas in Alaska. These findings demonstrate that caution is needed before drawing any conclusions about the cause of stranding from the level of contamination at a stranding site. The results from pilot whales also showed evidence for maternal transport of organic contaminants and toxic elements to the fetus and accumulation of certain toxic elements (e.g., mercury, lead) in fetal brain tissue. Thus, the impact of pollution on the early life stages of marine mammals, especially those species at the top of the foods chain, is being explored.
KEY WORDS: chemical contamination, early life stages, marine mammals, toxic effects.

Vetter W, Hummert K, Luckas B, and Skirnisson K. 1995. Organochlorine Residues in Two Seal Species from Western Iceland. Sci. Total Environ. 170(3):159-64.
ABSTRACT: Harbour seals and grey seals from Faxafloi were analyzed from contamination with organochlorines. Although the values strongly varied, both harbour seals and grey seals on average showed comparable levels of PCBs, p, p'-DDE and alpha-HCH, as well as chlordanes (CD). The HCB/ alpha-HCH ratio in harbour seals was <1 and in grey seals >1. The results were compared with data derived from seal samples of the Antarctic, the Arctic (Spitzbergen) and the North Sea (Germany) in order to give insight into the global distribution of pollution with chlorinated organics.
KEY WORDS: grey seal, harbour seal, Iceland, organochlorines.

Vetter W, Luckas B, Heidemann G, and Skirnisson K. 1996. Organochlorine Residues in Marine Mammals from the Northern Hemisphere-A Consideration of the Composition of Organochlorine Residues in the Blubber of Marine Mammals. Sci. Total Environ. 186(1-2):29-39.
ABSTRACT: Levels of organochlorines (PCBs, sigma DDT, lindane and its isomers, HCB, chlordane, and toxaphene) were determined in blubber of marine mammals from the northern hemisphere. Differences in both levels and ratios of organochlorine compounds were detected in different species of marine mammals living in the same region, e.g. blubber of harbour seals (*Phoca vitulina*) accumulated significantly lower levels of lindane, HCB, toxaphene, and DDT and its metabolites than harbour porpoises (*Phocoena phocoena*). Compared to such elementary differences in the organochlorine pattern in different marine mammals, the influence of age and sex on the results was only minimal. Varying ratios of contaminants in individual harbour porpoises were explained by migration. Constant PCB/DDT ratios were measured in harbour seals. Due to the sedentariness of harbour seals, every local sources of contaminants could be recognized. Careful evaluation of the organochlorine levels and ratios in marine mammals made it possible to monitor the transport of PCBs from the European continent to European Arctic regions.
KEY WORDS: Arctic, blubber, contaminants, DDT, harbour seals, Northern Europe, PCB.

Waldichuck M. 1987. Marine Mammals' Contaminants. Mar. Poll. Bull. 18(10):567-8.
ABSTRACT: This brief report reviews the topics discussed at the Sixth Biennial

Conference on the Biology of Marine Mammals, held in Vancouver, Canada, November 22-26, 1985. A number of papers discussed the isolated stock of beluga whales, *Delphinapterus leucas*, in the St. Lawrence River estuary and Gulf. Other speakers presented information on mammals and evidence for pollution-related problems in Puget Sound of Washington. Polychlorinated biphenyls were found in harbour seals, *Phoca vitulina richardsi*, and killer whales, *Orcinus orca*, in concentrations that are among the highest in the world. A Japanese scientist spoke of the global contamination by persistent organochlorines in the northern hemisphere and that the distribution is reflected in the concentrations of these compounds found in small cetaceans. One scientist suggested that there are two main areas of concern related to the effects of pollutants on marine mammals and hopes to see theses approaches advocated through in the future. More toxicological work on mammals exposed to high concentrations of contaminants still needs to be completed to better understand the cause-effect relationship.
KEY WORDS: cetaceans, contaminants, fish, marine mammals, organochlorines, pollution-related problems, polychlorinated biphenyls, seals, Sixth Biennial Conference.

Walker II W, Risebrough RW, Jarman WM, de Lape BW, Tefft JA, and DeLong RL. 1989. Identification of Tris (Chlorophenyl) Methanol in Blubber of Harbor Seals from Puget Sound. Chemosphere 18(9/10):1799-804.
ABSTRACT: A compound detected in extracts of blubber of harbor seals, *Phoca vitulina*, found dead in Puget Sound in the north-western United States over the period 1972-1982 was identified as tris (chlorophenyl) methanol from its mass spectral characteristics and by synthesis. Concentrations in harbor seal blubber ranged from 23 to 750 ng/g of the lipid weight and showed no evident changes over the time interval of the study. Concentrations were highly correlated with those of most of the other organochlorines detected in the harbor seal extracts, indicating a similar pattern of uptake and accumulation. The compound is used in the manufacture of optically active polymers, which appear to be a plausible source.
KEY WORDS: bioaccumulation, harbor seals, organochlorine, *Phoca vitulina*, Puget Sound, tris (chlorophenyl) methanol, uptake.

Walsh M, Beusse D, and Dinne M. 1993. Zinc Toxicity in Marine Mammals. In: Andrews, B.F. (Ed). International Association for Aquatic Animal Medicine (IAAAM) Proceedings 24.
ABSTRACT: Pica, the compulsive eating of non-nutritive substance has been observed in wild animals as well as animals maintained in zoos and aquaria. In general this syndrome is seen in younger individuals and if present is often limited to a very small percentage of the population. Similar eating disorders in children may occur in the second year, decrease with age and have been theorized to be associated with mineral deficiencies. The pathogenic effects related to foreign principal. The substitution of zinc (97.6%) for copper (2.4%) in pennies in 1982 has resulted in the possibility of increased exposure of zinc. Three juvenile bottlenose dolphins (*Tursiops truncatus*) and one juvenile harbor seal (*Phoca vitulina*) have shown zinc levels compatible with intoxication. Clinical signs such as depression, anorexia, hemorrhage, and amelanosis may be observed with chronic zinc intoxication. Diagnostic methods included whole blood or serum element levels, CBC, clinical chemistry and radiology. Tissue zinc levels are elevated in animals which may expire. Prevention of exposure of young animals or those with a history of foreign body ingestion effectively eliminates the problem.

Treatment is dependent on proper diagnosis removal of foreign material if present and the use of chelating agents such as CA EDTA.
KEY WORDS: bottlenose dolphin, copper, eating disorders, harbor seal, heavy metal, pathological effects, pica, young animals, zinc intoxication.

Wenzel C, Adelung D, Kruse H, and Wassermann O. 1993. Trace Metal Accumulation in Hair and Skin of the Harbour Seal, *Phoca vitulina*. Mar. Poll. Bull. 26(3):152-5.
ABSTRACT: Skin and hair samples of harbour seals (*Phoca vitulina*) found dead along the west coast of northern Germany in 1988 were analysed for total mercury, cadmium and lead. Cadmium and lead concentrations were below the detection limit in most skin samples. The mercury content of the hair (median: 23.1 $\mu g \cdot g^{-1}$ wet wt) was several magnitudes higher than the mercury content of the skin (0.27 $\mu g \cdot g^{-1}$ wet wt). Mercury concentrations in hair samples were significantly higher than lead concentrations (0.54 $\mu g \cdot g^{-1}$ wet wt), which significantly exceeded cadmium levels (0.09 $\mu g \cdot g^{-1}$ wet wt). Female seals revealed lower cadmium concentrations in the hair than male seals. Accumulations of metals with age were observed for cadmium and lead in hair samples and for mercury in skin samples of male seals. A connection between metal accumulation and pigmentation or rather moult was clearly recognizable.
KEY WORDS: harbour seals, marine mammals, moult, *Phoca vitulina*, trace metal.

Zook DR, Buser H, Bergqvist P, Rappe C, and Olsson M. 1992. Detection of *Tris* (chlorophenyl) Methane and *Tris* (4-chlorophenyl) Methanol in Ringed Seal (Phoca hispida) from the Baltic Sea. Ambio 21(8):557-60.
ABSTRACT: This report concerns two relatively unstudied chlorinated aromatic substances of intermediate polarity which have been detected between ppb and ppm levels in ringed seal from the Baltic Sea. Both of them, tris(chlorophenyl)methane and tris(4-chlorophenyl)methanol, have only recently been detected in wildlife sampled throughout North America and elsewhere in both the Northern and Southern Hemispheres. No point sources have yet been identified to account for the global distribution of these closely-related substances. The non-destructive extractive methods used for recovery of these compounds, as well as their chromatographic and mass spectrometric properties which will assist in their identification, are described. Initial results indicate that levels for these substances are comparable to those found in harbor seal from North America.
KEY WORDS: chlorinated aromatic substances, extractive methods, ringed seal.

Supplemental Information

Addison RF, and Brodie PF. 1987. Transfer of Organochlorine Residues From Blubber Through the Circulatory System to Milk in the Lactating Grey Seal *Halichoerus grypus*. Can. J. Fish. Aquat. Sci. 44:782-6.

ABSTRACT: Residues of the DDT group of insecticides and the polychlorinated biphenyls (PCBs) were measured in maternal blubber, milk, and blood or serum and in pup blubber and blood or serum of grey seals (*Halichoerus grypus*) from Sable Island, N.S. sampled in 1984 and 1985. DDT-group and PCB concentrations in blubber samples were lower in 1984 than in a sample of this population taken in the mid-1970s, but not lower than those in a sample taken in 1982. Concentrations in 1985 samples were slightly higher than those in the 1984 samples for unknown reasons. On a lipid weight basis, residue concentrations in blood or serum were consistently about 50% of those in blubber lipid. The more highly chlorinated and therefore more lipid-soluble PCB components were transferred less efficiently from blubber to the circulatory system. Net transfer of residues from maternal blubber to maternal milk was about 70% efficient; this implies considerable degradation of circulatory lipid and resynthesis, probably to milk carbohydrate and other compounds. There was some selection against movement of especially the lower chlorinated PCB congeners from circulatory lipids into milk lipids, compared with transfer of the DDT group. Thus, a nonselective barrier exists to quantitative transfer of residues from blubber lipids to circulatory lipid, and a partially selective barrier exists against PCBs in the transfer of residues from circulatory to milk lipids; at least the latter barrier to involve lipid solubility.

KEY WORDS: circulatory system, DDT, grey seal, lactation, organochlorine residues, PCBs, Sable Island, N.S.

Aguilar A. 1985. Compartmentation and Reliability of Sampling Procedures in Organochlorine Pollution Surveys of Cetaceans. Residue Reviews 95:93-114.

ABSTRACT: This paper deals with: basis for current sampling procedures; compartmentation of organochlorines in the body of cetaceans; and blubber as a representative tissue.

KEY WORDS: biological sampling, biology, Cetacea, chlorinated hydrocarbons, organochlorine compounds, pollution, pollutant detection, pollution monitoring, sampling method, surveys.

Aguilar A. 1984. Relationship of DDE/ DDT in Marine Mammals to the Chronology of DDT Input into the Ecosystem. Can. J. Fish. Aquat. Sci. 41(6):840-4.

ABSTRACT: The DDE/DDT (DDT = DDT + DDE + DDD) ratios in the blubber of North Atlantic pinnipeds and odontocete cetaceans, as determined by several scientists and surveys, are compiled to obtain a biannual mean series. Conversion of DDT to DDE is interpreted as being due not only to the marine mammals but also to the overall detoxifying activity of the North Atlantic marine biota. The change of these ratios during the period 1964-81 is examined and a strong correlation between these ratios and time is found in both groups, which demonstrates that such an index can be tentatively used when one assesses the chronology of pollutant input into the ecosystem. An equilibrium

value may be reached at the beginning of the next century when the ratio reaches a value of approximately 0.60, provided that no new inputs of contaminant into North Atlantic waters exist.
KEY WORDS: biannual mean series, cetaceans, DDE, DDT, marine biota, pinnipeds.

Aguilar A, and Borrell A. 1994. Abnormally High Polychlorinated Biphenyl Levels in Striped Dolphins (*Stenella coeruleoalba*) Affected by the 1990-1992 Mediterranean Epizootic. Sci. Total Environ. 154(2,3):237-47.
ABSTRACT: PCB concentrations and total lipid content were determined in the blubber and liver of striped dolphins affected by the 1990 morbillivirus epizootic in the Mediterranean Sea, and in the blubber of striped dolphins from the same area sampled with a biopsy dart in 1987-1989 and 1991. PCB levels were found to be significantly higher in the individuals that succumbed to the epizootic than in the healthy population sampled before or after the event. Although recent mobilization of lipid reserves was found to have occurred in some of the diseased dolphins, this had little effect on their PCB blubber concentrations and cannot explain the observed difference with the healthy individuals. Three hypotheses are put forward to explain the apparent link between high PCB levels and mortality caused by the epizootic: (i) depressed immunocompetence caused by PCBs leading to an increase in individual susceptibility to the morbillivirus infection, (ii) mobilization of fat reserves leading to increased PCB levels in blood which, in turn, may produce a liver lesion capable of increasing the individuals susceptibility to the morbillivirus infection, and (iii) previous existence of an unspecific hepatic lesion producing impairment of the liver function which, in turn, could lead to an increase both in tissue PCB concentrations and in individual susceptibility to the morbillivirus infection.
KEY WORDS: distemper, epizootic, immunosuppresion, mass mortality, Mediterranean Sea, pollution, polychlorinated biphenyls, *Stenella coeruleoalba*, Striped dolphin.

Aguilar A, and Borrell A. 1994. Assessment of Organochlorine Pollutants in Cetaceans by Means of Skin and Hypodermic Biopsies. In: M.C. Fossi, C. Leonzio (Eds.). Nondestructive Biomarkers in Vertebrates. Lewis Publishers, Boca Raton, Florida. pp. 245-270 .
ABSTRACT: The present chapter reviews the potentials and difficulties involved in monitoring organochlorine pollutant loads in cetaceans through biopsy techniques, and presents some new data concerning the questions raised in the last few years as to the reliability and practical usefulness of this technique The unpublished results on tissue organochlorine residue levels used here were obtained following standard analytical techniques. PCB congener composition in the samples were determined by means of individual congener standards and of a precalibrated Aroclor 1260 standard.
KEY WORDS: biopsies, cetaceans, marine mammals, organochlorines, PCB congener.

Anas RE and Worlund DD. 1975. Comparison Between Two Methods of Subsampling Blubber of Northern Fur Seals for Total DDT Plus PCB's. Pestic. Monit. J. 8(4):261-2.
ABSTRACT: Samples of 100 g blubber were collected from each of twelve 8- to 13-year-old fur seals (*Callorhinus ursinus*) taken off the coast of Washington State in March 1972. Two methods of subsampling the blubber were compared. The mean level of total DDT (DDE, DDD, and DDT) plus polychlorinated biphenyls (PCBs) from a 5-g chunk of blubber taken from a 100-g sample was significantly less than the mean level from a 5-g

subsample taken from the remainder of the blubber sample after it had been thoroughly ground. Total DDT plus PCB residues ranged from 5.66 to 72.17 ppm, with a mean of 23.69 ppm in the chunks, and from 5.33 to 95.70 ppm, with a mean of 28.64 ppm in the homogenized blubber.
KEY WORDS: DDT, fur seals, polychlorinated biphenyl, subsampling, Washington State.

Anas RE, and Wilson Jr. AJ. 1970. Residues in Fish, Wildlife, and Estuaries: Organochlorine Pesticides in Fur Seals. Pestic. Monit. J. 3(4):198-200.
ABSTRACT: Samples of liver and brain tissue from 30 northern fur seals (*Callorhinus ursinus*) and 7 fur seal fetuses that were collected on the Pribilof Islands, Alaska, in 1968 and off the Washington coast in 1969, were analyzed for organochlorine pesticides. These compounds were found in all of the fur seals and in three of the fetuses. Polychlorinated biphenyls (PCB) were not detected. Of 30 samples of liver tissue from the seals, all contained DDE; 21, DDD; 24, DDT; and 3 contained dieldrin. Of the 30 brain samples, all contained DDE; 5, DDD; 4, DDT; and none contained dieldrin. DDE was present in liver tissue from three of the fetuses and in brain tissue from two.
KEY WORDS: Alaska, *Callorhinus ursinus*, DDE, northern fur seals, organochlorine pesticides, PCBs.

Anderson DM, and White AW. 1992. Marine Biotoxins at the Top of the Food Chain. Oceanus 35(3):55-61.
ABSTRACT: This article discusses marine biotoxins and their affects on marine organisms. Many microscopic algal species contain potent toxins that can accumulate in shellfish, fish, other marine animals, and move through the food chain, eventually affecting humans and marine mammals. Blooms of these algae are known as red tides and have effected several marine organisms all over the world. Individual and mass mortalities of whale, dolphin, fish and bird communities are discussed. Although red tides are a natural occurrence, they can be stimulated by human activities, such as pollution or habitat destruction. Therefore, with increased knowledge, mortality events can be explained and possibly prevented from becoming worse due to human activities.
KEY WORDS: algae, fish, food chain, marine biotoxins, marine birds, marine mammals, red tide.

Andersson O, and Wartanian A. 1992. Levels of Polychlorinated Camphenes (Toxaphene), Chlordane Compounds and Polybrominated Diphenyl Ethers in Seals from Swedish Waters. Ambio 21(8):550-2.
ABSTRACT: Blubber samples from different seal species collected both from the Baltic and the west coast of Sweden have been analyzed for the presence of polychlorinated camphenes (toxaphene, PCC), chlordane-related compounds (sCHL) and polybrominated diphenyl ethers (PBDE). Spatial and species variations as well as the influence of age and health status on the contamination levels have been studied. The results show that the levels of PCC and sCHL in Baltic seals are higher than those found in animals from the west coast of Sweden. Comparison of the data for adult and juvenile seals shows one major species and age-related variation in contamination, i.e. the levels of PCC and sCHL in adult Baltic ringed seal were significantly higher compared to adult grey seal from the Baltic, and 5-10 times higher than in juvenile ringed seal from the same water region. It

is noteworthy that the data for PBDE do not reflect this variation in contaminant levels in Baltic seal species. The contaminant levels in seals suffering from pathological changes in the uterus were significantly higher than those found in healthy animals. In a pooled sample of diseased seals with poor nutritional status the levels of PCC, sCHL and PBDE were 2-3 times, 10 times, and 3-5 times higher, respectfully, than in the healthy seal samples.
KEY WORDS: chlordane compounds, marine mammals, polybrominated camphenes, polybrominated diphenyl, seals, spatial and species variation.

André JM, Ribeyre F, and Boudou A. 1990. Mercury Contamination Levels and Distribution in Tissues and Organs of Delphinids (*Stenella attenuata*) from the Eastern Tropical Pacific, in Relation to Biological and Ecological Factors. Marine Environ. Res. 30:43-72.
ABSTRACT: Based on a sample of 44 dolphins belonging to the *Stenella attenuata* species and captured in the Eastern tropical zone of the Pacific Ocean this study was devoted to the analysis of the total mercury accumulation levels and distribution in 18 organs or tissue samples. The average concentrations measured varied from 0.36 mg Hg kg^{-1} in the blood, to 62 mg Hg kg^{-1} in the liver. The average level of contamination in most of the organs was between 1 and 5 mg Hg kg^{-1}. These three tissue compartments, liver, skeletal muscle and blubber, contain almost 95% of the estimated total burden present in the organs collected. The mercury distribution in the organs is an indication that the trophic contamination route, via the marine alimentary networks, may play a leading role with regard to the uptake of the metal. The different biological and ecological factors taken into account such as age, body weight, sex or geographical origin, interact with the mercury concentrations and burdens in the collected organs or tissues. This is not confirmed for the date of the capture, but the location of the capture area appears to be of prime importance, especially the latitude. The accumulation levels in the organs increase when the capture site is nearer the equator.
KEY WORDS: biological and ecological factors, dolphins, Pacific Ocean, *Stenella attenuata*, total mercury.

Andre JM, Amiard JC, Amiard-Triquet C, Boudou A, and Ribeyre F. 1990. Cadmium Contamination of Tissues and Organs of Delphinids Species (*Stenella attenuata*)-Influence of Biological and Ecological Factors. Ecotoxicol. Environ. Safety 20:290-306.
ABSTRACT: Based on a sample of 27 dolphins (*Stenella attenuata*) captured in the Eastern tropical zone of the Pacific Ocean, this study was carried out to analyze the cadmium accumulation levels and distribution in 12 organs or tissue samples. The average cadmium concentrations were between 0.2 mg $Cd{\cdot}kg^{-1}$ in the brain and muscle and 48 mg $Cd{\cdot}kg^{-1}$ in the kidneys. For most of organs and tissues the average values were between 1 and 5 mg $Cd{\cdot}kg^{-1}$. Kidneys, liver, muscle, and intestine contained almost 85% of the total cadmium burden of all tissues considered in this study. Most of the biological and ecological factors taken into account (age, sex, total weight, and length of the dolphins, weight of the organs, place and date of capture) interacted with the cadmium concentrations and burdens in the collected organs or tissues. Three factors appear to be of prime importance: age, body weight, and geographical location of the area of capture.
KEY WORDS: biological factors, cadmium, dolphins, ecological factors, marine mammals, *Stenella attenuata*.

Andre J, Boudou A, Ribeyre F, and Bernhard M. 1991. Comparative Study of Mercury Accumulation in Dolphins (*Stenella coeruleoalba*) from French Atlantic and Mediterranean Coasts. Sci. Total Environ. 104:191-209.

ABSTRACT: Total mercury concentrations (Hg) have been determined in liver, kidneys, skeletal muscle, melon, stomach and intestine of 35 specimens of *Stenella coeruleoalba* stranded on French Atlantic and Mediterranean coasts. Very high mercury levels with concentrations reaching 80 mg Hg kg^{-1} fresh weight (FW) in muscle and about 1500 mg Hg kg^{-1} FW in liver tissue, were observed. Liver has the highest concentration followed by muscle and kidney. The lowest concentrations were found in the melon. The levels observed in the Mediterranean specimens are among the highest observed in marine organisms and confirm previous reports of high mercury levels in marine mammals from the Mediterranean. Comparison between Hg accumulation levels in these two geographic groups of dolphins shows that Mediterranean individuals have much higher concentrations than specimens from the Atlantic. These differences provide additional confirmation for the higher Hg concentrations observed previously in other pelagic species (tuna, sardine, anchovy, etc.) from the Mediterranean Sea. Taking into consideration the pelagic habitat of the dolphin and the local influence of anthropogenic mercury sources it seems reasonable to assume that the main source of the high mercury concentrations observed in Mediterranean biota is natural mercury deposits located in many regions of the Mediterranean basin.

KEY WORDS: dolphins, geographic distribution, Mediterranean biota, *Stenella coeruleoalba*, total mercury.

Anonymous. 1991. Contaminants and Marine Mammals. Report of the Meeting of the Scientific Advisory Committee of the Marine Mammals Action Plan, Palma, Spain. 6 pp.

ABSTRACT: The increased occurrence of unusual environmental events, such as, large-scale disease events and die-offs of several marine animals have coincided with a variety of environmental factors. These events have caused concern among scientists and therefore the Scientific Advisory Committee (SAC) has recognized the immediate need to assess the health status of many marine mammal populations. The SAC has recommended a TASK FORCE to be established which will be drawn from 5 WORKING GROUPS, composed of specialists representing each of the disciplines required to undertake a comprehensive study. A long-term research program must also be developed which will require information including general health evaluation, contaminant levels, toxicity and bio-markers of environmental contaminants and archiving. A list of delegates present at the 1991 SAC Meeting is also included in the report.

KEY WORDS: archiving, biomarkers, contaminant levels, health status, marine mammals, task force.

Aono S, Tanabe S, Fujise E, and Tatsukawa R. Specific Accumulation of Persistent Organochlorines in Minke Whale (*Balaenoptera acutorostrata*) and Their Prey Species from the Antarctic and the North Pacific.

ABSTRACT: Persistent organochlorines such as PCBs, DDTs, CHLs, HCHs and HCB were determined in the blubber of minke whale and its diet collected from the Antarctic and the North Pacific Oceans. Residue levels of these compounds except HCB in minke whale from the Antarctic were apparently lower than those from the North Pacific. This

is probably due to the smaller extent of contamination by these pollutants in the Southern Hemisphere than in the Northern Hemisphere and the specific feeding habit of the minke whale from the Antarctic which feeds on lower trophic organisms primarily euphausiids. The north-south difference for HCB residue levels was small, reflecting the more dispersible nature of HCB through long-range atmospheric transport. Compositions of DDT and CHL compounds in minke whale from the Antarctic were similar to those from the North Pacific. However, the composition of HCH isomers in minke whale from the Antarctic and the North Pacific were different as was observed in their diet, suggesting a larger or ongoing usage of lindane in the Southern Hemisphere countries. In North Pacific minke whale, higher concentrations of PCBs and lower ratios of DDE/PCBs were observed in 1994 than in 1987, suggesting continuous environmental input of PCBs in the Northern Hemisphere.
KEY WORDS: minke whale, organochlorines, prey species.

Arima S, and Nagakura K. 1979. Mercury and Selenium Content of *Odontoceti*. Bull. Jap. Soc. Sci. Fish. 45(5):623-6.
ABSTRACT: Several species of *Odontoceti* from the coastal waters of Japan were analysed for total mercury and selenium content in the muscle. The highest mercury content , 51.8 ppm, was found in Gills Bottle-nosed Dolphin (*Tursiops gilli*). The lowest value 0.16 ppm, was obtained in the foetus of Finless Black Porpoise (*Neophocaena phocaenoides*). The mean mercury contents were 4.63 ppm (0.95~9.43) in Blue White Dolphin (*Stenella caeruleo-alba*) and 4.16 ppm (3.01~5.18) in Pilot Whale (*Glolicephala melaena*). These values are rather high compared with those of marine mammals such as seals and whales. The mercury content in muscle increases linearly along with the age of animals. A high correlation was obtained between mercury and selenium content in the muscles of all species investigated. The molar ratio of mercury to selenium was about 1.5, indicating an excess of mercury in muscles.
KEY WORDS: heavy metals, Japan, marine mammals, mercury, *Odonteceti*, selenium.

Augier H, Park WK, and Ronneau C. 1993. Mercury Contamination of the Striped Dolphin *Stenella coeruleoalba* Meyen from the French Mediterranean Coasts. Mar. Poll. Bull. 26(6):306-11.
ABSTRACT: Total mercury content was determined by neutron activation analysis in tissues and organs of 13 striped dolphins *Stenella coeruleoalba* Meyen, beached along the French Mediterranean coasts. Analysis showed high values of mercury, with considerable variations according to location and the considered organs or tissues. The highest concentrations were found in the liver (from 68 to 2272 $g \cdot kg^{-1}$dry wt. Basis), then in the lung (from 3 to 396 $g \cdot g^{-1}$), kidney (from 14 to 341 $g \cdot g^{-1}$), muscle (from 7 to 155 $g \cdot g^{-1}$), heart (from 4 to 100 $g \cdot g^{-1}$) and brain (from 4 to 81 $g \cdot g^{-1}$). The possible implications of Hg in dolphin death is discussed, and various hypotheses are formulated about the origin of mercury in this sea and its possible uptake by dolphins.
KEY WORDS: French Mediterranean Coast, *Stenella coeruleoalba*, striped dolphins, total mercury, uptake.

Béland P, DeGuise S, Girard C, Lagacé A, Martineau D, Michaud R, Muir DCG, Norstrom RJ, Pelletier E, Ray S and others. 1993. Toxic Compounds and Health and Reproductive Effects in St. Lawrence Beluga Whales. J. Great Lakes Res. 19(4):766-75.

ABSTRACT: An epidemiologic study was carried out over a period of 9 years on an isolated population of beluga whales (*Delphinapterus leucas*) residing in the St. Lawrence estuary (Quebec, Canada). More than 100 individual deaths were aged, and/or autopsied and analyzed for toxic compounds, and the population was surveyed for size and structure. Arctic belugas and other species of whales and seals from the St. Lawrence were used for comparison. Population dynamics: population size appeared to be stable and modeling showed this stable pattern to result from low calf production and/or low survival to adulthood. Toxicology: St. Lawrence belugas had higher or much higher levels of mercury, lead, PCBs, DDT, Mirex, benzo[a]pyrene metabolites, equivalent levels of dioxins, furans, and PAH metabolites, and much lower levels of cadmium than Arctic belugas. In other St. Lawrence cetaceans, levels of PCBs and DDT were inversely related to body size, as resulting from differences in metabolic rate, diet, and trophic position, compounded by length of residence in the St. Lawrence basin. St. Lawrence belugas had much higher levels than predicted from body size alone; levels increased with age in both sexes, although unloading by females through the placenta and/or lactation was evidenced by overall lower levels in females and very high burdens in some calves. No PCDDs and only low levels of some PCDFs were detected in St. Lawrence belugas, while proportions of toxic non-ortho (coplanar) PCBs were low relative to proportions seen in other species. At least ten different PCB methylsulphone metabolites were detected in St. Lawrence belugas. Levels of B[a]P adducts to DNA in St. Lawrence beluga brain and liver approached those associated with carcinogens in small laboratory animals. Pathology: St. Lawrence belugas were not emaciated, and major findings were : a high prevalence of tumors (40% of animals) including eight malignant neoplasms; a high incidence of lesions to the digestive system (53%), to the mammary glands (45% of adult females), and to other glandular structures (11%); some evidence of immuno-suppression; frequent tooth loss and periodontitis. Two animals had sever ankylosing spondylosis and another was a true bilateral hermaphrodite. No such lesions were observed in 36 necropsies of Arctic belugas and of seals and cetaceans from the St. Lawrence.
KEY WORDS: Beluga whales, PCBs, population dynamics, St. Lawrence River, toxic substances.

Bacon CE, Jarman WM, and Costa DP. 1992. Organochlorine and Polychlorinated Biphenyl Levels in Pinniped Milk from the Arctic, the Antarctic, California and Australia. Chemosphere 24(6):779-91.

ABSTRACT: This study presents levels of organochlorines and polychlorinated biphenyls in pinniped milk samples collected from four geographical regions. These regions include the Arctic, the Antarctic, California and Australia. Twenty milk samples from five species of pinnipeds were analyzed for organochlorines and polychlorinated biphenyls. Analyses were carried out by high resolution gas chromatography/electron capture (HRGC/ECD) and high resolution has chromatography/low resolution mass spectrometry (GC-MS). All samples had detectable levels of p,p'-DDE(DDE) with geometric mean (geom. mean) values ranging from 12 g/kg in Antarctic fur seals to 1400 g/kg in California sea lions. Geom. mean values reported for DDE in northern hemisphere pinniped milk ranged between 14 and 118 times larger than values reported for southern hemisphere pinniped milk. In addition, every sample contained detectable levels of PCBs; the primary congeners reported include 99, 118, 153, 138, 180, and 187.

Geom. mean values reported for the sum of these six congeners range from 6.78 g/kg in Antarctic fur seals up to 360 g/kg in northern elephant seals from California. Pinniped milk samples from California contained the highest overall levels of organochlorines and polychlorinated biphenyls. DDT (and metabolites), chlordane compounds, and dieldrin were also detected in most samples with a wide range of levels reported.
KEY WORDS: milk, organochlorines, pinnipeds, pollutants, polychlorinated biphenyls.

Baker JR. 1992. The Pathology of Phocine Distemper. Sci. Total Environ. 115:1-7.
ABSTRACT: The gross and microscopic pathology of phocine distemper is described. The most striking features were pulmonary congestion and emphysema associated with proliferation of type II pneumocytes often forming syncytia. Secondary bacterial infection was common and associated with marked atrophy of lymphoid tissues and degenerative changes in the mucosa of the airways.
KEY WORDS: morbillivirus, pathology, phocine distemper, seals.

Ballachey BE, and Kloecker KA. 1997. Hydrocarbon Residues in Tissues of Sea Otters (*Enhydra lutris*) Collected Following the *Exxon Valdez* Oil Spill, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report Marine Mammal Study 6-16. U.S. Fish and Wildlife Service, Anchorage, Alaska .
ABSTRACT: Ten moderately to heavily oiled sea otters were collected in Prince William Sound early during the *Exxon Valdez* oil spill and up to seven tissues from each were analyzed for hydrocarbons. All of the animals had gross pathological lesions consistent with exposure to all tissues. The alkane series C20 through C30 frequently was observed at relatively high concentrations in all tissue types, as were the aromatic compounds naphthalene, its alkylated derivatives C1-C4-naphthalene, and biphenyl. Concentrations of aromatic hydrocarbons in fat samples were an order of magnitude higher than in other tissues. The patterns of distribution of these hydrocarbons suggested crude oil as the source of contamination. However, there was variation among oiled otters in the concentrations of individual hydrocarbons, which may be due to differing proximate causes of mortality and varying lengths of time the sea otters survived following oil exposure. The ability of sea otters and other mammals to metabolize the hydrocarbon compounds found in crude oil probably helped to reduce total concentrations of hydrocarbons and changed the distribution of individual hydrocarbons present in tissues. The concentrations of both aliphatic and aromatic hydrocarbons in the tissues of the ten oiled sea otters generally were higher than in tissues from 7 seal otters with no external oiling that were collected from Prince William Sound in 1989 and 1990, or from 12 sea otters collected from an area in southeast Alaska which had not experienced an oil spill.
KEY WORDS: carcasses, *Enhydra lutris*, *Exxon Valdez*, hydrocarbons, mortality, oil spill, sea otter.

Bandiera SM, Torok SM, Lin S, Ramsay MA, and Norstrom RJ. 1995. Catalytic and Immunologic Characterization of Hepatic and Lung Cytochromes P450 in the Polar Bear. Biochem. Pharmacol. 49(8):1135-46.
ABSTRACT: The Arctic Ocean is subject to considerable influx of anthropogenic pollutants including halogenated organic compounds. The polar bear (*Ursus maritimus*) is at the top of the arctic marine food web and is an ideal species for monitoring the level

and distribution of contaminants in the arctic ecosystem. As the first step in the development of a biological method for assessing the functional exposure of polar bears to xenobiotics, biochemical studies were undertaken to characterize polar bear cytochromes P450. Liver and lung samples were obtained in the field from four, freshly killed, adult, male polar bears and immediately frozen at -196 degrees. Microsomes were subsequently prepared and used for the measurement of total cytochrome P450 content and animopyrine N-demethylase, benzphetamine N-demethylase, ethylmorphine N-demethylase, ethylmorphine N-demethylase, p-nitrophenol hydroxylase and testosterone hydroxylase activities. Immunoblots containing hepatic and lung microsomal samples from the polar bears were probed using antibodies generated against several purified rat cytochrome P450 isozymes. Monoclonal antibody to rat cytochrome P450 1A1 and polyclonal antibodies to rat cytochrome P450 1A1, 2B1 and 3A1, as well as antibody to epoxide hydrolase, cross-reacted to varying degrees with polar bear hepatic microsomes. In addition, polyspecific antibody to the rat cytochrome P450 2C subfamily gave several immunostained protein bands, but antibodies specific to rat cytochrome P450 2C11 yielded an ambiguous result. Except for anticytochrome P450 2B1 and polyspecific antibody to the cytochrome P450 2C subfamily, the antibodies listed above did not cross-react with polar bear lung microsomes at the protein concentrations used. The results demonstrate that polar bear liver contains multiple forms of cytochrome P450 that are catalytically active toward diverse substrates and that several of these forms are immunochemically related to rat cytochrome P450 isozymes. Immunochemical homologues of rat cytochrome P450 1A, 2B, 2C and 3A subfamilies, and of rat epoxide hydrolase are present in polar bear liver. In addition, the polar bears all had high levels of immunoreactive cytochrome P450 1A and 2B proteins, probably as a consequence of induction by environmental contaminants.
KEY WORDS: Arctic Ocean, cytochrome P450, environmental contaminants, polar bear, xenobiotics,

Barnes DG. 1991. Toxicity Equivalents and EPA's Risk Assessment of 2,3,7,8-TCDD. Sci. Total Environ. 104:73-86.
ABSTRACT: Toxicity equivalent factors (TEFs) have proved useful in estimating the toxicity of complex mixtures of chlorinated dibenzo-*p*-dioxins and dibenzofurans (CDDs/CDFs). An international consensus has formed around a specific set of TEF values as interim solution for addressing environmental contamination by CDDs/CDFs. This procedure capitalizes on the congener-specific analytical results that are more routinely available in recent years. The TEF approach should be updated as necessary and replaced by more definitive bioassay approaches as soon as practicable. In an independent activity, the USEPA considered a proposal to change (reduce) the cancer potency ascribed to 2,3,7,8-TCDD by a factor of 16. The recommendation was based upon an analysis of the literature and the Agency's earlier risk assessment. The proposal was reviewed by the Science Advisory Board, a group of outside scientific advisors. Subsequently, the Agency decided against making any changes in its assessment at this time. However, it is likely that a reassessment will be conducted shortly that will incorporate new data and a new app4oach to estimating of cancer risks posed by 2,3,7,8-TCDD.
KEY WORDS: bioassay, cancer risk, CDDs/ CDFs, toxicity equivalent factors, 2,3,7,8-TCDD,.

Beck KM, Fair P, McFee W, and Wolf D. 1997. Heavy Metals in Livers of Bottlenose Dolphins Stranded along the South Carolina Coast. Mar. Poll. Bull. 34(9):734-9.
ABSTRACT: This report discusses the results of liver samples taken from stranded bottlenose dolphins along the South Carolina coast and analyzed for heavy metals, including As, Cd, Cr, Cu, Pb, Hg, Se and Zn. This data provides some of several parameters that are necessary for the health assessment of the dolphin population in these coastal waters. The accumulation of toxic elements may vary depending on biochemical regulatory mechanisms. Information on the level of contaminants in marine mammals over time would determine whether bioaccumulation is occurring, and may have application in predicting populations at risk.
KEY WORDS: bioaccumulation, bottlenose dolphin, contaminants, heavy metals, mercury, South Carolina.

Becker PR, Mackey EA, Demiralp R, Suydam R, Early G, Koster BJ, and Wise SA. 1995. Relationship of Silver with Selenium and Mercury in the Liver of Two Species of Toothed Whales (Odontocetes). Mar. Poll. Bull. 30(4):262-71.
ASTRACT: Liver specimens archived in the National Biomonitoring Specimen Bank from beluga whales, *Delphinapterus leucas*, and from Alaska and pilot whales, *Globicephala melas*, from the North Atlantic were analysed for silver, selenium and total mercury. Silver concentrations in beluga whales were one to three orders of magnitude higher than the concentrations in pilot whales and those reported elsewhere for other marine mammals. The concentrations of silver in the livers of beluga whales were the same or in some instances higher than the concentrations of selenium or mercury. Like mercury, silver was positively correlated with selenium in both pilot and beluga whales. This suggests a possible role for selenium in the accumulation and storage of silver in both species of whales, and raises questions about the potential for silver at such high concentrations to affect radical-scavenging enzyme systems in these marine mammals.
KEY WORDS: accumulation, liver, marine mammals, mercury, odontocetes, selenium, toothed whales.

Becker PR, Koster BJ, Wise SA, and Zeisler R. 1990. Alaskan Marine Mammal Tissue Archival Project. In: Schrauzer, G.N. (Ed)., Biological Trace Element Research, The Humana Press, Inc. 329-34.
ABSTRACT: A project to establish an archive of Alaskan marine mammal tissues was conceived in 1987 to be a part of the National Biomonitoring Specimen Bank (NBSB). Protocols and field collection of marine mammals, long-term storage, and analysis are summarized in this paper. Instrumental neutron activation analysis has been used for an initial evaluation of trace element content in samples of northern fur seal (*Callorhinus ursinus*) from the Pribilof Islands. The findings agree with previously observed trace element levels in northern fur seals. The archived specimens can be used in future studies when comparisons of past and present pollution levels are needed.
KEY WORDS: Alaska, long-term storage, marine mammals, neutron activation analysis, northern fur seal, ringed seal, specimen bank, trace element analysis.

Beckman K. unpublished. Immunotoxicology of Northern Fur Seals. Institute of Arctic Biology, Fairbanks, Alaska .
KEY WORDS: Alaska, blood, blubber, contamination, DDE, DDT, marine mammals,

milk, northern fur seal, organochlorines, PCB, toxicology.

Bergman A, and Olsson M. 1985. Pathology of Baltic Grey Seal and Ringed Seal Females with Special Reference to Adrenocortical Hyperplasia: Is Environmental Pollution the Cause of a Widely Distributed Disease Syndrome? Finnish Game Res. 44:47-62.
ABSTRACT: Sixty-one grey seal (*Halichoerus grypus*) and 24 ringed seal (*Phoca hispida botnica*) females found dead on the shore or caught in fishing tackle in the Baltic have been investigated macroscopically. The condition of nineteen of the grey seals and ten of the ringed seals was so fresh that the autopsies could be followed by histological examinations. Uterine stenoses and occlusions were present in 30 per cent of the adult grey seals. The corresponding figure for ringed seals was 70 per cent. Uterine tumours (Leiomyomas) were common in older grey seals but not found in ringed seals. Common lesions in other organs of both species were regional chronic intestinal ulcers, bilateral adrenocortical hyperplasia, arteriosclerosis and renal glomerulopathy. In some grey seals regional bilaterally symmetric skin changes were observed as a thin epidermis, hyperkeratosis and cystic dilatations of hair follicles. Deformations and fractures of the claws were found in some grey seals. Because of the high frequency and character of the lesions that occurred in combination in the individuals, the influence of exogenous toxins such as PCB and other organochlorines is believed to be part of a disease complex. This influence seems to interfere primarily with the endocrine system causing changes similar to those present in hyperadrenocorticism.
KEY WORDS: adrenocortical hyperplasia, Baltic grey seal, endocrine system, exogenous toxins, organochlorines, ringed seal.

Bergman A, Olsson M, and Reiland S. 1992. Skull-bone Lesions in the Baltic Grey Seal (*Halichoerus grypus*). Ambio 21(8):517-9.
ABSTRACT: The prevalence of skull-bone lesions in adult grey seals (*Halichoerus grypus*) was significantly higher in a late Baltic sample collected after 1960 compared with the prevalence found in grey seals skulls in an early Baltic sample, collected before 1950, and in a sample from the British Isles. The lesions were consistent with those present in severe periodontitis, quite often with substantial loss of alveolar bone in the mandible and maxilla. A suggested cause of the high prevalence of skull-bone lesions in the Baltic sample collected during the last decades in the toxic influence of environmental pollutants such as organochlorines.
KEY WORDS: environmental pollutants, grey seals, *Halichoerus grypus*, skull-bone lesions, toxicity.

Bernhoft A, Wiig O, and Skaare JU. 1997. Organochlorines in Polar Bears (*Ursus maritimus*) at Svalbard. Env. Poll. 95(2):159-75.
ABSTRACT: A comprehensive survey on organochlorine (OC) contaminants in polar bears at Svalbard has been undertaken. Subcutaneous tissue, blood and milk have been sampled from anesthetized free-ranging bears of both sexes and different ages in the period from 1990 to 1994. A number of sexually mature females have been fitted with satellite transmitters which make it possible to follow their reproductive behaviour patterns. We report on contamination levels and pattern of PCB congeners, chlordanes, DDT-compounds, HCB and HCH-isomers in the various tissues. The relation of age, sex and reproductive status to OC contamination has been described, and the capacity of

polar bears in metabolising OCs has been discussed from the isomer/metabolite composition of residues. Finally, the possible association between OC contamination and reproduction success has been assessed. The PCB levels present in polar bears at Svalbard are extremely high. Especially high levels of higher chlorinated PCBs are found, and they accumulate with age, particularly in males. With females, considerable amounts of OCs are transferred to the offspring via milk. However, more efficient OC transfer between subcutaneous depot lipid and circulatory lipids than from the circulatory system to milk is found particularly for the most lipophilic compounds. The OC pattern in suckling yearlings reflects the low transfer of the highest chlorinated PCBs into maternal milk. The levels of most other OCs, however, are higher in depot lipid of yearlings than in that of their mothers. The polar bears have high capacity to metabolise several OCs. This may protect them against toxic action of the contaminants. No relation between OC levels in females and their ability to get pregnant is found in this preliminary investigation on OC effects on the polar bears at Svalbard.
KEY WORDS: maternal milk, organochlorine contaminants, polar bears, reproduction success, Svalbard, *Ursus maritimus*.

Bidleman TF, Patton GW, Walla MD, Hargrave BT, Vass WP, Erickson P, Fowler B, Scott V, and Gregor DJ. 1989. Toxaphene and Other Organochlorines in Arctic Ocean Fauna: Evidence for Atmospheric Delivery. Arctic 42(4):307-13.
ABSTRACT: Residues of the insecticide toxaphene (polychlorinated camphenes, PCCs) and other organochlorines (OCs) were determined in air, snow, seawater, zooplankton, and benthic amphipods collected from an ice island in the Canadian Arctic. The simultaneous determination of OCs in the atmospheric, hydrologic, and biologic compartments provided evidence of an atmospheric link to polar food chains. PCCs were identified and quantified using capillary gas chromatography - negative ion mass spectrometry. The order of OC abundance in arctic air was: hexachlorocyclohexanes (HCHs) > hexachlorobenzene > PCCs > polychlorinated biphenyls (PCBs) > chlordanes > DDTs. In seawater, PCCs were exceeded only by the HCHs. Concentrations of PCBs and PCCs in two samples of benthic amphipods were the highest of the OCs detected.
KEY WORDS: air, Arctic, biota, Canada, organochlorines, pollution, water.

Bidleman TF, Walla MD, Muir DCG, and Stern GA. 1993. Selective Accumulation of Polychlorocamphenes in Aquatic Biota from the Canadian Arctic. Env. Tox. Chem. 12:701-9.
ABSTRACT: Polychlorocamphenes (PCCs; e.g., toxaphene) are major organochlorine contaminants in fish, marine mammals, and other aquatic life from the Arctic. Because PCCs yield complex GC patterns that are often greatly altered in environmental samples compared to a toxaphene standard, identification by GC with electron-capture detection is problematic. We examined PCC profiles in the blubber of narwhal (*Monodon monoceros*) and the liver of freshwater burbot (*Lota lota*) from the Canadian Arctic by GC-negative ion mass spectrometry (GC-NIMS). Chromatograms of these specimens showed that certain PCCs were greatly enriched, compared to a toxaphene standard. Mass spectra of accumulated PCCs were consistent with octachloro-and nonachlorobornanes, with possible contribution from chlorinated bornenes. Corresponding GC peaks in the toxaphene standard appeared to be mixtures of seven- and eight-chlorine or eight- and nine-chlorine PCCs. The same peaks in biological

samples showed selective accumulation of the more highly chlorinated components. To properly characterize the levels and biological effects of PCCs in arctic food chains will require isolation or synthesis of pure PCC congeners and an evaluation of their physiochemical and toxicological properties.
KEY WORDS: Arctic, bioaccumulation, mass spectrometry, organochlorine pesticides.

Boon JP, Oostingh I, van der Meer J, and Hillebrand MT. 1994. A Model for the Bioaccumulation of Chlorobiphenyl Congeners in Marine Mammals. Eur. J. Pharmacol. 270(2-3):237-51.
ABSTSRACT: The behaviour of chlorobiphenyls in marine mammals is best described by a pharmacokinetic model where the blood acts as the central transport compartment between the external environment and a number of peripheral organs, each maintaining a dynamic balance with the concentrations in the blood. Thus, blood samples can be a useful tool in monitoring programmes of chlorobiphenyl concentrations. Differences in the chlorobiphenyl patterns between seals and fish could be explained by the structure-biotransformation relationship developed in an experimental study. A harbour porpoise (*Phocoena*) seemed also able to metabolize chlorobiphenyl congeners with vicinal hydrogen atoms in the meta and para positions and two ortho-Cl atoms. Because the ratios between persistent and metabolizable congeners differed between specimens, it was not possible to derive dioxin type toxic equivalents from concentrations of congeners occurring at much higher concentrations by calculation of their ratios.
KEY WORDS: bioaccumulation, blood samples, chlorobiphenyls, congeners, marine mammals.

Boon JP, van der Meer J, Allchin CR, Law RJ, Klungsoyr J, Leonards PEG, Spliid H, Storr-Hansen E, Mckenzie C, and Wells DE. 1997. Concentration-dependent Changes of PCB Patterns in Fish-eating Mammals: Structural Evidence for Induction of Cytochrome P450. Arch. Environ. Contam. Toxicol. 33(3):298-311.
ABSTRACT: Data sets on CB concentrations in fish-eating mammals from five laboratories were combined to test and refine a pharmacokinetic model. Clear differences in PCB patterns were observed between species. The ability to metabolize chlorobiphenyl (CB) congeners with vicinal H-atoms only in the ortho- and meta-positions and with one ortho-chlorine substituent generally increased in the order otter<cetaceans (harbor porpoise, common dolphin)< phocid seals (harbor and grey seal), but the metabolism of congeners with vicinal H-atoms in the meta- and para-positions and with two ortho-chlorines increased in the order cetaceans <seals<otter. Both categories of congeners are probably metabolized by different families of cytochrome P450 (1A and 2B) of which levels apparently differed between the cetaceans, the pinnipeds, and the otter. Within-species CB patterns differed in a concentration-dependent manner. The induction of cytochrome P450 enzymes offers the most likely explanation for this phenomenon, but starvation could have a similar effect on occasion.
KEY WORDS: chlorobiphenyl congeners, fish, marine mammals, P450 enzyme.

Born EW, Kraul I, and Kristensen T. 1981. Mercury, DDT and PCB in the Atlantic Walrus (*Odobenus rosmarus rosmarus*) from the Thule District, North Greenland. Arctic 34(3):255-60.
ABSTRACT: Tissue samples of 69 Atlantic walruses (*Odobenus rosmarus rosmarus*)

were collected in the Thule district, North Greenland, in May-July 1975 and 1977. The mean concentration of total mercury in liver was 1.78 $mg \cdot kg^{-1}$ (SD=1.54; N=46), wet weight basis, with the mean percentage of methyl mercury being 5.5%. The mean concentration in muscle was 0.08 $mg \cdot kg^{-1}$ (SD=0.05; N=58; mean age = 10.9 years; range 1-26 years; neonates excluded). In neonates (N=9) the mean concentration of total mercury was 0.31 $mg \cdot kg^{-1}$ (SD=0.45) in liver (19.9% methyl mercury) and 0.06 $mg \cdot kg^{-1}$ (SD=0.03) in muscle. Mean DDT and PCB concentrations in blubber of 28 walruses (mean age=7.4 years; range: 0-19 years) were 0.063 $mg \cdot kg^{-1}$ (SD=0.080) and 0.221 $mg \cdot kg^{-1}$ (SD=0.207), respectively. In males, the concentration of DDT and PCB increased with age. In females there was no correlation between the concentration of DDT and age, while there was a negative correlation between the concentration of PCB and age. The values of mercury concentrations are low compared with values for seals in Greenland and the eastern Canadian Arctic, and the values of organochlorine concentrations are the lowest reported for pinnipeds.
KEY WORDS: Atlantic walrus, DDT, mercury, North Greenland, *Odobenus rosmarus rosmarus*, PCB.

Borrell A, Aguilar A, and Pastor T. 1997. Organochlorine Pollutant Levels in Mediterranean Monk Seals from the Western Mediterranean and the Sahara Coast. Mar. Poll. Bull. 34(7):505-10.
ABSTRACT: Blubber samples from 31 Mediterranean monk seals from the Sahara coast (Atlantic ocean) and from 2 individuals from the northern coast of Africa (western Mediterranean) were analysed for DDTs and PCBs. Seals from both regions carried qualitatively similar pollutant profiles although levels were significantly higher in the individuals from the western Mediterranean than in those from the Sahara coast. Western Mediterranean seals presented higher relative abundance of recalcitrant PCB congeners in relation to those labile. This was associated with higher levels of enzyme induction in Mediterranean individuals, and therefore of their metabolic capacity, than in seals from the Sahara coast. Effects of organochlorine pollution in the Sahara coast population are considered to be negligible. Conversely, organochlorine levels detected in the single western Mediterranean monk seal male analysed were higher than thresholds commonly associated with immune depression and reproductive impairment in other pinnipeds. Given the extremely low number of monk seals surviving in the Mediterranean today, this possibility is a matter of serious concern.
KEY WORDS: DDT, monk seal, organochlorine, PCB, western Mediterranean, Sahara coast.

Borrell A, Aguilar A, Corsolini S, and Focardi S. 1997. Evaluation of Toxicity and Sex-Related Variation of PCB Levels in Mediterranean Striped Dolphins Affected By An Epizootic. Chemosphere 32(12):2359-69.
ABSTRACT: Individual PCB congener concentrations, including non-ortho chloro substituted, were determined in 30 striped dolphins (*Stenella coeruleoalba*) affected by the 1990-92 Mediterranean epizootic to investigate their toxic potential. PCB congener concentrations in these dolphins were among the highest ever found in comparable studies on marine mammals. Concentrations in males and females were significantly different because of pollutant transfer to offspring by females. Thus, PCB concentrations and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents (TEQ) in males were

approximately double those in females. Non-ortho, mono-ortho and di-ortho coplanar congeners accounted for approximately one third of the overall toxicity assessed through toxic equivalent factors (TEFs), as defined by Ahlborg et al. (1994). Di-ortho congener 170 and non-ortho congener 126 were the major contributors to TEQ (33% and 30% respectively).
KEY WORDS: bioaccumulation, marine animals, marine mammals, Mediterranean Sea, PCB, pollution effects, polychlorinated biphenyls, sex, *Stenella coeruleoalba*, TCDD, water pollution effects.

Borrell A, and Aguilar A. 1990. Loss of Organochlorine Compounds in the Tissues of a Decomposing Stranded Dolphin. Bull. Environ. Contam. Toxicol. 45:46-53.
ABSTRACT: A large number of organochlorine pollution surveys in cetaceans have been traditionally carried out on samples from stranded individuals, which are found in variable states of freshness and from which the cause of death can often not be ascertained. Tissue specimens from a stranded animal are hardly ever collected immediately after the cetacean's death, but carcasses usually remain on the beaches under different conditions of conservation over a variable period of time before being sampled. During this outdoor exposure, pollutants may be affected by a number of physical and biological agents. The pattern of variation in organochlorine pollutants in the tissues of a fresh dolphin carcass left under outdoor conditions for 55 days is examined at different time intervals, and the importance for common field-work situations is discussed.
KEY WORDS: carcasses, chemical pollutants, DDE, DDT, decomposition, degradation, Delphinidae, 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane, dolphins, PCB, pesticides (organochlorine), stranding, time series, tissues.

Borrell A, and Aguilar A. 1987. Variations in DDE Percentage Correlated with Total DDT Burden in the Blubber of Fin and Sei Whales. Mar. Poll. Bull.18(2):70-4.
ABSTRACT: Total DDT burden and DDE percentage (DDE/DDT+TDE+DDE) in the blubber of fin and sei whales are highly correlated. Total DDT concentration may be an important source of variation for the DDE percentage detected in different individuals of the same population. Such a positive correlation is explained by the intensification of the dehydrochlorinative and differential excretive functions at higher pollutant levels. In the past, variations in the DDE percentage have been attributed to differences in the chronology of DDT input into the ecosystem and assumed to be indicators of population discreteness or changes in the pattern of DDT exposure of a given population. However, changes in the DDE percentage as related to total DDT burden may be important within the observed normal ranges of variation of total DDT residue levels caused by age and sex composition of the population. Therefore, the DDE percentage may be reliably used only when full control of the life history parameters of the sample is achieved and when strict homogeneity among the samples to be compared has been proved.
KEY WORDS: blubber, DDT, Fin whale, homogeneity, pollutant levels, population, Sei whale.

Botta JR, Arsenault E, and Ryan HA. 1983. Total Mercury Content of Meat and Liver from Inshore Newfoundland-caught Harp Seal (*Phoca groenlandica*). Bull. Environ. Contam. Toxicol. 30:28-32.
ABSTRACT: Total mercury content of meat and liver samples of harp seals, *Phoca*

groenlandica, of different ages were determined from animals shot in March and April, 1980 in White Bay, Newfoundland. Differences between sexes and total mercury content were observed although they were not consistent with either the carcass cut or the liver. Total mercury content of carcass cuts of harps seals 4 years and older were below acceptable Canadian limit of 0.5ppm. The liver samples exceeded this limit by a wide margin, except for a few samples taken from beaters. Therefore, meat but not liver from inshore Newfoundland seal hunt was acceptable for human consumption.
KEY WORDS: harp seal, mercury, Newfoundland, *Phoca groenlandica*.

Bowes GW, and Jonkel CJ. 1972. Polychlorinated Biphenyl (PCB) Identification in Marine Arctic and Subarctic Food Chains. Presented at the American Chemical Society 164th National Meeting, New York City, August 27-September 1, 1972.
ABSTRACT: The results of a systematic study of the penetration of the polychlorinated biphenyls (PCB) into the Arctic and Subarctic are presented. The study is divided into 2 parts. The first part examines the residue level in marine life (polar bears, seals, fish, zooplankton) in Canadian Territory. The second part extends the first to include a comparative analysis of similar animals from the entire circumpolar region bounded by Norway, Greenland, Canada, the United States (Alaska), and the Soviet Union. The present report will discuss the first part of the study.
KEY WORDS: Arctic, fish, food chains, marine organisms, polychlorinated biphenyls, polar bears, seals, Subarctic.

Bowles D. 1994. An Overview of the Concentrations and Effects of Heavy Metals in Cetacean Species. Presented to the International Whaling Commission, Scientific Committee. SC/46/O 20.
KEYWORDS: Alasks, cetacean, contamination, heavy metals, marine mammals, North West Pacific.

Bowles D, Brown K, and Reeve RVA. 1993. The Incidence of Organochlorine Compounds in the North West Pacific Region with Special Reference to Their Impact on Cetaceans. Presented to the International Whaling Commission, Scientific Committee. SC/45/O 17.
KEYWORDS: Alasks, cetacean, contamination, marine mammals, North West Pacific, organochlorines.

Bratton GR, Flory W, and Spainhour CB. 1990. Environmental Pollutant Levels in Selected Tissues from Subsistence Harvested Bowhead Whales. In: T.F. Albert (Ed). Fifth Conference on the Biology of the Bowhead Whale, *Balaena Mysticetus*. Extended Abstracts and Panel Discussions. 115-22.
ABSTRACT: This report determines levels of heavy metals from samples of subsistence harvested Bowhead whales taken from Barrow and Kaktovic, Alaska from 1986 and 1988. Little is known about the current levels of these pollutants in the Arctic areas that these whales inhabit. Heavy metal levels found in this study are compared to other whale species and domesticated animals. The levels of metals found in Bowhead whales were similar to levels found in domestic mammals.
KEY WORDS: Alaska, *Balaena mysticetus*, bowhead whales, domesticated animals, heavy metals, marine mammals.

Bratton GR, Flory W, Spainhour CB, and Haubold EM. 1997. Assessment of Selected Heavy Metals in Liver, Kidney, Muscle, Blubber, and Visceral Fat of Eskimo Harvested Bowhead Whales *Balaena mysticetus* from Alaska's North Coast. Final Report, North Slope Borough Contracts #89-293; #90-294 :233 pp.

ABSTRACT: Kidney, liver, muscle, blubber, and visceral fat were collected from bowhead whales (*Balaena mysticetus*) captured by Eskimo subsistence hunters in the spring and fall of 1983-1990 (except for 1985). Tissues were taken from a total of 41 whales (18 females, 22 males, and 1 male fetus). Eight metals, (arsenic, cadmium, copper, iron, mercury, lead, selenium, and zinc), were reported on a wet weight basis (ug metal/gram of tissue) in tissues of bowhead whales. These eight metals were chosen because (1) they are the most common metal reported in the literature for cetaceans, (2) some represent the most toxic to marine organisms, (3) they are the most likely to enter the Arctic anthropogenically, (4) they are the most likely metals to enter the Eskimo food chain, and (5) since several of these metals (copper, selenium, iron, and zinc) are required for normal human health, it is important to know if whale tissue in the Eskimo diet would supply adequate levels of these metals to the consumers. Unfortunately, the data represent metal concentrations in these animals at a single point in time. Since metal concentrations are in a dynamic state, the data do not indicate how metal concentrations would change over time. In addition, the sample size is too small to establish statistically competent data for most questions of importance. Even so, generalizations and trends are worthy of reporting and should prove worthwhile for future studies. In conclusion, these data indicate that in relation to metals, the tissues from bowhead whales are, in general, nutritious and safe to consume. It is also indicated that the bowhead whale has little metal contamination as compared to other examined arctic marine mammals, except for cadmium, which requires further investigation as to its role in human and bowhead whale health. The only recommendation is to limit consumption of kidney from large bowhead whales pending further evaluation. This is simply a precaution, as there is no evidence it is causing harm. Otherwise, people should continue to consume and enjoy the products of the bowhead whale.

KEY WORDS: Alaska, *Balaena mysticetus*, bowhead whales, cetaceans, heavy metals, risk assessment.

Bratton GR, Flory W, Spainhour CB, and Haubold EM. 1994. An Assessment of Selected PAH's, Pesticides, Phenols and Chlorinated Biphenyls in Visceral Fat and Blubber of the Bowhead Whale *Balaena mysticetus*, and Grey Whale *Eschrictus robustus*, From Along Alaska's North Coast. Final Report on Chlorinated Hydrocarbons for the Period Through (North Slope Borough Contracts #89-293; #90-294) Submitted to Department of Wildlife Management .

ABSTRACT: Tissue samples were collected from bowhead whales (*Balaena mysticetus*) and grey whale (*Eschrictus robustus*) from North Slope Borough, Alaska during an eight year period (1983-1990). Tissues were analyzed for accumulated pesticides and PAHs and comparisons were made with known levels of contaminants in other marine mammal species. The potential hazards of the contaminant levels in humans who subsistence hunt bowhead whales is also evaluated. Napthalene was the most commonly detected compound although concentrations were not significant. Although there was a lack of evidence to conclude that pesticides may be a concern for continued survival of the bowhead whale, the levels observed in several whales would

suggest a concern for the native Eskimos who consume blubber and visceral fat from these animals. More information is still needed in regard to the polyaromatic hydrocarbons whose health hazard can only be surmised.
KEY WORDS: Alaska's north coast, bowhead whale, contaminants, eskimos survival, grey whale, North Slope Borough, pesticides, polyaromatic hydrocarbons.

Brody M. 1989. Explaining Sea Mammal Deaths Proves Challenging. ASM News 55(11):595-8.
ABSTRACT: This report discusses the probable cause of the mass bottlenose dolphin (*Tursiops truncatus*) deaths in 1987 along the mid-Atlantic coast of the U.S. The U.S. Marine Mammal Commission developed a clinical investigation team, headed by Joseph Geraci of the Ontario Veterinary College at the University of Guelph, Ontario, Canada, made up of several experts from a number of agencies. The initial and primary hypothesis was that the deaths were due to massive poisoning by brevetoxin, a neurotoxin produced by the phytoplankton *Ptychodiscus brevis*. This cause has been reviewed and discussed further along with other alternative explanations, including exposure to toxic chemicals in the water that caused chemical injuries to the dolphins skin, mouth, lips and blowhole regions. Currently, the primary cause has not been resolved but agreements have been established that more research needs to be implemented to find the answer.
KEY WORDS: bottlenose dolphin, brevetoxin, mass die-off, marine mammals, mid-Atlantic coast.

Bruhn R, Kannan N, Petrick G, Schulz-Bull DE, and Duinker JC. 1995. CB Pattern in the Harbour Porpoise: Bioaccumulation, Metabolism and Evidence for Cytochrome P450 IIB Activity. Chemosphere 31(7):3721-32.
ABSTRACT: Metabolism of chlorobiphenyls (CBs) was studied in harbour porpoise by comparing patterns of CB-X/CB-153 ratios in blood, brain, liver and blubber with the patterns in herring, the main food source. The CBs were classified in five groups, based on the presence/absence of vicinal H-atoms (vic. Hs) in meta,para (m,p) and/or ortho,meta (o,m) positions and the number of ortho-Cl-atoms (ortho-Cls). Plots of CB-X/CB-153 ratios in porpoise tissue vs the ratios on herring appeared to be linear for each CB group in all tissues. Slopes of these plots (metabolic slopes) were used as quantitative indicators of metabolic activity. In this way, activity of PB-type isozymes of the P450 monooxygenase system was apparent: in contrast to existing literature data, harbour porpoise appears to be able to metabolize congeners with m,p vic. Hs, even in the presence of more than 2 ortho-Cls. The presence of 3-MC-type (MC-type) isozymes was also detected. The metabolic slopes were also used as basis for risk assessment. Due to their metabolism the most toxic non-ortho CBs were not present in the tissues at detectable levels. We suggest a risk assessment approach which takes this into account. It is considered to be an alternative and more reliable basis for risk assessment than the use of toxic equivalent factors. The results support the model of equilibrium distribution of CBs in harbour porpoise and the role of blood a central transport medium. The model has been developed for persistent compounds; it appears to hold for metabolizable CB congeners as well.
KEY WORDS: chlorobiphenyls, cytochrome P450 IIB activity, harbour porpoise.

Burns JJ. unpublished. Unpublished Paper on Contamination of Heavy Metals in Bearded Seals. Alaska Department of Fish and Game, Wildlife Conservation, Fairbanks, Alaska .

KEY WORDS: Alaska, bearded seal, blubber, heavy metals, kidney, liver, marine mammals, muscle.

Byrne C, Balasubramanian R, Overton EB, and Albert TF. 1985. Concentrations of Trace Metals in the Bowhead Whale. Mar. Poll. Bull. 16(12):497-8.
ABSTRACT: This report presents the concentrations of trace metals in the bowhead whale, *Balaena mysticetus* . The western Arctic stock of bowhead whales inhabit the Bering, Chukchi, and Beaufort Seas.
KEY WORDS: Arctic, bowhead whale, marine mammals, trace metals.

Calambokidis J. 1986. Chlorinated Hydrocarbons in Harbor Porpoise from Washington, Oregon, and California: Regional Differences in Pollutant Ratios. Southwest Fisheries Science Center, National Marine Fisheries Service Administration Report LJ-86-35C :29 pp.
ABSTRACT: Concentrations of PCB, DDE, HCB were examined in 51 blubber samples collected from 36 harbor porpoise collected along the coasts of Washington, Oregon, and California. The primary purpose of the study was to test for regional patterns in the concentrations of contaminants and their ratios and to evaluate the feasibility of using contaminants to gain information about the degree of intermixing of harbor porpoise along the west coast of North America. Strong regional patterns were found in both the concentrations of DDE and the ratios of various contaminants. Contaminant ratios were far less variable then individual contaminant concentrations and were therefore more useful for examining regional patterns. The ratios of DDE/PCB and HCB/DDE showed the most dramatic differences by location with highly significant differences by state (ANOVA, $p<0.001$) and a strong correlation ($p<0.001$) between the ratio and latitude that the samples were collected. Within California samples from 3 subregions showed significant differences in contaminant ratios, though sample size was limited. The use of contaminant ratios to gain information on geographic interchange of harbor porpoise appears promising, especially in areas like California where the presence of pollutants in the marine environment varies widely by location. Significant patterns were also found in contaminant concentrations by year collected, animals length, and blubber thickness. Replicate samples of the blubber taken from different locations on the bodies of two harbor porpoise showed minimal variation. Only samples from the dorsal peduncle area of the porpoise deviated from values obtained from other parts of the body.
KEY WORDS: contaminants, DDE, harbor porpoise, pollution, polychlorinated biphenyls, west coast of North America.

Calambokidis J. 1987. Contaminant Concentrations in Northern Fur Seals and Preliminary Evaluation of Risk from Consumption. Final Report for Purchase Order No. 40-HANF-7-00013, National Marine Fisheries Service, Juneau, Alaska, February, 1987. 10 pp.
ABSTRACT: This report summarizes the results contaminant analyses of northern fur seals tissues collected during 1986 on St. George Island, Alaska. Concern over possible adverse health effects of consumption of northern fur seal tissues prompted testing of these tissues. A preliminary evaluation of the potential adverse health effects of consumption of these tissues is presented here, based on comparison to maximum consumption levels recommended by the Food and Drug Administration (FDA) and the World Health Organization (WHO) and health risk assessments procedures summarized by Tetra Tech (1986).

KEY WORDS: Alaska, contaminants, health effects, northern fur seals.

Calambokidis J, and Peard J. 1982. Chlorinated Hydrocarbons in the Tissues of Northern Fur Seals from St. Paul Island, Alaska. In: Kozloff, P (Ed). Fur Seal Investigations, 1982. NOAA Technical Memorandum NMFS-F/NWC-71. 75-79 pp.
ABSTRACT: Tissue samples of subadult male northern fur seals were taken in 1980 from St. Paul Island, Alaska. Tissues were analyzed for concentrations of polychlorinated biphenyls and DDT, two of the most prevalent chlorinated hydrocarbons in the environment. Concentrations of PCB and DDE were higher in blubber than in the liver samples. Both contaminants were below the levels detected in other pinniped species showing reproductive dysfunctions. Although there is no evidence that chlorinated hydrocarbons have an effect on fur seals, the monitoring of these pollutants is essential.
KEY WORDS: Alaska, chlorinated hydrocarbon, DDT, northern fur Seal, polychlorinated biphenyls, reproductive dysfunctions.

Cameron ME, Metcalfe TL, Metcalfe CD, and Macdonald CR. 1997. Persistent Organochlorine Compounds in the Blubber of Ringed Seals (*Phoca hispida*) from the Blecher Islands, Northwest Territories, Canada. Marine Environ. Res. 43(1-2):99-116.
ABSTRACT: Samples of blubber and morphometric data were obtained in 1991 from a population of *Phoca hispida* located in southeastern Hudson Bay near the Belcher Islands. Several PCB congeners, DDT and its metabolites, components of technical chlordane, HCH compounds, dieldrin and mirex were detected at concentrations below 150 ng/g lipid in the blubber. There was evidence that the male seals from the Belcher Islands had higher concentrations and blubber burdens of total PCBs and lower concentrations of total HCHs than male seals sampled in 1989 from a population at Holman Island in the northwest Canadian arctic. Morphometric data indicated that the Holman Island seals were in better condition than the Belcher Islands seals at the time of sampling.
KEY WORDS: DDT, dieldrin, Holman Island, Hudson Bay, morphometric, PCB congener, ringed seal.

Cardellicchio N. 1995. Persistent Contaminants in Dolphins: An Indication of Chemical Pollution in the Mediterranean Sea. Wat. Sci. Tech. 32(9-10):331-40.
ABSTRACT: Concentrations of metals (mercury and methylmercury, selenium, cadmium, lead), chlorinated pesticides and polychlorinated biphenyls (PCB) have been determined in tissues and organs of *Stenella coeruleoalba* dolphins beached along the Adriatic and Ionian coasts of Apulia (Southern Italy). The results obtained confirm that in Mediterranean dolphins the accumulation of contaminants is higher than in similar species living in the Atlantic. Therefore cetaceans can be considered organisms indicating pollution. Accumulation is influenced by factors such as diet, age and sex. Reproduction plays a fundamental role in the elimination of toxic compounds in females. Correlation between contamination and death has not been found; however it is clear that pollutants at sub-lethal doses have neuro-toxic effects, increase stress and alter immune-defenses, leaving the organism at a greater risk from disease.
KEY WORDS: bioaccumulation, dolphins, Mediterranean sea, metals, pesticides, polychlorinated biphenyls, *Stenella coeruleoalba*.

Caurant F, and Amiard-Triquet C. 1995. Cadmium Contamination in Pilot Whales *Globicephala melas*: Source and Potential Hazard to the Species. Mar. Poll. Bull. 30(3):207-10.
ABSTRACT: Among marine mammals, pilot whales (*Globicephala melas*) are characterized by high levels of tissular cadmium (Cd). In this species, squids are used as a major food item, inducing an important Cd intake. In a significant fraction of the mammal population sampled in the vicinity of the Faroe Islands, blood and urine Cd concentrations are higher than minimum adverse-effect levels established for human beings. However, the frequency-at-age data have not shown anomalies likely to reveal a major toxic problem, suggesting a remarkable tolerance of this species to heavy metals.
KEY WORDS: Faroe Islands, *Globicephala melas*, heavy metals, pilot whales, squid, tissular cadmium.

Cockcroft VG, De Kock AC, Lord DA, and Ross GJB. 1989. Organochlorines in Bottlenose Dolphins *Tursiops truncatus* from the East Coast of South Africa. S. Afr. J. Mar. Sci. 8:207-17.
ABSTRACT: Concentrations of polychlorinated biphenyls (PCBs), t-DDT (DDT+DDE+DDD) and dieldrin were determined in blubber samples of 105 bottlenose dolphins inhabiting the coastal waters of the east coast of South Africa. Residue concentrations increased with age and, in males, reached levels that may impair testosterone production. In females, however, there was a decline in concentrations of all three residues in animals with between 8 and 10 dentinal growth layer groups. A significant difference was found between residue levels in females before and subsequent to their first or second ovulation, suggesting that first-born calves receive the majority of the mothers load through lactation. Evidence is presented to indicate that primiparous females impart the majority of their load within seven weeks post-partum. Levels of PCBs, t-DDT and dieldrin differed significantly in different geographical areas, suggesting a degree of isolation of sections of the population.
KEY WORDS: bottlenose dolphin, dieldrin, polychlorinated biphenyls, South Africa, t-DDT, testosterone production.

Colborn T, and Smolen MJ. 1996. Epidemiological Analysis of Persistent Organochlorine Contaminants in Cetaceans. Rev. Environ. Contam. Toxicol. 146:91-172.
ABSTRACT: Information is provided to test the hypothesis that organochlorines introduced into the environment since the early 1940s could threaten the reproductive potential of baleen whales and other cetaceans. Comparisons are made using data on the role of organochlorines in a model system, the Great Lakes region of North America, and in model animals, including humans, pinnipeds, and other wildlife. DDT and PCB are used as model organochlorines with the caveat that there may be thousands of other chemicals in the environment also involved. Improved sensitivity in analytical quantification of synthetic chemicals in biological tissue has been accompanied by an increase in knowledge about biochemical processes that control development and function. The effects described in this review are the result of disrupted gene expression, not damage to the gene. The mechanisms of action of the organochlorines reveal their ability to affect developing organisms at very low concentrations during critical life stages: embryonic, fetal, and early postnatal. Exposure during early development can disrupt the organization of the endocrine, reproductive, immune and nervous systems, effecting irreversible damage that may not be expressed until the individuals reach

adulthood. The recent discovery that human sperm count is declining worldwide at a rate of 1 x 10(6) sperm/(mL.yr) suggests common exposure to estrogen-like chemicals during prenatal and early postnatal development. This raises concern for other top predator species that also share the same exposure. Periods of intense feeding followed by long periods of fasting are common among species of baleen whales. This unique strategy places the embryonic and nursing calves in vulnerable positions, because under both situations maternal blood levels are elevated as a result of absorption from food intake or as a result of mobilization as fat is metabolized. Estimates of Toxic Equivalents (TEQs) based on the occurrence of four PCB congeners (118, 183, 153, 180) in sigma PCB reported in whales are highest for St. Lawrence belugas and Faroe Island long-finned pilot whales. This conservative approach reveals that some whale species are within the range of enzyme-induced TEQs at which effects have been associated with adverse health effects in other aquatic species. The epidemiological approach was used for analysis because it was developed to handle multiple exposure scenarios in which direct causal links are virtually impossible to isolate. The analysis includes the tenets of timeorder, strength of association, specificity of cause and effect, consistency, coherence, and predictive performance.

KEY WORDS: cetaceans, DDT, envrionment, life stages, marine mammals, organochlorines, polychlorinated biphenyls, review, toxic equivalents.

Corsolini S, Focardi S, Kannan K, Tanabe S, Borrell A, and Tatsukawa R. 1995. Congener Profile and Toxicity Assessment of Polychlorinated Biphenyls in Dolphins, Sharks and Tuna Collected from Italian Coastal Waters. Marine Environ. Res. 40(1):33-53.

ABSTRACT: Bottlenose and Rissos dolphins found dead along the Italian coast in 1992 were analysed for the presence of PCB isomers and DDT. High concentrations of PCBs (90-1400 *u*g/g wet wt) were detected in the blubber of stranded carcasses. The concentrations were higher than those found in animals showing reproductive failure and physiological impairment following prolonged PCB exposure, suggesting that the contamination by PCBs as well as DDT may be a major causative factor for the large-scale deaths of dolphins in the Mediterranean Sea. The 2,3,7,8-TCDD toxic equivalents estimated for bottlenose and Rissos dolphins were 18.8 and 20.8 ng/g, respectively, with a major contribution from mono-ortho PCBs. The mono-ortho congeners of IUPAC Nos 105, 118, and 156 accounted for most of the toxicity exerted by PCBs in these dead dolphins. An increase in the proportion of non-ortho coplanar PCB congener IUPAC No. 169 to No. 126 with an increase in the total PCB concentration in the blubber suggested a strong induction of drug metabolizing enzymes. It is possible to use CB-169/CB-126 concentration ratio to indicate whether there has been a strong activation of cytochrome P450 enzyme system in severely exposed contaminated dolphin populations. The total PCB concentrations in the adipose fat of sharks from Italian coasts ranged from 70 to 4000 ng/g wet wt and that of DDT from 14 to 300 ng/g wet wt. In bluefin tuna, the total PCB and DDT concentrations were 170-2200 and 56-780 ng/g wet wt., respectively. These values were comparable to those reported for the same species in the Mediterranean Sea during the 1970s, suggesting the existence of PCB sources near this marine ecosystem.

KEY WORDS: bottlenose dolphin, DDT, Italy, PCB isomers, Risso's dolphin, sharks, tuna.

Cowles CJ, Hansen DJ, and Hubbard JD. 1981. Types of Potential Effects of Offshore Oil and Gas Development on Marine Mammals and Endangered Species of the Northern Bering Sea and Arctic Ocean. United States Bureau of Land Management Technical Paper No. 9 BLM-YK-ES-82-011-1792 .

ABSTRACT: Technical Paper No. 9 summarizes information on types of potential effects on marine mammals, endangered species, and rare plants which may be associated with oil and gas lease sales pending for the northern Bering Sea and arctic regions. Effects reviewed herein are those to which certain arctic species may be exposed. The discussion does not imply that any specific level of impact will be sustained by the relevant species but rather identifies the various potential effects associated with offshore exploration development, and production of petroleum hydrocarbon resources in the Alaska arctic regions. As necessary, this technical paper may be revised to broaden its scope or update relevant information.

KEY WORDS: Alaska Arctic region, endangered species, gas, marine mammals, offshore exploration, oil, petroleum hydrocarbon resources, rare plants.

Daelemans FF, Mehlum F, Lydersen C, and Schepens PJC. 1993. Mono-ortho and Non-ortho Substituted PCBs in Arctic Ringed Seal (*Phoca hispida*) from the Svalbard Area: Analysis and Determination of Their Toxic Threat. Chemosphere 27(1-3):429-37.

ABSTRACT: To determine the 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) toxic equivalent (TEQ) of the PCBs in ringed seal, we analyzed liver, blubber and kidney for non-ortho and mono-ortho substituted CBs as well as the total PCB and total DDE concentration. The blubber samples were compared with ringed seal blubber samples from another study1,2, in which total PCB and PCDD/PCDF concentrations were measured, and the TEQ values for the PCBs in our samples were 11 times higher than the TEQ values for the PCDDs/PCDFs in the other seal samples. Comparing the 3 different seal matrices, we found no significant difference in PCB pattern; the absolute concentrations expressed per unit lipid weight were for the females in the following order: blubber liver > kidney. We found another order for the males: blubber > liver > kidney. Among the different seals, there was a good PCB-sex correlation indicating that the results of different studies, without specific background information, must be compared with great caution.

KEY WORDS: PCBs, *Phoca hispida*, ringed seal, Svalbard area, total DDE concentration.

Davis JE, and Anderson SS. 1976. Effects of Oil Pollution on Breeding Grey Seals. Mar. Poll. Bull. 7:115-8.

ABSTRACT: Marine mammals are probably frequently exposed to floating oil but little is known about the effect oil pollution has on them. Oil stranded on the shore in Pembrokeshire, West Wales in September 1974 coincided with the start of the Grey Seal breeding season there. Observations have been made on the effect the oil had on the newborn pups and their mothers.

KEY WORDS: grey seals, marine mammals, oil pollution, pups.

Davis RW, Williams TM, and Awbrey F. 1988. Sea Otter Oil Spill Avoidance Study. OCS Study, MMS 88-0051 :65 pp.

ABSTRACT: To determine whether acoustic, visual or olfactory stimuli could be used

to move sea otters out of an area in the event of a variety of stimuli during captive studies in Alaska. The most effective stimuli were then tested on free-ranging sea otters in California. The results showed that the random presentation of synthetic sounds (warble tone and air horns) startled the otters, but they habituated within two hours and did not avoid the sound source. Killer whale calls from resident or transient pods were the most effective repellent for Alaskan sea otters. In California, where killer whales are less common, the otters showed little reaction. The playback of sea otter pups calls attracted some Alaskan sea otters, especially females with pups, but many of the otters in California did not respond. The otters that were attracted to the calls usually departed as soon as they determined that there was no pup. Consequently, the otters would not follow a skiff that was broadcasting pup calls. Olfactory stimuli were ineffective for herding sea otters. Visual stimuli such as boats, nets and the oil containment boom often attracted the sea otters (possibly a curiosity response) rather than repelling them. Certain sounds did alarm and disperse sea otters. Unfortunately, the observed effect had a limited range (ca. 100-200m) and habituation occurred quickly (within hours or, at most, 3-4 days). Our findings are similar to those of previous attempts to control the movements of sea otters and other marine mammals and birds. An alternative to herding is to capture otters in the vicinity of the spill and temporarily hold them in captivity. This approach is only practical if the number of otters in jeopardy is small (i.e. less than 60) and there is enough time to capture them. Tangle nets, dip nets and the Wilson trap are all safe and effective capture methods. Once captured, sea otters can be safely transported and held temporarily using current methods. Based on the results of this study and previous attempts by the California Department of Fish and Game to herd sea otters, we do not think acoustic, visual, and olfactory stimuli can be used to keep otters out of an oil spill. In the absence of effective methods to keep sea otters out of an oil spill, the emphasis must remain on spill prevention, containment, and cleanup.
KEY WORDS: Alaska, California, marine mammals, oil spill, prevention, stimuli.

DeBoer J, and Wester P. 1991. Chlorobiphenyls and Organochlorine Pesticides in Various Sub-Antarctic Organisms. Mar. Poll. Bull. 22(9):441-7.
ABSTRACT: Brains, livers and muscles of two Gentoo penguins (*Pygoscelis papua*) from the Falkland Islands and muscles of Argentinian hake (*Merluccius merluccius hubbsi*), flying fish (*Cypselurus cyanopterus*) and squid (*Illex illecebroscus argentinus*) were analysed for 24 individual chlorobiphenyl (CB) congeners and 15 other organochlorine compounds. In comparison with Atlantic hake (*Merluccius merluccius*) caught south of Ireland, and enrichment of lower chlorinated biphenyls in the sub-Antarctic organisms was found. The absolute values of the CBs and other organochlorine compounds were extremely low compared with the more polluted areas of the North-East Atlantic. Compared with earlier reported DDE/PCB ratios in Antarctic and sub-Antarctic organisms, up to more than 10, DDE/PCB ratios clearly below 1, were found, which may suggest a rise of CB concentrations in the sub-Antarctic region. The presence of trans-nonachlor, cis-chlordane and octachlorostyrene was confirmed by gas chromatographic-mass spectrometric analysis.
KEY WORDS: chlorobiphenyls, Gentoo penguins, organochlorine compounds, *Pygoscelis papua*, sub-Antarctic organisms.

DeGuise S, Bernier J, Martineau D, Béland P, and Fournier M. 1996. About Immunology and

Immunotoxicology of Beluga Whales. Proceedings of the International Association for Aquatic Animal Medicine (IAAAM) 27:3.

ABSTRACT: The nature, frequency and severity of the lesions observed during postmortem examination of beluga whales from a small isolated population that resided in the highly polluted St. Lawrence estuary suggested pollutants-related immunosuppression in these animals. A study was undertaken to investigate the possible relationships between environmental contamination by organohalogens and heavy metals and a possible immunosuppression in St. Lawrence beluga whales. Since relatively little was known about marine mammal immunology, assays were developed to evaluate different immune functions in beluga whales. These assays include phagocytosis and respiratory burst, the main functions of neutrophils which are responsible for ingestion and destruction of foreign material such as bacteria, *in vitro* mitogen-induced lymphoblastic transformation, that measures the ability of lymphocytes to respond to stimulation, NK activity, an important non-specific defense mechanism against viral infections and tumors, and immunophenotyping of peripheral blood lymphocytes using monoclonal antibodies. Another step in this study was to evaluate the possible effects of environmental contaminants on the immune functions of belugas. The effects of *in vitro* exposure to ecotoxicologically relevant heavy metals and organochlorines was evaluated. Exposure to mercury and cadmium at concentrations in the range of those found in the liver of wild belugas decreased beluga lymphocytes proliferation, while lead did not. While none of six organochlorines compounds had an effect on phagocytosis at the concentrations tested, PCBs 138, 180, and p,p'-DDT, but not PCBs 153, 169 nor p,p'-DDE, reduced the proliferative response of beluga lymphocytes. Also, the proliferation of beluga lymphocytes was reduced by exposure to mixtures of congeners at concentrations in the range of those observed in tissues of St. Lawrence belugas and at which they had no effect separately. In order to determine the immunotoxic potential of naturally occurring mixtures of environmental contaminants, rats were fed blubber from either highly contaminated St. Lawrence or relatively uncontaminated Arctic belugas. Surprisingly, no differences were found in immune functions between the groups, and the possible reasons will be discussed. The effects on proliferation of beluga whale lymphocytes exposed *in vitro* to heavy metals and mixtures of organochlorines at concentrations in the range of those observed in tissues of St. Lawrence belugas might support the hypothesis of pollutants-induced immunosuppression in these animals. A further step will be to compare immune functions of highly polluted beluga whales from the St. Lawrence to those of relatively uncontaminated Arctic populations.

KEY WORDS: beluga whales, environmental contamination, immunology, immunotoxicology, lesions, pollutants-related immunosuppression.

DeGuise S, Lagacé A, and Béland P. 1990. Pathology of Stranded Beluga Whales (*Delphinapterus leucas*) in the St. Lawrence Estuary, Quebec, Canada, 1988. IAAAM Proceedings 21:23.

ABSTRACT: In 1988, ten carcasses of stranded beluga whales from the polluted St. Lawrence River were necropsied. Some lesions were commonly seen, like gastric ulcerations and erosions, digestive parasitism, pneumonias and mammary gland problems. We also found some tumors. The common findings in the carcasses examined is the high levels of contaminants, mostly organochlorines, whose effects have been well studied. Many of the lesions observed in the beluga whale population of the St. Lawrence

River could be related to the toxicity of the chronic exposure to organochloric contaminants.
KEY WORDS: chronic exposure, contaminants, *Delphinapterus leucas*, pathology, St. Lawrence Estuary, stranded beluga whales.

Deguise S, Martineau D, Beland P, and Fournier M. 1995. Possible Mechanisms of Action of Environmental Contaminants on St. Lawrence Beluga Whales (*Delphinapterus leucas*). Env. Health Perspect. 103(4):73-7.
ABSTRACT: A small isolated population of beluga whales (*Delphinapterus leucas*) that are highly contaminated by pollutants, mostly of industrial origin, resides in the St. Lawrence estuary, Quebec, Canada. Overhunting in the first half of the century was the probable cause for this population to dwindle from several thousand animals to the current estimate of 500. The failure of the population to recover might be due to contamination by organochlorine compounds, which are known to lead to reproductive failure and immunosuppression in domestic and laboratory animals and seals. Functional and morphological changes have been demonstrated in thyroid gland and adrenal cortex in many species exposed to organochlorinated compounds, including seals. Morphological lesions, although different, were also found in belugas. Functional evaluation of thyroid and adrenal glands of contaminated (St. Lawrence) versus much less contaminated (Arctic) belugas is currently under way. Necropsy of St. Lawrence belugas showed numerous severe and disseminated infection with rather mildly pathogenic bacteria, which suggests immunosuppression. Organochlorine compounds and other contaminants found in beluga whales cause immunosuppression in a variety of animal species including seals. Thirty-seven percent of all the tumors reported in cetaceans were observed in St. Lawrence beluga whales. This could be explained by two different mechanisms, high exposure to environmental carcinogens and suppression of immunosurveillance against tumors. Overall, St. Lawrence belugas might well represent the risk associated with long-term exposure to pollutants present in their environment and might be a good model to predict health problems that could emerge in highly exposed human populations over time.
KEYWORDS: beluga whales, cetaceans, endocrinology, immunology, organohalogens, PCBs, reproduction, tumors.

DeKock AC, Best PB, Cockcroft V, and Bosma C. 1994. Persistent Organochlorine Residues in Small Cetaceans from the East and West Coasts of Southern Africa. Sci. Total Environ. 154(2,3):153-62.
ABSTRACT: Organochlorine pollutant levels in the blubber of small cetaceans and ratios between concentrations of compounds such as DDE/tDDT and tDDT/PCB, were used to identify the chronology of input of DDT and PCB into the coastal waters along the west and east coasts of southern Africa. Although regression analyses, with time as the only independent variable, do not show a statistically significant decline in tDDT from 1980 to 1987 in the common dolphin from the east coast of South Africa, there is a fairly strong indication that tDDT concentrations did not increase or even stay constant with time. tDDT concentrations in the bottlenose dolphin declined significantly from 1980 to 1987 ($P < 0.05$). The regression analyses for PCB in the bottlenose dolphin from the east coat show no decline ($P > 0.05$). The data from this study illustrate that it would take a long time in the coastal waters and open ocean before the restriction and prohibit

on the production and use of organochlorines will take effect.
KEY WORDS: cetaceans, DDT, marine mammals, organochlorines, PCBs.

DeLong RL, Gilmartin WG, and Simpson JG. 1973. Premature Births in California Sea Lions: Association with High Organochlorine Pollutant Residue Levels. Science 181:1168-9.
ABSTRACT: Premature pupping in California sea lions has been noted on the breeding islands since 1968. Organochlorine pesticides and polychlorinated biphenyl residues were two to eight times higher in tissues of premature parturient females and pups than in similar tissues of full-term parturient females and pups collected on San Miguel Island in 1970.
KEY WORDS: California sea lions, organochlorine pesticides, PCB, premature pupping, San Miguel Island.

Dietz R, Nielsen CO, Hansen MM, and Hansen CT. 1990. Organic Mercury in Greenland Birds and Mammals. Sci. Total Environ. 95:41-51.
ABSTRACT: Muscle, liver and kidney samples of 20 species of birds, seals, whales and polar bear were analyzed for total and organic mercury. Organic mercury concentrations varied considerably between individuals. A general tendency towards age accumulation was found together with log-linear correlations between organic mercury concentrations in the three tissues. The major part of the muscle mercury was organic (maximum concentration found was 1235 $g \cdot kg^{-1}$ wet wt). This also applied to liver of birds, while in mammal liver organic mercury concentrations approached a level of 2000 $g \cdot kg^{-1}$, which was not exceeded even when the total mercury concentrations was >100,000 $g \cdot kg^{-1}$ wet wt. The percentage of organic mercury in relation to total mercury in kidney of seals and whales was 10-20% (maximum 982 g organic mercury kg^{-1} wet wt), while in polar bear it was <6% (maximum 217 $g \cdot kg^{-1}$ wet wt). For the monitoring of local food in the Arctic, the simpler and less expensive analysis of total mercury suffices when testing muscle, whereas liver and kidney should be tested for organic mercury as well.
KEY WORDS: age accumulation, marine birds, marine mammals, organic mercury, toxic effects.

Dietz R, Riget F, and Johansen P. 1996. Lead, Cadmium, Mercury and Selenium in Greenland Marine Animals. Sci. Total Environ. 186:67-93.
ABSTRACT: Baseline concentrations of lead, cadmium, mercury and selenium are reported from different tissues in marine organisms from Greenland. Overall, lead levels in marine organisms from Greenland are low, whereas cadmium, mercury and selenium levels are high. Tissue differences are not very distinct for lead, whereas the opposite is the case for cadmium and mercury. Selenium shows an intermediate behavior in this respect. In general, lead concentrations do not correlate with the age/size of animals, whereas cadmium, mercury and selenium increase with age/size of most species and tissues analysed. No clear conclusions can be drawn in relation to geographical differences in lead, mercury and selenium concentration in Greenland. In general, cadmium levels are higher in Northwest Greenland compared to southern areas. Local differences with increasing cadmium levels from inner fjords to the open sea in stationary species may be of the same order of magnitude as those observed over long distances in Greenland. There is no indication that lead and selenium levels increase in higher trophic levels, although this is clearly the case for cadmium and mercury. In almost all cases lead

levels in marine mammals and seabirds in Greenland have cadmium and mercury levels exceeding the Danish standard limits. No food standard limits are given for selenium in food, but in some cases human intake of selenium is estimated to be high.
KEY WORDS: cadmium, crustaceans, fish, food, Greenland marine ecosystem, heavy metals, lead, mercury, molluscs, polar bears, seabirds, seals, selenium, standard limits.

Duffy LK, Bowyerman RT, Testa JW, and Faro JB. 1996. Acute Phase Proteins and Cytokines in Alaskan Mammals as Markers of Chronic Exposure to Environmental Pollutants. Proceedings of the *Exxon Valdez* Oil Spill Symposium. AFS, Bethesda, MD. Am. Fish. Soc. Symp. 18:809-13.
ABSTRACT: We examine the usefulness of developing acute phase proteins and cytokines as markers of biological effects for free-ranging Alaskan mammals. Blood assays for these markers are already in widespread use as indicators of chemical pollution exposure, disease, and stress in humans. The acute phase response includes fever and changes in the plasma concentrations of several proteins that originate in the liver. The acute phase response is mediated by cytokines, such as interleukin-1 and interleukin-6, which are released by macrophages and other cells. The few data available indicate that these biochemical markers are valuable for documenting chemical exposure when used in conjunction with an overall biostatistical model. Additional baseline studies using this nonlethal, analytical method for mammal populations are needed to characterize age, sex, and season as sources of variation.
KEY WORDS: acute phase protein, Alaska, biochemical markers, chemical exposure, cytokines, environmental pollutants, mammal populations.

Duinker JC, Hillebrand MTJ, Zeinstra T, and Boon JP. 1989. Individual Chlorinated Biphenyls and Pesticides in Tissues of Some Cetacean Species from the North Sea and the Atlantic Ocean; Tissue Distribution Biotransformation. Aquatic Mammals 15.3:95-124.
ABSTRACT: Individual chlorinated biphenyls (CBs) and organochlorine pesticides (alpha- and gamma- HCH, dieldrin HCB, p,p'-DDT, p,p'-DDD, and p,p'-DDE) were investigated in blubber, brain heart, kidney, liver and muscle of 19 cetaceans from the Dutch coastal area, the open North Sea and the western Atlantic. Multidimensional gas chromatography (MDGC) with electron capture detection (ECD) was used to check the results of single capillary column GC-ECD data. Absolute concentrations and concentration patterns of individual compounds were investigated to describe their distribution between tissues and to interpret the findings in terms of lipophilicity and persistence to biotransformation of individual compounds. A clear relation could be established between the chemical structure of each CB and its biomagnification in marine mammal tissues. Persistent congeners are biomagnified but metabolizable congeners appeared at much lower extractable lipid based concentrations than in the food sources. The CBs with the highest concentrations in the mammal tissues were hexa- and heptachloro-biphenyls. The results are compared with published data on individual CBs in cetaceans and in blood of seals from the coastal area. CB patterns in different tissues of any organism were almost identical. A large similarity in the patterns of persistent congeners was also found between tissues and organs of mammals from widely separated oceanic areas, although absolute concentrations differed sometimes by more than an order of magnitude. Differences we found in the relative contributions of less persistent congeners. The apparent rates of biotransformation were higher in seals than in

cetaceans, for which the lowest rates were generally observed in the animals from the open sea and in particular in *Physeter macrocephalus* and also *Sotalia fluviatilis*. Especially CB congeners with vicinal H-atoms only in the m,p positions were more rapidly metabolized in seals than in cetaceans. This can be due to the lower activity of the MFO enzyme system at lower CB levels or to physiological differences between species. CB congeners with vicinal H-atoms in the o,m positions with not more than one ortho-chlorine were metabolized in each case. Of the most toxic CB congeners, i.e., those showing a 3-MC or mixed 3-MC and PB-type MFO induction in rats, CBs-77,-105,-118,-128, and -138 were present (although at low concentration levels), but CBs -81,-114,-123,-126,-167,-157,-169, and -189 were below detection levels. The concentrations of individual CBs were of similar magnitude as those of some pesticides. In Wadden Sea fish and in porpoises from the coastal North Sea, p,p'-DDD was the dominant contributor to Σ–DDT but in the open North Sea and the western Atlantic, p,p'-DDE was by far the largest contributor (80-90%).
KEY WORDS: biotransformation, cetaceans, chlorinated biphenyls, lipophilicity.

Duinker JC, Knap AH, Binkley KC, Van Dam GH, Darrel-Rew A, and Hillebrand MTJ. 1988. Method to Represent the Qualitative and Quantitative Characteristics of PCB Mixtures: Marine Mammal Tissues and Commercial Mixtures as Examples. Mar. Poll. Bull. 19(2):74-9.
ABSTRACT: A new method is proposed to represent the qualitative and quantitative aspects of the complex mixtures of polychlorinated biphenyls in environmental samples. It is based on individual congener data. It involves the sum of concentrations of congeners (PCB) and the percentage contributions of these congeners to PCB. The concentration of each of the congeners in the sample is obtained from these numbers by a simple procedure. This generally applicable, concise and accurate information useful for comparison purposes (trend analysis, monitoring, comparisons between different matrices), for research purposes (processes, effect processes) and for contamination/pollution assessment purposes. It allows administrators to understand the scope and limitations of PCB data and scientist to apply the information on individual congeners to other studies.
KEY WORDS: contamination/ pollution assessment, individual congener data, marine mammal, PCB.

Eaton RDP, and Farant JP. 1982. The Polar Bear as a Biological Indicator of the Environmental Mercury Burden. Arctic 35(3):422-5.
ABSTRACT: 128 fresh (current) and 18 preserved (museum) polar bear hair samples were subjected to mercury analysis. Mercury levels ranging from <0.5-44.3 ppm were observed in the fresh samples with a geographic distribution showing higher levels in the western Arctic and substantially lower levels in the eastern Arctic and in Hudsons Bay. A similar geographic range and distribution was found in the museum specimens. No correlation can be demonstrated between observed levels and industrial releases of mercury. There is no real indication of increase in general levels over time. The source of observed high levels of mercury in arctic marine fauna appears to be geologic rather than industrial.
KEY WORDS: mercury, polar bear.

Efurd DW, Miller GG, Rokop DJ, Roensch FR, Attrep JrM, Thompson JL, Incret WC, Miller G, Poths H, Banar JC and others. 1997. Evaluation of the Anthropogenic Radionuclide Concentrations in Sediments and Fauna Collected in the Beaufort Sea and Northern Alaska. Los Alamos National Laboratory, U.S. Department of Energy, Nuclear Radiochemistry, CST-11, LA-13302-MS :41 pp.
ABSTRACT: This study was performed to establish a quality controlled data set about the levels of radionuclide activity in the environment and in selected biota in the U.S. Arctic. Sediment and biota samples were collected by the National Oceanic and Atmospheric Administration (NOAA), the National Biological Service, and the North Slope Boroughs Department of Wildlife Management to determine the impact of anthropogenic radionuclides in the Arctic. The results summarized in this report are derived from samples collected in northwest Alaska with emphasis on species harvested for subsistence in Barrow, Alaska. Samples were analyzed for the anthropogenic radionuclides 90Sr, 137Cs, 238Pu, 239Pu, 240Pu, and 241Am. The naturally occurring radionuclides 40K, 212Pb and 241Pb were also measured. One goal of this study was to determine the amounts of anthropogenic radionuclides present in the Baeufort Sea. Sediment samples were isotopically fingerprinted to determine the sources of radionuclide activities. Biota samples of subsistence and ecological value were analyzed to search for evidence of bio-accumulation of radionuclides and to determine the radiation exposures associated with subsistence living in northern Alaska. The anthropogenic radionuclide content of sediments collected in the Beaufort Sea was predominantly the result of the deposition of global fallout. No other sources of anthropogenic radionuclides could be conclusively identified in the sediments. The anthropogenic radionuclide concentrations in fish, birds and mammals were very low. Assuming that ingestion of food is an important pathway leading to human contact with radioactive contaminants and given the dietary patterns in coastal Arctic communities, it can be surmised that marine food chains are presently not significantly affected.
KEY WORDS: Alaska, anthropogenic radionuclide content, Arctic, fauna, marine biota, marine birds, marine mammals, sediments.

Egeland GM. 1997. The Use of Traditional Food in a Healthy Diet: Risks in Perspective, Cadmium Chapter, April 1997. Alaska Division of Public Health, Section of Epidemiology :26 pp.
KEYWORDS: Alaska, contamination, cadmium, diet, human studies, kidney, liver, marine mammals, muscle, risk assessment, subsistence, traditional food.

Ekker M, Lorentsen S, and Rov N. 1992. Chronic Oil-Fouling of Grey Seal Pups at the Froan Breeding Ground, Norway. Mar. Poll. Bull. 24(2):92-3.
ABSTRACT: Frequent oil contamination of grey seal, *Halichoerus grypus,* pups is shown to be a severe problem within the Froan breeding area off central Norway. Since 1985, annual surveys have revealed that 30-60% of all pups born become oil-fouled during their first month of life. The location of the Froan archipelago within the coastal current serve to accumulate petroleum residues, and the main source of contamination of the pups is beached oil spots that melt when pups lay upon them. The proportion of oil contaminated pups therefore increases with time spent ashore.
KEY WORDS: Froan archipelago, grey seal pups, Norway, oil contamination.

Engelhardt FR, Geraci JR, and Smith TG. 1977. Uptake and Clearance of Petroleum Hydrocarbons in the Ringed Seal, *Phoca hispida*. J. Fish. Res. Board Can. 34:1143-7.
ABSTRACT: Ringed seals, *Phoca hispida*, showed rapid absorption of hydrocarbons from Norman Wells crude oil into body tissues and fluids when exposed by both immersion and ingestion. Relatively low but significant levels were found in tissue, blood, and plasma. Levels in bile and urine were high, indicating these to be routes of excretion.
KEY WORDS: benzene, clearance, hydrocarbons, immersion, ingestion, petroleum, ringed seals.

Estes JA, Bacon CE, Jarman WM, Norstrom RJ, Anthony RG, and Miles AK. 1997. Organochlorines in Sea Otters and Bald Eagles from the Aleutian Archipelago. Mar. Poll. Bull. 34(6):486-90.
ABSTRACT: Unusually high levels of organochlorine compounds (OC) have been discovered at Adak Island in the west-central Aleutians. This study will determine if these high OC levels are localized near Adak or are more widely occurring. Tissue samples of sea otters (*Enhydra lutris*) along with unhatched bald eagle eggs (*Halicetus leucocephalus*) were collected from Adak and three other islands surrounding Adak Island during 1991-1992. Samples were analysed for PCBs, PCDDs, and PCDFs. PCBs and DDTs were the principal OCs in sea otter livers and were also observed in elevated levels in the bald eagles. The source of OCs in the Aleutian Islands is unknown but several possibilities are discussed.
KEY WORDS: Adak Island, Aleutian Islands, bald eagles, DDTs, organochlorine compounds, PCBs, pollution, sea otters.

Evans RD, Richner P, and Outridge PM. 1995. Micro-Spatial Variations of Heavy Metals in the Teeth of Walrus as Determined by Laser Ablation ICP-MS: The Potential for Reconstructing a History of Metal Exposure. Arch. Environ. Contam. Toxicol. 28:55-60.
ABSTRACT: This study explored the possibility of using laser ablation inductively-coupled plasma-mass spectroscopy to measure trace metals and other elements within the annual growth layers of the teeth of walrus harvested from the Canadian Arctic. Using sample ablation footprints of 125 m diameter on transects across the exposed cross-sections of teeth, this technique detected Pb, Cu, Zn and Sr, but not Cd, in tooth cementum. The micro-spatial patterns of elements were consistent among different transects on the same tooth, and revealed subtle differences between animals of different ages. The youngest walrus in the sample (4 yr) contained higher concentrations of Pb and Cu than older animals in the growth layer deposited during the first year of life, while the oldest animal (33 yr) exhibited higher Pb and Zn than younger animals in the outer layer corresponding to the year 1988. The differences between animals and across annual layers may reflect both life history and metal exposure phenomena, including high amounts of metals transferred from mothers to pups in maternal milk. The ability to detect metals in a repeatable fashion with annual growth layers suggests that metal exposure histories accurate to within a year might be re-constructed for the life times of long-lived animals, and that a series of such individual studies would allow exposure histories covering centuries to be quickly assembled. These data may suggest the most likely explanation for the currently high levels of some metals observed in certain Arctic marine mammals, i.e., natural phenomenon or anthropogenic contamination.

KEY WORDS: heavy metals, laser ablation ICP-MS, life history, teeth, walrus.

Falconer CR, Davies IM, and Topping G. 1983. Trace Metals in the Common Porpoise, *Phocoena phocoena*. Marine Environ. Res. 8:119-27.
ABSTRACT: Mercury, cadmium, copper and zinc concentrations in brain, liver, kidney, heart and spleen of twenty-six specimens of the common porpoise (*Phocoena phocoena*) are presented. Mercury and cadmium levels in liver and kidneys tended to increase with length of animal, but copper and zinc levels show no such trends. The proportion of methylmercury to total mercury (9%-57%) in the liver decreased with increasing total mercury concentrations. Lead, chromium, nickel and cobalt levels were below the analytical detection limits (05, 10, 10 and 25 $g \cdot g^{-1}$, respectively).
KEY WORDS: common porpoise, *Phocoena phocoena*, trace metals.

Florence TM, Morrison GM, and Stauber JL. 1992. Determination of Trace Element Speciation and the Role of Speciation in Aquatic Toxicity. Sci. Total Environ. 125:1-13.
ABSTRACT: Knowledge of trace element speciation in waters is essential to an understanding of aquatic toxicity and bioaccumulation, as well as to the partitioning of elements between water and colloidal and particulate phases. In natural waters, only very small percentages of the dissolved heavy metals, such as copper, lead, cadmium or zinc, are present as free (aquo) metal ion, most of the metal is adsorbed to colloidal particles or combined in complexes. For aquatic toxicity studies, the aim of the speciation measurement is to determine the fraction of total dissolved metal (the toxic fraction) that will react with, and be transported across, a biological membrane such as a fish gill. In this review, a range of trace element speciation techniques is discussed and compared. A simple anodic stripping voltammetric method is recommended for the measurement of the fraction of electroactive metal in a sample, i.e. the fraction of total dissolved metal that can be deposited into a mercury electrode at the natural pH of the sample. The electroactive fraction is believed to approximate the toxic reaction. A rapid ion exchange method, suitable for field use, is proposed for the determination of the toxic reaction of copper in waters.
KEY WORDS: anodic stripping voltammetry, bioavailability, metals, speciation, toxicity.

Ford CA, Muir DCG, Norstrom RJ, and Simon M. 1990. Accumulation of Non-ortho and Mono-ortho Substituted PCBs in Arctic Marine Food Chains. Presented at the 11th Annual Meeting of the Society of Environmental Toxicology and Chemistry .
ABSTRACT: Concentrations of toxic non-ortho (coplanar) and mono-ortho substituted PCBs in marine mammal and fish tissues in the Canadian arctic were determined in order to assess (1) the dietary exposure of native people and (2) the possible effects on marine biota. Non-ortho PCBs were separated from other OCs using an automated carbon column technique and quantified by GC-MS using 13C-internal standards. Concentration of 3,3',4,4',5-pentachlorobiphenyl (PCB-126) ranged from 41 to 607 ng/kg in beluga, 23 to 195 ng/kg in ringed seal and from 22 to 217 ng/kg in narwhal blubber. Arctic charr had lower concentrations of PCB-77 and PCB-126 than marine mammals ranging from 27 to 119 ng/kg for PCB-77 (3,3',4,4'-tetrachlorobiphenyl (TCB)) and PCB-126 from 5 to 25 ng/kg in whole fish. PCBs-126 and 105 (2,3,3,4,4-TCB) contributed greater than 98% of TCDD toxic equivalent factors (TEQ) in polar bear, and beluga and narwhal

blubber, and 78% in ringed seal blubber samples. The remaining 2 to 22% of TEQ was due to the contribution of 2,3,7,8-TCDD. Arctic charr samples contained a higher proportion of non-ortho congeners (0.2% of PCB) than marine mammals (0.001-0.02 %).
KEY WORDS: fish, food chain, marine biota, marine mammals, non-ortho-, mono-ortho substituted PCBs.

Ford CA, Muir DCG, Norstrom RJ, Simon M, and Mulvihill MJ. 1993. Development of a Semi-Automated Method for Non-ortho PCBs: Application to Canadian Arctic Marine Mammal Tissues. Chemosphere 26(11):1981-91.
ABSTRACT: A semi-automated carbon column method was developed for the analysis of the non-ortho substituted PCB congeners (3,4,4'-tri; 3,4,4',5-tetra; 3,3',4,4'-tetra; 3,3',4,4',5-penta; and 3,3',4,4',5,5'-hexachlorobiphenyl) (PCBs 37, 81, 77, 126 and 169). The system consisted of an AX21 carbon/glass fiber column with a programmable pumping and valving system. Precision and accuracy measurements indicated the method was reproducible for concentrations greater than 50 ng/kg. Canadian Arctic ringed seal and whale blubber samples were analysed using this method. Parts-per-trillion levels (ng/kg) of non-ortho PCBs were found in all samples. The non-ortho and mono-ortho PCBs (2,3,3',4,4'-penta; 2,3,4,4',5-penta; 2,3',4,4',5-penta; 2,3,3',4,4',5-hexachlorobiphenyl) (PCBs 105, 114, 118, and 156) were the major contributors to total TCDD equivalents in the whale samples (98% in beluga and narwhal) and contributed greater than 50% in the ringed seal samples.
KEY WORDS: Canadian Arctic, marine mammals, non-ortho substituted PCB congeners, ringed seal, semi-automated carbon column method.

Frank R, Ronald K, and Braun HE. 1973. Organochlorine Residues in Harp Seals (*Pagophilus groenlandicus*) Caught in Eastern Canadian Waters. J. Fish. Res. Board Can. 30:1053-63.
ABSTRACT: From 1969 to 1971, 78 harp seals (*Pagophilus groenlandicus*), ranging in age from newborn to 18 years were obtained from the Gulf of St. Lawrence and the Newfoundland and Labrador coasts (Front). A further 12 seals captured in the Gulf died (in captivity) after being held for various periods of time. Total DDT and metabolites (DDT) in the blubber of wild beaters and bedlamers from the Gulf were >2 ppm, from the Front <2 ppm. DDT levels increased to 8.7 ppm as the animals matured, and in females leveled off at 6.5 ppm when the breeding age was reached. Dieldrin levels were only 5% of those for DDT, and did not accumulate appreciably in either wild or captive seals. PCB residues were only slightly less than DDT and showed a similar increase with the age of the seal. Residues in tissues of captive seals were as much as eight times higher than in nature, indicating either that natural diets contain lower residues than the selected, often monospecific diet, or differing rates of assimilation of organochlorines in wild and captive animals. The differences between levels in wild seals from the Gulf and Front may offer evidence for sub-population groups in the harp seals of the North West Atlantic. In seals examined brain lipids contained between 7 and 20% of concentrations of all three chlorinated hydrocarbons found in the extractable fat of blubber, muscle, and liver, indicating a brain barrier.
KEY WORDS: DDT, harp seals, North West Atlantic, organochlorine, PCB.

Frost KJ, and Lowry LF. 1987. Effects of Industrial Activities on Ringed Seals in Alaska, As Indicated by Aerial Surveys. In: Proceeding of Ports and Oceans Conference. 10 pp.

ABSTRACT: Ringed seals are the most abundant and widely distributed marine mammal in Arctic and subarctic waters of Alaska. The preferred pupping habitat is the stable shorefast ice which also provides a convenient platform for some types of industrial activity. Concern for the possible effects of on-ice industrial activities on ringed seals has resulted in restrictions on industry and research to evaluate the problem. Aerial surveys were conducted in 1970, 1975-1977, and 1981-82, and the data were used to compare ringed seal abundance in industrial and control areas. Results were equivocal and sometimes contradictory, perhaps because only the 1981-1982 surveys were specifically designed to address this question. In 1985-87 a major program of aerial surveys was conducted to monitor the ringed seal population off Alaska and to continue investigating the possible effects of industrial activities. Industrial activities varied from moderate to non-existent during the study. Studies around artificial islands in the central Beaufort Sea suggest some displacement of seals within 2 nm of the islands. Comparison of industrial and control blocks indicated seals were more abundant in the industrial block whether or not industrial activity had occurred. Broad regional comparisons incorporation historical data indicate that seal density in the Beaufort Sea was high in 1975, decreased greatly by 1977, and subsequently increased to a 1986 level that was comparable to 1975. Although these trends correlate well with levels of industrial activity (high in the late 1970s and early 1980s then decreasing greatly in 1985-87), the changes occurred in areas both with and without activity and are therefore probably due to some other cause. These results indicate that industrial activities in the 1970s and 1980s have had no broad-scale effects on ringed seal distribution and abundance. That does not mean that small-scale effects have not occurred or that broad-scale effects could not occur with different types and levels of activity. Other studies in addition to aerial surveys are needed in order to understand ringed seals and how they may be affected by human activities.
KEY WORDS: Alaska, industrial activities, ringed seals, seal distribution.

Fujise Y. Heavy Metal Concentrations in Minke Whales from the Pacific Coast of Japan and an Offshore Area in the Western North Pacific. The Institute of Cetacean Research, 4-18, Toyomi-Cho Chuo-Ku, Tokyo 104, Japan :7 pp.

ABSTRACT: A preliminary comparison of the accumulation levels of heavy metals (Cd and Hg) in minke whales from the Pacific coast of Japan (sub-area 7) and an offshore area of the western North Pacific (sub-area 9), was carried out in order to investigate possible geographical differences in the accumulation levels. With this objective, we examined samples of minke whales from the 1994 and 1995 JARPN surveys (sub-area 9) and from the small-type coastal whaling in 1987 (sub-area 7). Although relatively higher concentrations of Cd and Hg were found in whales from sub-area 9, such apparent differences could be explained by the length-related (possibly age-related) accumulation characteristic of these pollutants. Further analyses involving more samples from the coastal sub-area, especially mature animals, are needed in order to corroborate whether the differences in the levels of heavy metals reported here can be interpreted as the length-related accumulation within a stock.
KEY WORDS: geographical differences, heavy metals, minke whales.

Fuller GB, and Hobson WC. 1972. Effect of PCBs on Reproduction in Mammals. *In*: PCBs and the Environment, Volume II, Washington, D.C., Department of Agriculture, Commerce

H.E.W. and Interior. Chapter 7:101-25.
ABSTRACT: It is the purpose of this chapter to provide a current assessment of the effects of PCBs on reproduction in mammals. The chapter will be organized by references to maturational reproductive stages. The possible site(s) and/or mechanism(s) of action will be discussed although these aspects remain largely speculative due to the tenuous nature of present evidence.
KEY WORDS: male/female, mammals, mechanisms of action, PCBs, reproduction, reproductive function, review.

Gaskin DE, Holdrinet M, and Frank R. 1971. Organochlorine Pesticide Residues in Harbour Porpoises from the Bay of Fundy Region. Nature 233:499-500.
ABSTRACT: In 1969-1970, sixty harbour porpoises, *Phocoena phocoena*, were collected in western North Atlantic waters with blubber and liver samples taken from a number of these animals. Average concentrations of dieldrin and DDT levels were 1.37 ppm and 69.03 ppm, respectively, in pregnant or lactating females. These levels were much lower than in immature and resting female blubber, 7.75 ppm dieldrin and 241.27 ppm DDT. Further studies need to be implemented to the status of contaminants in the higher trophic levels of the Bay of Fundy food web.
KEY WORDS: DDT, dieldrin, harbour porpoises, lactating, North Atlantic, organochlorine, *Phocoena phocoena*, pregnant.

Gaskin DE, Ishida K, and Frank R. 1972. Mercury in Harbour Porpoises (*Phocoena phocoena*) from the Bay of Fundy Region. J. Fish. Res. Board Can. 29(11):1644-6.
ABSTRACT: During 1969-71, 41 muscle and 20 liver samples were collected from harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy region. These tissues were analyzed for total mercury content. Total Hg levels ranged from 0.21 to 1.92 ppm (average 0.75) in muscle tissue of males and from 0.26 to 2.58 ppm (average 1.02) in muscle tissue of females, from 0.89 to 18.30 ppm in liver tissue of males and from 0.55 to 91.30 ppm in liver tissue of females. Averages for the two latter series would be meaningless. A limited number (four muscle and six liver samples) of determinations of the methylated fraction were also made. In the muscle, Hg was virtually 100% methylated; in the liver the methylated fraction varied from 7.4 to 41% being lowest in livers with highest total Hg.
KEY WORDS: Bay of Fundy, harbour porpoises, mercury, *Phocoena phocoena.*

Gauthier JM, Metcalfe CD, and Sears R. 1997. Chlorinated Organic Contaminants in Blubber Biopsies from Northwestern Atlantic Balaenopterid Whales Summering in the Gulf of St. Lawrence. Marine Environ. Res. 44(2):201-23.
ABSTRACT: Concentrations and patterns of chlorinated biphenyls (CBs) and other persistent organochlorine compounds (OCs) were determined from small blubber biopsy samples collected from northwestern Atlantic minke (*Balaenoptera acurostrata*), fin (*Balaenoptera physalus)*, blue (*Balaenoptera musculus*), and humpback (*Megaptera novaeangliae*) whales summering in the Gulf of St. Lawrence, Quebec. Concentrations of Sigma PCB (sum of 19 congeners) in biopsy samples ranged from 0.2 10 $\mu g \cdot g^{-1}$ lipid, and congeners 52, 101, 118, 153, 138 and 180 accounted for 79% of Sigma PCB. Mean concentration of the sum of nonortho CB congeners in selected biopsy samples was 2 $ng \cdot g^{-1}$ lipid, and relative concentrations of these analytes were: 77 > 126 > 81 > 169.

Concentrations of Sigma DDT ranged from 0.6 13 $\mu g \cdot g^{-1}$ lipid, and the average proportion of DDE to Sigma DDT was 72%. All other organochlorine analytes were present at concentrations below 2 $\mu g \cdot g^{-1}$ lipid. On average, cis nonachlor, trans nonachlor and oxychlordane accounted for 27, 26 and 23%, respectively, of the chlordane related analytes, and alpha hexachlorocyclohexane (HCH) comprised 67% of Sigma HCH. Concentrations of Sigma DDT were significantly lower and mirex concentrations were significantly higher in minke whales than in the other balaenopterid species. Concentrations of all other analytes were similar in the four whale species. Ratios of proportions of oxychlordane to trans nonachlor were highest in fin whales. Blue whales had the lowest proportions of alpha HCH but the highest proportions of DDT. Interspecies differences in the concentrations and patterns of certain CB congeners and OC compounds may reflect differences in diet or in metabolic capabilities. Males usually had higher mean concentrations of CBs and OCs than females, but these differences were significant only for Sigma DDT, dieldrin, Sigma HCH and HCB. Higher proportions of lower chlorinated CB congeners were found in calves compared to adult females, indicating selective reproductive transfer.
KEY WORDS: Atlantic minke whale, biopsies, blue whale, chlorinated biphenyls, fin whale, Gulf of St. Lawrence, humpback whale, organochlorine compounds.

Geraci JR, and Smith TG. 1984. Direct and Indirect Effects of Oil on Ringed Seals (*Phoca hispida*) of the Beaufort Sea. J. Fish. Res. Board Can. 33:1976-84.
ABSTRACT: Ninety-six ringed seals (*Phoca hispida*) were taken from nets at Browns Harbour, Northwest Territories in the fall of 1974. Comparison with two other net samples from 1971 and 1972 revealed a lower proportion of young-of-the-year and a lower mean weight of seals in all age-classes. Six seals immersed in Norman Wells crude oil for 24 h at the field netting site suffered only transient eye problems and minor kidney and possibly liver lesions; no permanent damage was observed. Three seals transported to the University of Guelph all died within 71 min after oil was introduced into their pool. Hematologic and blood chemical studies indicate that death was caused by oil superimposed on the stress of captivity. Six, 3-4 week-old wild whitecoat harp seal (*P. groenlandica*) pups at the Magdalen Islands, Quebec, were coated with crude oil. No significant differences in core body temperatures were noted and no deleterious effects were observed. Five captive ringed seals at Guelph were subjected to a cumulative dosage of Norman Wells crude oil fed with their fish food. High dosage (75 ml) and low dosage (25 ml) of crude oil were also fed to two groups of six harp seal pups. No significant lesions or behavioral changes were noted. These experiments were of an acute nature and reflect the effects of a brief contact with oil only. Effects of longer contact as would probably be the case in an offshore oil well blowout situation are discussed. Possible effects of large-scale offshore oil fields are also considered.
KEY WORDS: crude oil, large-scale offshore oil exploitation, *Phoca hispida*, ringed seal, stress indicators.

Geraci JR, and St. Aubin DJ. 1985. Expanded Studies of the Effects of Oil On Cetaceans. U.S. Government Report, Contract #14-12-0001-29169, Final Report, Part I :74 pp.
ABSTRACT: This report discusses the effects of oil on cetaceans. Research was conducted to find out how dolphins react to crude and refined oil slicks and how effectively they avoid them. It was suggested that tactile stimulation plays an important

role in their avoidance of oils which are difficult to detect visually. Memory is another sense that was significant on dolphins behavior. Another study assessed the mechanisms by which petroleum might harm cetacean skin. Morphological studies noted the location of intracellular lipids, their composition and possible function as a prelude to determining the consequences of petroleum contact. Other studies determined the fate of epidermal lipids in skin exposed to gasoline, which showed that these lipids are shielded from surface attack for as long as skin remains viable. Previous studies indicated that spilled oil would foul baleen and interfere with feeding therefore a system was designed to measure absolute changes in flow resistance after oil fouling. Overall, these studies confirm the hypothesis that oil has a relatively short-term impact on baleen function.
KEY WORDS: baleen fouling, bioaccumulation, bottlenose dolphin, cetacean skin, crude oil, intracellular lipid, marine mammals, oil detection, petroleum, refined oil.

Geraci JR, and St. Aubin DJ. 1982. Study of the Effects of Oil on Cetaceans. U.S. Department of the Interior, Contract #AA 551-CT9-29. 274 pp.
ABSTRACT: The objective of this study were: 1) to determine the ability of cetaceans to detect and avoid an oil slick; 2) to determine the effects of oil on the integument, and the ocular, respiratory, reproductive, digestive and excretory systems of cetaceans; 3) to evaluate the long-term impact of the above effects on cetacean survival and behavior, such as feeding, breeding, calving, and migration, also, analyze the potential for bioaccumulation of petroleum hydrocarbons and metabolites in cetaceans and where practical, determine the toxic threshold levels for mammalian species; and 4) to identify a range of mitigating measures which would eliminate or minimize the effects of oil pollution on marine mammals. From the study it was found that *Tursiops*, as a representative odontocete, can detect oil, and is inclined to avoid it, especially after contacting it. Also, a dolphin or whale, anywhere except in the heart of a fresh spill, could not inhale enough vapor or ingest enough oil to pose any immediate threat. Due to limited studies conducted on a single species, the behavior of mysticetes toward the oil spill is not as certain, however, their reaction to contact oil is expected to be similar to that of odontocetes.
KEY WORDS: cetaceans, long-term pollution effect, metabolite bioaccumulation, oil detection, oil pollution, petroleum hydrocarbon bioaccumulation, petroleum spill, pollution effect, toxic threshold level.

Geraci JR, Palmer NC, and St. Aubin DJ. 1987. Tumors in Cetaceans: Analysis and New Findings. Can. J. Fish. Aquat. Sci. 44:1289-300.
ABSTRACT: We describe 14 tumors, including 5 leiomyomas, 6 papillomas, 2 adrenal adenomas, and a bronchogenic carcinoma collected from over 1800 free-ranging and captive cetaceans examined since 1973. These bring to 41 the number of confirmable tumors reported from cetaceans. Of the 52 cases previously reported, 23 were described in sufficient detail to confirm the diagnoses, 15 were considered probable, and 4 were reclassified. Organ systems most commonly affected were the gastrointestinal tract (31%), skin (24%), and female reproductive tract (12%). Sampling bias may account for this apparent trend. Etiologic agents have rarely been identified, and attempts to do so are hampered by inadequate sample sizes.
KEY WORDS: cetaceans, etiologic agents, neoplasms, tumors.

Gilmartin WG, Delong RL, Smith AW, Sweeney JC, DeLappe BW, Risebrough RW, Griner LA, Dailey MD, and Peakall DB. 1976. Premature Parturition in the California Sea Lion. J. Wildl. Dis. 12:104-15.

ABSTRACT: Twenty percent of the California sea lion pups born on San Miguel Island died due to premature parturition. Specimens collected from premature-partus animals resulted in recovery of a virus, San Miguel Sea Lion Virus, indistinguishable from Vesicular Exanthema of Swine Virus, and *Leptospira pomona* from some of the premature cows and pups. The age range of 10 females delivering healthy pups in June was 10-14 years. With one exception, the ages in 10 aborting females was 6-8 years. The p,p'-DDE levels of the premature parturient cows blubber and liver were 7.6 and 4.8 times greater, respectively, than corresponding tissue concentrations in the full-term animals. Polychlorinated biphenyls residues were 4.4 and 3.8 times greater in aborting animals blubber and liver than in the same tissues of full-term sea lions. Premature-partus females had tissue imbalances of mercury, selenium, cadmium and bromine. Pathology, parasitology, serum enzyme and hormone results are also presented. These data suggest an interrelationship of disease agents and environmental contaminants as the cause of premature parturition.

KEY WORDS: California sea lion, DDE, disease agents, environmental contaminants, polychlorinated biphenyls, premature parturition, San Miguel Island, trace metals.

Goessler W, Rudorfer A, Mackey E, Becker P, and Irgolic K. 1988. Determination of Arsenic Compounds in Marine Mammals with High Performance Liquid Chromatography and Inductively Coupled Plasma Mass Spectrometry as Element Specific Detector. Appl. Organomet. Chem. 12:491-501.

ABSTRACT: Total arsenic concentrations and the concentrations of arsenic compounds were determined in liver samples of pinnipeds [9 ringed seals (*Phoca hispida*), I bearded seal (*Erginathus barbatus*)] and cetaceans [2 pilot whales (*Globicephalus melas*), 1 beluga whale (*Deliphinapterus leucus*)]. Total arsenic concentrations ranged from 0.167 to 2.40 mg As/kg wet mass. The arsenic compounds extracted from the liver samples with a methanol/water mixture (9+1 v/v) were identified and quantified by anion- and cation-exchange chromatography. An ICP-MS equipped with an hydraulic-high-pressure nebulizer served as the arsenic specific detector. Arsenobetaine (0.052 to 1.67 mg As/kg wet mass) was the predominant arsenic compound in all the liver samples. Arsenocholine was present in all livers (0.005 to 0.044 mg As/kg) but not in any of the cetaceans. The concentration of dimethylarsinic acid ranged from < 0.001 to 0.019 mg As/kg wet mass. Most of the concentrations for methylarsonic acid (< 0.001 to 0.025 mg As/kg wet mass) were below the detection limit. Arsenous acid and arsenic acid concentrations were below the detection limit of the method (0.001 mg As/kg). An unknown arsenic compound was present in all liver samples at concentrations from 0.002 to 0.027 mg As/kg.

KEY WORDS: arsenic, arsenobetaine, arsenocholine, cetaceans, HPLC-ICP-MS, pinnipeds, seals, whale.

Goksøyr A, Beyer J, and Larsen H. 1992. Cytochrome P450 in Seals: Monooxygenase Activities, Immunochemical Cross-Reactions and Response to Phenobarbital Treatment. Marine Environ. Res. 34:113-6.

ABSTRACT: Cytochrome P450 monooxygenase activities, reflecting the expression of

various subfamilies of P450, were measured in liver samples of harp and hooded seal. Differences in some of the investigated parameters were observed between the two species, between sexes, and between pups and adults. Treatment of single female pups from each species with phenobarbital (i.v., 45 mg/kg), resulted in increased levels of EROD and estradiol 2-hydroxylase activities in both species, whereas MCOD, ECOD and PROD activities were induced only in the harp seal sample. Antibodies against a dog P450 2B form (anti-dog P BD-2 IgG) gave a single band around 52 kD in both species, strongest in male pups. This band seemed elevated in the PB-treated harp seal pup. Based on the single treated pup of each species, the results suggest that seals respond to PB-type treatment with a weaker response, and with different enzyme patterns, than most terrestrial mammals. Antibodies against cod P450 1A1 cross-reacted with two bands in liver samples from adult seals of both species (about 54 and 52 kD), but this was strongest in the hooded seal. The intensity of the bands reflected the EROD activities in the samples, suggesting the application of immunodetection in screening marine mammals for effects of environmental contamination.
KEY WORDS: antibodies, cytochrome P450 monooxygenase, environmental contamination, harp seal, hooded seal, phenobarbital treatment.

Gregg MG, Hochberg FH, and Sherman SA. 1972. Possible Mercury Exposure, Pribilof Islands, Alaska. Information to Director of CDC. Public Health Service-HSM-CDC-Atlanta RPI-71-43-2. 9 pp.
KEY WORDS: Alaska, contamination, liver, marine mammals, mercury, northern fur seal.

Groff JM, Blake JE, Rideout B, Basaraba R, and Wilson D. 1990. Necrosopy Observations in Alaskan Sea Otters *Enhydra lutris* from Prince William Sound affected by the Exxon Valdez Oil Spill. In: Francis-Floyd, R.(Ed). 21st Annual International Association for Aquatic Animal Medicine (IAAAM) Conference :31-2.
KEY WORDS: Alaska, contamination, *Exxon Valdez*, marine mammals, necropsy, sea otter, oil spill effects.

Guitart R, Guerrero X, Silvestre AM, Gutierrez JM, and Mateo R. 1996. Organochlorine Residues in Tissues of Striped Dolphins Affected by the 1990 Mediterranean Epizootic: Relationships with the Fatty Acid Composition. Arch. Environ. Contam. Toxicol. 30:79-83.
ABSTRACT: A simple and rapid method was developed for the simultaneous determination of fatty acids, organochlorine pesticides, and polychlorinated biphenyl (PCB) congeners in the same sample in order to explore possible connections between levels of contaminants and fatty acid composition. The method was applied to samples of melon, cerebrum, cerebellum, lung, liver, kidneys, and skeletal muscle obtained from 5 male and 5 female striped dolphins (*Stenella coeruleoalba*) found stranded in 1990 in the northeastern Spanish coasts during the morbillivirus epizootic that affected this cetacean in the Mediterranean Sea. The results indicate that PCBs were dominant in all tissues, with the highest geometric mean concentration being found in melon (903$\mu g \cdot g^{-1}$ wet wt); sDDTs were also found at high concentrations (111 $\mu g \cdot g^{-1}$ wet wt, in melon). Statistical analysis indicate that organochlorine concentration was correlated with the fatty acid composition of tissues, although some of these variations can be interpreted as a

consequence of a shift in the diet produced in the striped dolphin population. However, other changes such as the negative correlation with arachidonic acid may suggest that the eicosanoid production could have been affected by the extremely high concentrations of PCBs and sDDTs.

KEY WORDS: eicosanoid production, fatty acid composition, organochlorine pesticides, polychlorinated biphenyl congeners, striped dolphins.

Hall AJ, Watkins J, and Hiby L. 1996. The Impact of the 1993 *Braer* Oil Spill on Grey Seals in Shetland. Sci. Total Environ. 186:119-25.

ABSTRACT: Signs of acute respiratory distress were reported in moulting grey seals (*Halichoerus grypus*) hauled out on Ladys Holm, Shetland, following the *Braer* oil spill in January, 1993. Behavioral observations carried out between 16 January and 13 February 1993 showed that the proportion of animals exhibiting a discharge of nasal mucus was significantly higher than the proportion at a control site in the north (Papa Stour). The proportion of animals affected on Ladys Holm increased for up to one month following the spill. However, the time lag between exposure and peak response was approximately 30 days, longer than may be expected for an acute effect. The proportion of non-specific signs of respiratory distress in unexposed Shetland seals was assessed from observations made between 16 January and 25 January 1994. Symptoms similar to those seen in 1993 were also reported during this period, but the proportion of affected animals was higher in 1993. Symptoms were not observed at a grey seal moult site on the east coast of England in March 1993 and 1994. Grey seals moulting in Shetland during the time of the oil spill may have been acutely affected by exposure to hydrocarbons, but without sufficient baseline data on the occurrence of respiratory distress in grey seals it is difficult to determine the proportion attributable to other causes.

KEY WORDS: grey seals, oil spill, Shetland.

Halpert JR, Guengerich FP, Bend JR, and Correia MA. 1994. Selective Inhibitors of Cytochrome P450. Toxicol. Appl. Pharmacol. 125(2):163-75.

ABSTRACT: The balance between detoxification and bioactivation of a compound in a particular species or organ is highly dependent on the relative amounts and activities of the different forms of cytochrome P-450 (P450) that are expressed. Therefore, knowledge of the catalytic specificities and regulation of individual P450 forms is of paramount importance in predicting and/or rationalizing species, strain, and individual differences in xenobiotic metabolism as well as metabolic interactions between compounds, both endogenous and exogenous. The emergence in recent years of a better of isoform-selective chemical inhibitors that can be used in vitro and in vivo in experimental animals and humans has greatly facilitated the identification of individual cytochromes P450 responsible for specific bioactivation and detoxification reactions. Many of these inhibitors are mechanism-based and owe their selectivity to metabolism by the target enzyme. Such compounds have also proven valuable as probes of the catalytic mechanism of cytochrome P450, for identifying amino acid residues of importance for the various functions of the enzyme, for assessing the physiological roles of P450-derived oxidation products of endogenous compounds, in chemical-induced models of acute hepatic porphyria, and for studying protein turnover. The identification of isoform-selective, nontoxic inhibitors of individual human cytochromes P450 raises the real possibility of modulation of human drug metabolism for therapeutic purposes.

KEY WORDS: bioactivation, cytochrome P450, detoxification, inhibitor, physiological role.

Hamanaka T, Itoo T, and Mishima S. 1982. Age-related Change and Distribution of Cadmium and Zinc Concentrations in the Stellar Sea Lion (*Eumetopias jubata*) from the Coast of Hokkaido, Japan. Mar. Poll. Bull.13(2):57-61.

ABSTRACT: Tissue cadmium and zinc levels in Steller sea lions have been analysed to elucidate the body distribution of these metals and their age-related accumulation. A significant correlation between age (0.7-8.8 year old) and renal and hepatic cadmium concentration was noted. Of the tissues examined, the kidney manifested the highest cadmium content (mean: 20.9 $g \cdot g^{-1}$ dry wt). A similar zinc distribution pattern was observed; its concentration was more uniform among tissues than that of cadmium. The tissue cadmium concentration in the Steller sea lion was lower than in other pinnipeds from various areas, possibly due to their feeding habits which may represent a major pathway of metal accumulation.

KEY WORDS: age-related accumulation, cadmium, metals, pinnipeds, Steller sea lion.

Hammill MO, and Smith TG. 1990. Application of Removal Sampling to Estimate the Density of Ringed Seals (*Phoca hispida*) in Barrow Strait, Northwest Territories. Can. J. Fish. Aquat. Sci. 47:244-50.

ABSTRACT: The density of ringed seals (*Phoca hispida*) in 2 to 4 km study plots was determined using a combination of removal sampling to determine density of seal holes and estimates of hole to seal ratios. A dog survey technique was adapted to removal sampling, where seal holes located under the snow by the dogs during surveys of fixed effort were marked and treated as removals from the population. Computer simulation indicates that estimates of seal hole density are within 10% of the true population size if for each plot there are 4 searches, sampling intensity is 0.85, the coefficient of variation of the estimate is 0.3, and the probability of detecting a seal hole is 0.35. The quality of survey results was affected by the number of dogs used to survey each plot, plot size, and surface topography. Densities of seal holes varied from 4.8 to 7.9 holes km^{-2}. Eight seals had an average hole to seal ration of 3.4. Seal densities ranged from 1.4 to 2.3 seals km^{-2}, and may be much higher if pup production is included.

KEY WORDS: dog survey technique, Northwest Territories, *Phoca hispida*, population dynamics, ringed seals, seal hole density.

Hansen CT, Nielsen CO, Dietz R, and Hansen MM. 1990. Zinc, Cadmium, Mercury and Selenium in Minke Whales, Belugas and Narwhals from West Greenland. Polar Biol. 10:529-39.

ABSTRACT: Samples of muscle, liver and kidney from 24 minke whales (*Balaenoptera acutorostrata*), 43 belugas (*Delphinapterus leucas*), and 98 narwhals (*Monodon monoceros*) were analyzed for zinc, cadmium, mercury, and selenium. Highly significant age accumulation of mercury was found. A lower level of significance of age accumulation of cadmium in belugas and narwhals is probably due to the fact that some of the highest cadmium concentrations are in subadults and young adults. The maximum concentrations of cadmium and mercury are very high: 1.68, 73.7, and 125 g cadmium, and 9.88, 42.8, and 4.61 g mercury per g wet weight of narwhal muscle, liver and kidney, respectively. The cadmium concentrations are correlated in the three organs, as are

mercury and to a lesser extent selenium concentrations. The concentrations of mercury and selenium in liver are highly correlated.
KEY WORDS: age accumulation, *Balaenoptera acutorostrata*, beluga whale, *Delphinapterus leucas*, heavy metals, minke whales, *Monodon monoceros*, narwhals.

Harrison PT, Holmes P, and Humfrey CD. 1997. Reproductive Health in Humans and Wildlife: Are Adverse Trends Associated with Environmental Chemical Exposure. Sci. Total Environ. 205(2-3):97-106.
ABSTRACT: In recent years, evidence from disparate observations has indicated adverse changes in the reproductive health and fecundity of animals and humans. In humans, there is strong evidence for such trends in the incidences of testicular and female breast cancer, and concern has also been expressed regarding semen quality, cryptorchidism, hypospadias and polycystic ovaries. Laboratory studies have indicated that some chemicals in the environment, both natural and synthetic, have the potential to disrupt the endocrine system and that these could, at least theoretically, be partly responsible for the observed change. Chemicals thus identified include the naturally occurring steroid hormones, phyto- and myco-estrogens, and anthropogenic chemicals such as synthetic hormones, organotins, organochlorine pesticides, polychlorinated biphenyls, dioxins, alkylphenol polyethoxylates, phthalates and bisphenol-A. While there is no direct evidence from human studies to confirm a causal link between exposure and effect, concern exists and is strengthened by reports of adverse reproductive and developmental effects in wildlife, possibly mediated via endocrine disruptive pathways. The development of imposex in neogastropod molluscs exposed to tributyltin has been attributed to such a mechanism and in wild populations of fish, alligators and birds, instances of masculinisation or feminisation in polluted areas have been noted. Among mammals, disturbed fertility of Florida panthers and some marine species has also been reported. A concentrated research and monitoring programme is required to clarify the nature and extent of effects on reproductive health in humans and wildlife, and to assess human and wildlife exposure to relevant naturally occurring or anthropogenic endocrine disrupting substances. This will enable a more robust evaluation of the contribution that environmental chemical exposure may have on adverse trends in the reproductive health of humans and wildlife.
KEY WORDS: endocrine disrupters, environmental exposure, human health, reproductive disorders, wildlife effects.

Heide-Jorgensen MP, Harkonen T, Dietz R, and Thompson PM. 1992. Retrospective of the 1988 European Seal Epizootic. Diseases of Aquatic Organisms 13:37-62.

Helle E. 1985. Occurrence and Effects of Environmental Toxins in Seals in Finland. Suomen Riista 32:5-22.

Helle E, Hyvärinen PH, and Wickstrom K. 1983. Levels of Organochlorine Compounds in an Inland Seal Population in Eastern Finland. Mar. Poll. Bull. 14(7):256-60.
ABSTRACT: Fourteen Saimaa ringed seals (*Phoca hispida saimensis*) were studied for PCB, DDT, chlordane and chlorophenol compounds in blubber, liver, muscle, heart and kidney in Lake Saimaa, eastern Finland, in 1977-1981. Both PCBs and total DDT increased on average from a good 5 $mg \cdot kg^{-1}$ in extractable fat of blubber in a new-born to

a good 65 $mg \cdot kg^{-1}$ in sexually mature specimens, the maximum being 93 and 104 $mg \cdot kg^{-1}$ respectively. Concentrations of PCBs and tDDT in blubber and liver were most clearly dependent on the age and weight of the seal. Chlordanes were found in all 14 specimens (mean 0.59 $mg \cdot kg^{-1}$ in blubber), trichlorophenol in one, tetrachlorophenol in two and pentachlorophenol in all three specimens studied. Although some of the Saimaa seals had reached quite high levels of both PCBs and tDDT, the present results do not indicate that the steady decrease of the Saimaa seal population during the last two decades would have been caused by these toxins, at least not in isolation.
KEY WORDS: environmental toxins, organochlorine compounds, *Phoca hispida saimensis*, Saimaa ringed seals, seal population.

Helle E, Olsson M, and Jensen S. 1976. DDT and PCB Levels and Reproduction in Ringed Seal from the Bothnian Bay. Ambio 5:188-9.
ABSTRACT: The serious DDT and PCB contamination of the Baltic area might explain the rapid decrease of the Baltic seal populations. In the Bothnian Bay only 27 percent of the Ringed Seal females of reproductive age are pregnant, compared to a normal of 80-90 percent in areas with low levels of pollution. Significantly higher levels of both DDT and PCB have been found in the non-pregnant females compared to the pregnant ones. In November, about four months before normal pupping, half of the non-pregnant females showed enlarged uteri and scars in the uterine wall. This indicates that implantation occurred, followed by resorption or abortion. Comparing analytical data on Californian Seal Lions, where similar reproductive disturbances have been reported, it seems probable that PCB and not DDT substances are responsible for the perturbation of reproduction in seals.
KEY WORDS: contaminants, DDT, PCB, reproduction, ringed seal.

Hild C. Cadmium Contamination in Alaska Native Food Chain. Rural Alaska Community Action Plan (RuralCAP) :1-8.
KEY WORDS: Alaska, cadmium, contamination, marine mammals, pacific walrus.

Holden AV, and Marsden K. 1967. Organochlorine Pesticides in Seals and Porpoises. Nature 216:1274-6.

Hope B, Scatolini S, Titus E, and Cotter J. 1997. Distribution Patterns of Polychlorinated Biphenyl Congeners In Water, Sediment and Biota from Midway Atoll (North Pacific Ocean). Mar. Poll. Bull. 34(7):548-63.
ABSTRACT: To increase our understanding of critical pathways of polychlorinated biphenyl (PCB) transfer from abiotic media into marine organisms, this study quantified 20 PCB congeners in surface water, sediment and tissues of marine biota (macrophytes, snails, urchins, bivalves, sea cucumbers, fishes) taken from Midway Atoll, PCBs 138, 153, 170, 180 and 187 were the most abundant congeners in all samples analysed. Distribution of PCB congeners was shifted in favor of higher (hexa and chlorinated) congeners in all species; only macrophytes displayed significant bioaccumulation of lower (tri and tetra) chlorinated congeners. Evidence is presented for the differential metabolism of congeners by marine species. Non ortho substituted congeners (PCBs 77, 126) with elevated toxic potency were not present at significant levels in the sampled species, Certain mono ortho congeners (PCBs 105, 118), implicated in marine mammal

toxicity, comprised only approximate to 4.5% of total congener load in prey for piscivorous birds and marine mammals.
KEY WORDS: abiotic media, congeners, marine biota, marine mammals, marine organisms, pollution, polychlorinated biphenyls.

Hurst RJ, Øritsland NA, and Watts PD. Metabolic and Temperature Responses of Polar Bears to Crude Oil:263-80.
ABSTRACT: The metabolic and temperature responses of three sub-adult polar bears (*Ursus maritimus*) were monitored before and after exposure to a 1 cm slick of Midale crude oil. Body and skin temperatures were measured by surgically implanted radio transmitters and metabolism by open circuit respirometry. Resting metabolic rate increased by 27% to 86% and averaged over 50% higher following oil fouling. Activity metabolism also increased in the one animal tested after oil contact, to 24% above the pre-oil level. Body temperature increased slightly in 2 of the animals and dropped in the 3rd polar bear within 24 hours of oil contact. Skin temperatures of all animals remained abnormally high for approximately one week following oiling. The metabolic changes induced by oil, and the potential energetic consequences, are discussed in relation to a possible metabolic compensation for a reduction in fur insulation; a change in the minimum level of energy turnover of body tissues; and a skin reaction to the physical oil coating.
KEY WORDS: metabolic changes, Midale crude oil, polar bear, temperature response, *Ursus maritimus*.

Iwata H, Tanabe S, Miyazaki N, and Tatsukawa R. 1994. Detection of Butyltin Compound Residues in the Blubber of Marine Mammals. Mar. Poll. Bull. 28(10):607-12.
ABSTRACT: The blubber samples of eight species (12 specimens) of marine mammals caught between 1981 and 1993 in seas surrounding Japan and in the Indian, North Pacific and Antarctic Oceans, were analysed for butyltin compounds (BTCs). The column chromatography using dry florisil and acetonitrile enabled isolation of BTCs from lipids in fatty tissues like blubber, and led to the reliable analysis with efficient recoveries for these contaminants. BTCs were detected in all the animals except a minke whale from the Antarctic Ocean. The highest residue levels were found in a finless porpoise from the Seto-inland Sea, Japan with a BTC concentration of 770 ng g^{-1} on wet wt basis. Geographical distribution of the BTC concentrations in marine mammals showed a decreasing trend from the coastal to the open seas, indicating the presence of larger pollution sources nearby the coastal regions. Compositions of the BTCs in the blubber of finless porpoises seemed to be different from those found in aquatic organisms of lower trophic levels. Lower contributions of dibutyltins to the total BTCs in the blubber suggest the presence of their specific metabolic pathways. To our knowledge, this is the first report on the detection of BTCs in marine mammals.
KEY WORDS: blubber, butyltin compounds, contaminants, marine mammals.

Jarman WM, Norstrom RJ, Muir DCG, Rosenberg B, Simon M, and Barid RW. 1996. Levels of Organochlorine Compounds, Including PCDDS and PCDFS, in the Blubber of Cetaceans from the West Coast of North America. Mar. Poll. Bull. 32(5):426-36.
ABSTRACT: Levels of organochlorine compounds (PCDD, PCDF, PCB and organochlorine pesticides) were determined in cetaceans collected from the west coast of

North America between 1986 and 1989. The samples included grey whale (*Eschrichtius robustus*), killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), Rissos dolphin (*Grampus griseus*) and Dalls porpoise (*Phocoenoides dalli*) collected in British Columbia, and harbour porpoises (*Phocoena phocoena*) collected in British Columbia and central California. TCDD and TCDF levels ranged from 1 to 8 $ng \cdot kg^{-1}$ and 2.0 to 109 $ng \cdot kg^{-1}$, respectively. The highest levels of PCDDs were found in the harbour porpoises, the levels of 1,2,3,6,7,8-hxCDD in the samples from Victoria, Campbell River and Qualicum River were 128, 128 and 62 $ng \cdot kg^{-1}$, respectively. Five other 2,3,7,8-substituted dioxins and dibenzofurans were detected in the cetaceans at levels ranging from 1 to 10 $ng \cdot kg^{-1}$. In addition to the 2,3,7,8-substituted congeners, several non 2,3,7,8-substituted congeners were detected. The patterns of the PCDDs and PCDFs, which were either present in wood chips used in bleached kraft paper mills, or came from direct contamination by chlorophenols. No PCDDs or PCDFs were detected in the California samples. One false killer whale sample had exceptionally high levels of DDT compounds (1700 $mg \cdot kg^{1}$ DDE 120 $mg \cdot kg^{-1}$ DDT and 40 $mg \cdot kg^{-1}$ *o,p'*-DDT) and toxaphene (89 $mg \cdot kg^{-1}$). PCB levels in the cetaceans were highest in the false and killer whales (22 to 46 $mg \cdot kg^{-1}$ GM), the lowest in the Rissos dolphin (1.7 $mg \cdot kg^{-1}$). Levels of DDE in the British Columbia harbour porpoises were 6.0 mg kg^{-1}, and probably reflect the accumulation of global background levels of DDE.
KEY WORDS: cetaceans, organochlorine contaminants, West Coast of North America.

Jenssen BM. 1996. An Overview of Exposure to, and Effects of , Petroleum Oil and Organochlorine Pollution in Grey Seals (*Halichoerus grypus*). Sci. Total Environ. 186:109-18.
ABSTRACT: Most incidences involving oil pollution of grey seals (*Halichoerus grypus*) seem to have occurred at the breeding sites. Because of the high concentration of animals at this time, even small oil spills will pollute many animals. As a result of chronic low-level pollution from coastal ship traffic and discharges from offshore petroleum activity in the North Sea, ~50% of the grey seal pups at the largest breeding colony in Norway are polluted each year by oil. In this case, as well as in other similar cases of spills at breeding colonies oil has produced little visible disturbance to the seals behaviour and there has been little mortality. The effects and mortality may, however, be more serious following a spill of crude oil, where animals may be affected by inhalation of toxic volatile compounds. High body burdens of PCBs and DDTs seem to have caused skull-bone lesions and occlusions of the uteri in grey seals in the Baltic Sea. Exposure to these persistent compounds has also been suspected to be the cause of reduction in the population of Baltic grey seals. There are indications that thyroid hormone and vitamin A status of grey seal pups are affected by the low exposure concentrations experienced at the Norwegian coast (~1/20 of the concentration detected in grey seal pups from the Baltic Sea). This gives serious cause for concern about the effects that chronic low-level exposure to persistent organochlorine pollutants may have on individuals and on populations of grey seals.
KEY WORDS: grey seals, oil pollution, organochlorines.

Jenssen BM, Skaare JU, Ekker M, Vongraven D, and Lorentsen SH. 1996. Organochlorine Compounds in Blubber, Liver, and Brain in Neonatal Grey Seal Pups. Chemosphere 32(11):2115-25.

ABSTRACT: The present study focuses on the distribution and accumulation of persistent organochlorine compounds in different tissues and organs of grey seal (*Halichoerus grypus*) pups. Thus, levels of drins (aldrin, dieldrin, endrin), chlordanes (heptachlor, heptachlorepoxide, oxychlordane, transnonachlor), DDTs (p,p'-DDE, o,p'-DDD, p,p'-DDD, o,p'-DDT, p,p'-DDT) and 22 PCB congeners were determined in samples of brain, fat, and liver of 0-10 days old grey seal pups from the species main breeding site in Norway. Whereas 10 different compounds were detected in blubber, 8 compounds were detected in the liver. The concentrations of the two major classes of OCs (PCBs and DDTs) in liver were both about 75% of that in blubber. In cerebral tissue, only two PCB congeners were detected, and sigma PCB was only about 1% of that measured in the blubber. The distribution pattern of PCB-congeners in liver and brain differed significantly from that in blood and blubber tissue, indicating that the physico-chemical properties of the individual congeners and the lipid composition of the tissue are decisive for the tissue-specific pattern of congener distribution. A significant increase of the sigma DDT/sigma PCB-ratio as a function of blubber thickness indicated that DDT compounds are more readily accumulated in older pups.
KEY WORDS: chlordanes, DDTs, drins, environmental contaminants, grey seal, Norway, organochlorine compounds, PCBs.

Kannan K, Guruge K, Thomas N, Tanabe S, and Giesy J. 1998. Butyltin Residues in Southern Sea Otters (*Enhydra lutris*) Found Dead along California Coastal Waters. Environ. Sci. Technol. 32(9):1169-75.

ABSTRACT: Tributyltin (TBT) and its degradation products, mono- (MBT) and dibutyltin (DBT), were determined in liver, kidney, and brain tissues of adult southern sea totters (*Enhydra lutris nereis*) found dead along the coast of California during 1992-1996. Hepatic concentrations of butyltin compounds (BTs = MBT + DBT + TBT) ranged from 40 to 9200 ng/g wet wt, which varied depending on the sampling location and gender. Concentrations of BTs in sea otters were comparable to those reported in stranded bottlenose dolphins from the U.S. Atlantic Coast during 1989-1994. Greater accumulation of butyltins in sea otters was explained by their bottom-feeding habit ad the diet that consists exclusively of invertebrates such as mollusks and gastropods. Livers of female sea otters contained approximately 2-fold greater concentrations of BTs than did those of males. The composition of butyltin compounds in sea otter tissues was predominated by TBT in most cases and suggestive of recent exposure. Large harbors such as Monterey Harbor that handle ships legally painted with TBT-containing antifouling paints continued to experience ecotoxicologically significant butyltin contamination. Sea otters, which were affected by infectious diseases, contained greater concentrations of BTs in their tissues than those that died from trauma and other unknown causes.
KEY WORDS: butyltin residues, California coast, *Enhydra lutris*, liver, sea otter, tissues, tributyltin.

Kannan K, Senthilkumar K, Loganathan BG, Takahashi S, Odell DK, and Tanabe S. 1997. Elevated Accumulation of Tributyltin and Its Breakdown Products in Bottlenose Dolphins (*Tursiops truncatus*) Found Stranded Along the U.S. Atlantic and Gulf Coasts. Environ. Sci. Technol. 31:296-301.

ABSTRACT: Butyltin compounds, including mono- (MBT), di- (DBT), and tributyltin

(TBT), were determined in the liver, kidney, and muscle of bottlenose dolphins (*Tursiops truncatus*) found stranded along the southeast U.S. Atlantic and Gulf coasts during 1989-1994. Total butyltin (BTs: MBT + DBT + TBT) concentrations in dolphin liver ranged between 110 and 11 340 ng/g (wet wt) with a mean value of 1400 ng/g. Butyltin concentrations in bottlenose dolphins were higher than those reported from other locations. The liver of a adult male dolphin collected in 1989 had the highest BT concentration (11 340 ng/g wet wt) reported. The concentrations of butyltins increased during the early life stages until maturity, for both sexes, and then tended to remain constant. Analysis of fish muscle collected from the Gulf of Mexico indicated the existence of recent inputs of TBT. The biomagnification factor of BTs in dolphins, on average, was 1.0 with the highest value of 6.8. In addition to polychlorinated biphenyls (PCBs), the presence of noticeable concentrations of TBT and DBT, which are potential immunosuppressing agents, might have also contributed to bottlenose dolphin mortality events in the U.S. Atlantic and Gulf coasts.

KEY WORDS: accumulation, biomagnification, bottlenose dolphin, butyltin compounds, Gulf coast, U.S. Atlantic.

Kannan K, Sinha RK, Tanabe S, Ichihashi H, and Tatsukawa R. 1993. Heavy Metals and Organochlorine Residues in Ganges River Dolphins from India. Mar. Poll. Bull. 26(3):159-62.

ABSTRACT: The Ganges River dolphin, *Platanista gangetica*, is predominantly found in the Ganges River and its tributaries in India. The Ganges is heavily polluted by the annual usage and discharge of about 2500 t of pesticides and 1.2 million t of fertilizers in its catchment area. A recent survey documented declining trends in the populations of river dolphins, including the Ganges dolphin. The monitoring of contaminant levels in river dolphins may therefore be an important aspect of their conservation. The present study provides information on the levels of major organochlorines and heavy metals in Ganges River dolphins collected from Patna, India. Four specimens found entangled in fishing nets or drowned were used for analysis.

KEY WORDS: aquatic mammals, bioaccumulation, diets, freshwater pollution, Ganges River, heavy metals, India, nature conservation, organochlorine compounds, PCB, pesticides, *Platanista gangetica*, rivers.

Kannan K, Tanabe S, Borrell A, Aguilar A, Focardi S, and Tatsukawa R. 1993. Isomer-Specific Analysis and Toxic Evaluation of Polychlorinated Biphenyls in Striped Dolphins Affected by an Epizootic in the Western Mediterranean Sea. Arch. Environ. Contam. Toxicol. 25:227-33.

ABSTRACT: Isomer-specific concentrations of polychlorinated biphenyls (PCBs) including planar, mono- and di-*ortho* congeners and concentrations of DDT were determined in striped dolphins affected by a morbillivirus epizootic in the western Mediterranean in 1990. Extremely high concentrations of PCBs ranging from 94 to 670 *ug*/g (wet wt) were detected in the blubber. Similarly, DDT concentrations were high, between 22 and 230 *ug*/g (wet wt). The concentrations of three non-*ortho* coplanar PCBs were 43 3,3',4,4'-T4CB), 6.8 (3,3',4,4',5-P5CB), and 7.8 (3,3',4,4',5,5',-H6CB) ng/g (wet wt), respectively, the highest residue levels reported to date. The estimated 2,3,7,8-TCDD toxic equivalents of non-, mono- and di-*ortho* PCB congeners in striped dolphins were several times higher than those observed for other marine mammals and humans.

Mono-*ortho* congeners contributed greater 2,3,7,8-TCDD toxic equivalents than non-*ortho* members. The higher ratios of 3,3',4,4',5,5'-H6CB/3,3',4,4',5-P5CB (IUPAC 169/126) suggested a strong induction of mixed function oxidase enzymes and highlighted the possibility of using this ration as an index for risk assessment of PCB contamination in marine mammals. Elevated concentrations of PCBs may have played a role in the immune depression in striped dolphins, ultimately leading to the development of morbillivirus disease.
KEY WORDS: DDT, isomer-specific, marine mammals, morbillivirus epizootic, polychlorinated biphenyls, striped dolphin, toxic evaluation, Western Mediterranean Sea.

Kawai S, Fukushima M, Miyazaki N, and Tatsukawa R. 1988. Relationship Between Lipid Composition and Organochlorine Levels in the Tissues of Striped Dolphin. Mar. Poll. Bull. 19(3):129-33.
ABSTRACT: Lipid content and lipid composition were studied in the various tissues of striped dolphins (*Stenella coeruleoalba*) collected from Japanese waters in order to elucidate the relationship between the levels of organochlorine compounds and the lipid composition. Total lipid content was highest in the adipose tissues such as blubber and melon, followed by mammary gland and milk. Also kidney, pancreas and brain contained about 10% of lipid. Other tissues such as liver, muscle, spleen and lung had low lipid contents ranging from 1-5%. In the tissues with high lipid contents, triglycerides comprised more than 70% of total lipids. Phospholipids and total cholesterol were dominant in brain tissues including cerebrum, cerebellum and medulla oblongata. Organochlorine compounds such as PCBs and DDTs were mainly distributed in tissues with high lipid content and the levels of these compounds were correlated with the content of triglycerides in the tissues. Abnormalities in lipid metabolism such as fatty livers were noticed in individuals with high PCBs and DDTs.
KEY WORDS: adipose tissues, Japan, lipid composition, organochlorine compounds, *Stenella coeruleoalba*, striped dolphins, Wakayama Prefecture.

Kawano M, Inoue T, Hidaka H, and Tatsukawa R. 1984. Chlordane Compounds Residues in Weddell Seals (*Leptonychotes weddelli*) from the Antarctic. Chemosphere 13(1):95-100.
ABSTRACT: Weddell seal samples taken from the Antarctic have been found to be contaminated with chlordane compounds. Chlordane (*cis*-chlordane + *cis*-nonachlor + *trans*-nonachlor + oxychlordane) was present in blubber of seals at the range of 12-62 ng/g fresh weight. The order of chlordane compound concentrations was trans-nonachlor > oxychlordane > *cis*-nonachlor > *cis*-chlordane. Relative abundance of *cis*-chlordane in chlordane is higher than that in humans. A probable explanation for their occurrences in the Antarctic is an airborne transport.
KEY WORDS: airborne transport, Antarctic, chlordane compounds, *Leptonychotes weddelli*, Wedell seal.

Kawano M, Inoue T, Hidaka H, and Tatsukawa R. 1986. Chlordane Residues in Krill, Fish and Weddell Seal from the Antarctic. Toxicol. Environ. Chem. 11:137-45.
ABSTRACT: Chlordane compounds (CHLs) were quantitated in krill (*Euphausia superba*), benthic fish (*Trematomus bernacchii*) and Weddell seal (*Leptonychotes weddelli*) collected around the Japanese Antarctic Research Station (Syowa Station: 6900S, 3935E). The concentrations of CHL (*cis*-, *trans*-chlordane + *cis*-, *trans*-nonachlor

+ oxychlordane) in krill was much lower than that of benthic fish. The ratio of CHL to the sum of CHL, DDT and PCBs decreased with the trophic levels. These results indicate that CHLs appear to be easily degraded in higher organisms.
KEY WORDS: Antarctic, benthic fish, chlordane compounds, environmental pollutants, krill, Weddell seal.

Kawano M, Inoue T, Wada T, Hidaka H, and Tatsukawa R. 1988. Bioconcentration and Residue Patterns of Chlordane Compounds in Marine Animals: Invertebrates, Fish, Mammals, and Seabirds. Environ. Sci. Technol. 22:72-797.
ABSTRACT: The bioconcentration and compositional patterns of chlordane compounds (CHLs: *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane) were investigated in organisms from two marine ecosystems. The bioconcentration factors (BCF: concentration in organism/concentration in seawater) of CHLs in lower trophic organisms were in between the values obtained for HCHs (-HCH, -HCH, and -HCH) and DDTs (*p,p*-DDE and *p,p*-DDT). In the case of higher trophic organisms, the scatter in the biomagnification factors (BMF: concentration in organism/concentration in food) of CHLs was found to be wider than those observed for HCHs and DDTs. Also, there were remarkable differences in CHLs composition among higher trophic organisms. For example, the percent composition of oxychlordane, which is one of the persistent metabolites of CHLs in seabirds from both areas, was higher than those of marine mammals.
KEY WORDS: bioconcentration, biomagnification factors, chlordane compounds, marine organisms.

Kemper C, Gibbs P, Obendorf D, Marvanek S, and Lenghaus C. 1994. A Review of Heavy Metal and Organochlorine Levels in Marine Mammals in Australia. Sci. Total Environ. 154(2,3):129-39.
ABSTRACT: Study of toxic contaminants in marine mammal specimens collected around Australia is currently uncoordinated and piecemeal. Most states collect samples but there is little or no financial support for their analysis. This study combines data, published or unpublished, from 13 sources. Heavy metals have been analysed in about 676 specimens; over 400 were for mercury levels in *P. macrocephalus* taken at a whaling station. The remaining samples were mostly from toothed whales, a few baleen whales (<20), pinnipeds (41) and dugongs (49). The most consistently analysed metals were lead, mercury and cadmium. Liver and kidney lead levels ranged from <1-3 ppm; levels in bone were 0-418 ppm, with most less than 10 ppm. Mercury levels in a large sample of *P. macrocephalus* muscle were < 12.2 ppm. Mercury levels in the small number of samples from other species were 0.51-143 ppm (kidney), 1.52-479 ppm (liver) and < 0.1-36 ppm (muscle). Cadmium levels in liver (0-52 ppm) and kidney (0-106 ppm) were extremely variable. Levels greater than 10 ppm were recorded in many species and were especially high in *Hydrurga leptonyx*, *Dugong dugon*, *Mesoplodon layardii* and *Pseudorca crassidens*. Adult *Tursiops truncatus* inhabiting the inshore gulfs of South Australia had considerably higher levels of cadmium compared with other regions. Information on organochlorine levels is sparse (approximately 39 specimens) and suggest low levels when compared to other parts of the world. Total DDT was highest (28.4 ppm) in a neonatal *Orcinus orca*. Some high levels of DDT were recorded in *Tursiops truncatus*, *Delphinus delphis* and *Arctocephalus pusillus doriferus*. PCBs ranged form

<0.05 to 3.87 ppm. A comprehensive pathological assessment of marine mammals is needed in order to evaluate the effects of toxic contaminants.
KEY WORDS: cadmium, cetaceans, dugongs, lead, mercury, pinnipeds, toxic contaminants.

Kim GB, Lee JS, Tanabe S, Iwata H, Tatsukawa R, and Shimazaki K. 1996. Specific Accumulation and Distribution of Butyltin Compounds in Various Organs and Tissues of the Steller Sea Lion (*Eumetopias jubatus*): Comparison with Organochlorine Accumulation Pattern. Mar. Poll. Bull. 32(7):558-63.
ABSTRACT: The present study was conducted to elucidate the specific distribution of butyltin (BT) compounds in various tissues and organs of Steller sea lions collected from coastal waters of Hokkaido, Japan. BT concentrations were an order of magnitude higher in the liver than in other tissues and organs except hair, whereas organochlorine (OC) compounds accumulated at two to three orders of magnitude higher in blubber than in other tissues. No relationship was observed between BT concentrations and the lipid content in tissues while the levels of OCs were positively associated with the lipid content. The levels of BTs in hair (1500 $ng \cdot g^{-1}$ on a wet weight basis) were the highest of all the tissues analysed. Results also suggested that 26% of the total BT burden in the body was eliminated through shedding. Selective accumulation of BTs in liver and hair is attributed to its protein-binding capacity rather than lipophilicity. The discovery of high concentrations of BTs in hair implies their excretion by shedding in piliferous animals.
KEY WORDS: accumulation, butyltin compounds, *Eumetopias jubatus*, Japan, organochlorines, Steller sea lions.

Kleivane L, Espeland O, Ugland KI, and Skaare JU. 1995. Seasonal Variation of Organochlorine Concentrations in Harp Seal (*Phoca groenlandica*). In: Whales, Seals, Fish and Man: Proceedings of the International Symposium on the Biology of Marine Mammals in the North East Atlantic, Tromso, Norway. 599-605.
ABSTRACT: The organochlorine (OCs) pollutants PCB, DDT, chlordanes, HCH and HCB were determined in blubber samples of 97 harp seals by capillary gas chromatography. The harp seal undergoes dramatic changes in the blubber layer during the year, with a minimum layer in the breeding and moulting periods. Seasonal differences in the OC concentrations between adult harp seals (>6 years) of both sexes were found. Highest and lowest OC levels were detected in animals caught during April/May and September, when the animals are at the leanest and at the fattiest, respectively. A decline in OC levels in blubber of juvenile harp seals was observed from January to May.
KEY WORDS: Arctic, Berents Sea, DDT, harp seal, marine mammals, PCB.

Kleivane L, Skaare JU, Bjorge ED, and Reijnders PJH. 1995. Organochlorine Pesticide Residue and PCBs in Harbour Porpoise (*Phocoena phocoena*) Incidentally Caught in Scandinavian Waters. Env. Poll. 89(2):137-46.
ABSTRACT: During Norwegian and Danish harbour porpoise projects 1987-1991, subcutaneous blubber samples of 34 male harbour porpoises (*Phocoena phocoena*) were collected. Animals from three geographical locations, ranging from 56 degrees N, 12 degrees E to 71 degrees N, 26 degrees E, were chosen in order to study the organochlorine (OC) contamination in this species inhabiting the northeastern part of the

North Atlantic Ocean, the northern North Sea and Kattegat, at the locations of Tufjord, Vestlandet and Gilleleje, respectively, Analytical standards used consisted of the industrial chemicals PCBs (22 individual PCB congeners and 6 industrial mixtures which contained 104 PCB congeners or group of congeners) and HCB, and the organochlorine pesticides DDT, HCH, the cyclodienes endrin, dieldrin and the chlordane metabolites oxychlordane and trans-nonachlor, and heptachlor epoxide. A total of 16 PCB congeners or groups of congeners, all the DDT metabolites except o,p'-DDD, and all the pesticides were detected in all animals. The concentrations of Sigma PCB (sum of concentrations of 47 detected PCB congeners) and Sigma DDT (sum of concentrations of all DDT detected compounds) ranged from 3.7-65.3 and 3.2-45.0 $\mu g \cdot g^{-1}$ lipid weight, respectively. The range of mean concentrations of dieldrin, endrin and trans-nonachlor was 1-3 $\mu g \cdot g^{-1}$, while mean concentrations of HCHs, heptachlor epoxide, and HCB were <1 $\mu g \cdot g^{-1}$). No significant variation in PCB congener pattern was apparent between geographical areas. The major PCB congeners nos. 147/123, 153, 138/163/164, 182/187 and 180 at Gilleleje, Vestlandet and Tufjord represented 53%, 45% and 44% of Sigma PCB, respectively. A significant difference was found between the number of PCB congeners in blubber of new born and older porpoises. This might indicated the presence of a blood/placenta barrier and/or selective mammary transport of PCBs with specific structures. A significant OC accumulation with age was apparent, with the exception of HCB and HCHs. Geographical differences in the levels of OCs were apparent for all compounds except for dieldrin and heptachlor epoxide. Significantly higher levels of chlordane metabolites (trans-nonachlor and oxychlordane) and endrin were found in the group of animals from the northern location Tufjord, while Sigma DDT, p,p'-DDTs, HCHs and PCBs were highest in the group of animals from the southern location Gilleleje. Highest levels of the o,p-substituted DDTs were found in specimens from the middle location Vestlander. These findings indicate little or no regular migration of harbour porpoise between these three locations. No correlations were found between OC concentrations and blubber thickness. Although mean values of Sigma DDT and Sigma PCB were in the lower end of previously reported levels in harbour porpoise from adjacent waters in the eastern part of the North Atlantic Ocean and along the coasts of North America, these levels are relatively high. The organochlorine concentrations in harbour porpoises in the present study were 2-3 times higher than corresponding OC levels detected in harbour seals (*Phoca vitulina*) from the same areas.

KEY WORDS: cetaceans, chlordane, contamination, dolphins, ecosystem, metabolism, *Phoca vitulina*, pollution, polychlorinated biphenyls, seals, *Stenella coeruleoalba*.

Kooyman GL, Gentry RL, and McAlister WB. 1976. Physiological Impact of Oil on Pinnipeds. Final Report for Research Unit #71, Outer Continental Shelf Energy Assessment Program, U.S. Department of the Interior, Bureau of Land Management, December, 1976. 25 pp.

ABSTRACT: The objective of this study was to measure the effects of oil contamination on the northern fur seal through studies in the thermal conductance of pelts, dive performance, and alterations in the metabolic rate before and after contact with oil. A second objective was to compare thermal conductance in pelts of fur-bearing marine mammals with that of nonfur-bearing species to determine whether surface fouling might be a major route of impact for all species. The study has shown that small amounts of crude oil have large effects on thermal conductance of fur-bearing pelts, and

no effect on nonfur-bearing pelts. In living animals light oiling of approximately 30% of the pelts surface area resulted in a 1.5-fold increase in metabolic rate while immersed in water of various temperatures. Furthermore, this effect lasted at least 2 weeks. Although normal diving was measured, we did not obtain post-oiling data to show the effect of oil contact on dive performance. Any contact with oil at any time of year would have a profound influence on the health of individual northern fur seals through increases in pelt conductance with concommitant increases in metabolic rate. That death would inevitably follow such contact cannot be verified from the present effort. However, considering that (a) oiled animals have greatly increased maintenance costs, and (b) they are extremely reluctant to enter sea water (where their food is found), it is clear that the health of oiled animals would be in serious jeopardy. Light crude oils, coated heavily enough to have a severe metabolic impact, may not be visually detectable on the pelt. Therefore, oiled animals on the rookery may not be obvious which would make ineffective any rehabilitation program following an oil spill.
KEY WORDS: marine mammals, northern fur seal, oil contamination, pinnipeds, thermal conductance.

Krahn MM, Ylitalo GM, Buzitis J, Chan SL, and Varanasi U. 1993. Rapid High-Performance Liquid Chromatographic Methods that Screen for Aromatic Compounds in Environmental Samples. J. Chromatogr. 642:15-32.

Krahn MM, Ylitalo GM, Buzitis J, Sloan CA, Boyd DT, Chan S-L, and Varanasi U. 1994. Screening for Planar Chlorobiphenyl Congeners in Tissues of Marine Biota by High-Performance Liquid Chromatography with Photodiode Array Detection. Chemosphere 29(1):117-39.
ABSTRACT: A rapid method has been developed to screen for planar chlorobiphenyl (CB) congeners, as well as certain other CBs and DDTs, in tissue samples from marine biota. The analytes were extracted from tissue matrices with 1:1 hexane/pentane (v/v) and interfering compounds were separated from the CBs on a gravity-flow column packed with acidic, basic and neutral silica gel eluted with 1:1 hexane/methylene chloride (v/v). Subsequently, the planar CB congeners were resolved from the DDTs and other CBs by HPLC on Cosmosil PYE analytical columns cooled to 9°C and were measured by an ultraviolet (UV) photodiode array (PDA) detector. Two important advantages of PDA over conventional UV detection were the ability to identify individual analytes by comparing their UV spectra to those of reference standards and the ability to establish the spectral homogeneity (purity) of the analytes by comparing spectra within a peak to the apex spectrum. The HPLC/PDA method was tested with tissue samples from fish, shellfish and marine mammals; concentrations of certain CBs and DDTs in samples determined by screening compared favorably with those in the same samples analyzed by a comprehensive method (e.g., gas chromatography/high resolution mass spectrometry). However, the HPLC/PDA method was about an order of magnitude less sensitive than determinations by comprehensive methods.
KEY WORDS: HPLC/ PDA method, marine biota, planar chlorobiphenyl congeners, UV spectra.

Kreiss K. 1985. Studies on Populations Exposed to Polychlorinated Biphenyls. Env. Health Perspect. 60:193-9.

ABSTRACT: Mean serum levels of polychlorinated biphenyls (PCBs) in U.S. population groups without occupational exposure to PCBs are usually between 4 and 8 ng/mL with 95% of individuals having serum PCB measurements of less than 20. Subpopulations consuming fish taken from contaminated waters, such as Lake Michigan and near Triana, AL, have mean serum PCB levels several times those found in other general population groups and ranges that extend into concentrations found in industrial populations involved in capacitor manufacture. Two studies of general populations and several studies of industrial workers have demonstrated associations of PCBs with various serum lipids and liver enzyme levels. Six groups of investigators have found associations between PCB or chlorinated pesticide levels and blood pressure. Research efforts are needed in clarifying determinants of serum-adipose partition ratios; the utility of urinary porphyrine as a measure of subclinical hepatic effects; human metabolites and excretion of chlorinated hydrocarbons; and the relation, if any, between blood pressure and organochlorine compounds when controlled for confounding variables. Established cohorts, such as those in Triana, Lake Michigan sportfishers, the Michigan PBB cohort, residents of farms with PCB-lined silos, and occupational groups, could all be studied further with attention to these research questions.
KEY WORDS: blood pressure, chlorinated pesticide levels, polychlorinated biphenyls, populations.

Kuehl DW, and Haebler R. 1995. Organochlorine, Organobromine, Metal, and Selenium Residues in Bottlenose Dolphins (*Tursiops truncatus*) Collected During an Unusual Mortality Event in the Gulf of Mexico, 1990. Arch. Environ.Contam.Toxicol. 28:494-9.

ABSTRACT: Polychlorinated biphenyls (PCBs), cis-chlordane, oxychlordane, heptachlor epoxide, mirex, hexachlorobenzene (HCB), lindane, octachlorostyrene (OCS), *p,p'*-DDE, *p,p'*-DDT, dieldrin, triphenylphosphate (TPP), polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDPEs) were measured in the blubber, and five metals (mercury, lead, cadmium, chromium, and manganese and selenium) were measured in the liver of bottlenose dolphins (*Tursiops truncatus*) obtained from the Gulf of Mexico during an unusual mortality event in 1990. The collection of animals included fetuses, sucklings (<1 year old), immature dolphins (2-5 years old), and adults of both sexes. PCBs, *p,p'*-DDE, HCB, and PBDPEs were detected in the blubber of each animal. Mean concentrations of organic contaminants were generally highest in adult males. *p,p'*-DDE was the single component analyte measured at the highest concentration. Immature females had greater concentrations of most chlorinated organics than adult females. Mercury and cadmium concentrations in liver increased with increasing age-class. The correlation between mercury and selenium in all animals was r = 0.96, with a mole ratio of 0.90. Concentrations of lead, manganese, cadmium, and chromium did not follow any particular age-class trend.
KEY WORDS: bottlenose dolphin, Gulf of Mexico, metals, mortality event, organobromine, organochlorine, selenium, *Tursiops truncatus*.

Kuehl DW, Haebler R, and Potter C. 1991. Chemical Residues in Dolphins from the U.S. Atlantic Coast Including Atlantic Bottlenose Obtained During the 1987/88 Mass Mortality. Chemosphere 22(11):1071-84.

ABSTRACT: Bottlenose dolphins (*Tursiops truncatus*) collected during the 1987/88 mass mortality event along the Atlantic coast of the United States have been analyzed for

anthropogenic chemical contaminants. Average contaminant concentrations in adult males were higher than the average concentrations measured in adult females. Females could be divided into two groups by contaminant concentrations one with low concentrations, and another with concentrations 4.4 times (PCBs) to 8.9 times (p,p'-DDE) greater. Contaminant concentrations in bottlenose were generally greater than the concentrations measured in either common (*Delphinus delphis*) or white-sided (*Lagenorhynchus acutus*) dolphins from the western North Atlantic Ocean. A subset of animals screened for unusual chemical contaminants showed that numerous polybrominated chemicals were present, including polybrominated biphenyls and diphenyl ethers not previously found in marine mammals from U.S. coastal waters.
KEY WORDS: Atlantic coast, bottlenose dolphins, common dolphin, contaminant concentrations, DDT, mass mortality, PCB, white-sided dolphins.

Kurtz DA. Analysis of Northern Fur Seals for the Years 1975-1981 for DDT Analogs and PCB Mixtures. A Report, Department of Entamololgy, The Pennsylvania State University. 27 pp.
ABSTRACT: This study concerns the presence of the environmentally stable pesticidal compound, DDT and its analogs, and the commercial contaminant, polychlorinated biphenyl mixtures, PCBs, in tissues and organs of the northern fur seal. Time dependent concentrations were studied relating samples analyzed in 1972 with those collected in 1975, 1978, and 1981. When compared with seal life viability data, the potential influence of these compounds can be assessed. As a global indicator of zenobiotic contamination, these analyses could test modeling theories involving the distribution of these compounds in the global system as they related to the presence and disappearance of the concentrations of them throughout the system. Fat tissue will contain the highest concentrations of these compounds because of the lipophilicity of the analytes, and will therefore be the tissue providing the most sensitive analyses. Liver organ is included because of its role in detoxifying undesirable compounds in the body. Blood analysis has been included to determine its analytical sensitivity and its correlation with body tissue and organ levels. Brain tissues will be analyzed in order to determine the blood/brain barrier and indicate any potential effects on the brain.
KEY WORDS: *Callorhinus ursinus*, contamination, DDT analog, lipophilicity, Northern fur seal, polychlorinated biphenyl mixtures, zenobiotic contamination.

Kurtz DA. 1987. PCB/DDT Contamination in Northern Fur Seals: 1984. A Report to The National Geographic Society Committee for Research and Exploration, Grant No. 2921-84. 19 pp. **ABSTRACT:** This study was completed to assess potential chemical effects on seals. Male fur seal samples were collected from St. Paul Island, Alaska in 1984 and analyzed for polychlorinated biphenyl and DDT concentration levels. A comparison of overall means shows that liver concentrations for total DDT were only 4.4% of those in the fat tissue and for PCB only 5.6%. PCBs were found in greater concentrations in kidney organ tissues when compared with the liver concentrations.
KEY WORDS: Alaska, chemical effects, contamination, DDT, Northern fur seals, polychlorinated biphenyls, St. Paul Island.

Lahvis GP, Wells RS, Casper D, and Via CS. 1993. In-vitro Lymphocyte Response of Bottlenose Dolphins (*Tursiops truncatus*): Mitogen-Induced Proliferation. Marine Environ. Res.

35:115-9.

ABSTRACT: Stranded bottlenose dolphins, *Tursiops truncatus*, exhibit infections suggestive of immune dysfunction. Concurrent high levels of immunotoxic pollutants indicate that one possible cause of death is pollutant-induced immune dysfunction. In this study, immunological assays were adapted to assess immune function of healthy dolphins. Peripheral blood from 23 dolphins was obtained by capture/release near Sarasota, Florida. Blood was shipped at ambient temperature by overnight mail in vacutainers containing either sodium heparin or EDTA. Mononuclear cells were separated by centrifugation in Ficoll and cultured in RPMI 1640 containing 10% fetal calf serum, 2-ME, and antibiotics. Lymphocytes were stimulated with a panel of mitogens across a broad dose-response range in order to determine the kinetics of proliferative responses (i.e. 3H-thymidine uptake). Responses to Con A, PHA, and PWM were maximal at 6, 5 and 2 days of culture, respectively. No significant response to LPS was observed. We conclude that culture and shipment conditions for human lymphocyte assays are appropriate for assessment of dolphin immune function. Further studies will examine the use of both mitogenic and non-mitogenic stimuli to evaluate immune function in both normal and at risk dolphin populations.

KEY WORDS: bottlenose dolphin, immune dysfunction, immunotoxic pollutants, lymphocyte, mitogen-induced proliferation.

Lahvis GP, Wells RS, Kuehl DW, Stewart JL, Rhinehart HL, and Via CS. 1995. Decreased Lymphocyte Responses in Free-ranging Bottlenose Dolphins (*Tursiops truncatus*) are Associated with Increased Concentrations of PCBs and DDT in Peripheral Blood. Env. Health Perspect. 103(4):67-72.

ABSTRACT: Since 1987, large-scale mortalities of dolphins have been reported along the Atlantic coast of North America, in the Gulf of Mexico, and in the Mediterranean Sea. Autopsied bottlenose dolphins, *Tursiops truncatus*, which were collected from the large-scale mortality along the Atlantic coast in 1987 to 1988, exhibited opportunistic infections indicative of immune dysfunction. Further, these animals had high levels of chlorinated hydrocarbons, such as PCBs and DDT, that can suppress immune functions. The purpose of this study was to determine whether there is a relationship between chemical contaminant exposure and immune response in free-ranging dolphins. In June of 1991, peripheral blood was obtained from members of a bottlenose dolphin population that resides along the west coast of Florida. Peripheral Blood lymphocyte responses to Concanavalin A (Con A) and phytohernagglutinin (PHA) were determined in vitro and compared by regression analysis with contaminant concentrations in whole blood from a small subset of these animals (n=5). These data indicate that a reduced immune response in these bottlenose dolphins was correlated with increasing whole blood concentrations of several contaminants. Specifically, inverse correlations were found between Con A-induced lymphocyte proliferation and tetrachlorinated to octachlorinated biphenyls (r^2 values of 0.73 and 0.79); *o,p'*-DDE (r^2 values of 0.93 and 0.96); and *p,p'*-DDE (r^2 values of 0.73 and 0.81).

KEY WORDS: contaminant, DDT (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane), dolphin, immune response, lymphocyte, marine strandings, PCB (polychlorinated biphenyl), polychlorinated hydrocarbons, *Tursiops truncatus*.

Law RJ, Allchin CR, and Morris RJ. 1995. Uptake of Organochlorines (Chlorobiphenyls,

Dieldrin, Total PCB & DDT) in Bottlenose Dolphins (*Tursiops truncatus*) from Cardigan Bay, West Wales. Chemosphere 30(3):547-60.

ABSTRACT: High concentrations of organochlorine compounds (particularly PCB and chlorobiphenyls) have been found in three bottlenose dolphins from the vicinity of New Quay in West Wales. Although few in number, the animals ranged in age from 10 months to 23 years. The occurrence of high contaminant concentrations in all of these animals suggests that a high level of uptake of these compounds occurs in food after weaning as well as by transfer from mother to calf. In order to investigate this further we have tried to model the uptake using a bioenergetics-based approach. Using estimates of feeding rate we have calculated the concentrations of these contaminants in average prey items necessary to maintain the dolphins body burden during the juvenile growth stage. The data available to date are too few for a rigorous test of this approach, however these preliminary studies suggest that the contaminant concentrations in local food items analysed to date are not sufficiently high to explain the high concentrations found in dolphin blubber. Further information is needed on the contaminant burdens of bottlenose dolphins in Cardigan Bay, and of their relationships and diet (including seasonal and migratory components), in order to validate this approach.

KEY WORDS: bottlenose dolphins, diet, mother/calf pair, organochlorine compounds, uptake, West Wales.

Law RJ, Jones BR, Baker JR, Kennedy S, Milne R, and Morris RJ. 1992. Trace Metals in the Livers of Marine Mammals from the Welsh Coast and the Irish Sea. Mar. Poll. Bull. 24(6):296-304.

ABSTRACT: Samples of liver from forty-two marine mammals of six species found on the coast of Wales and the Irish Sea in 1989-91 have been analysed for a range of trace metals (Cr, Ni, Cu, Zn, Cd, g, and Pb). The animals sampled comprised eleven seals, twenty-two porpoises, eight dolphins and one Minke whale. The range of concentrations for each metal were, in $g \cdot g^{-1}$ wet wt: Cr, <0.5-2.1; Ni, <0.5-2.1; Cu, 2.2-79: Zn. 15-150; Cd, <0.06-2.2; Hg, 0.5-280; Pb, 0.05-7.0. The majority of values for Cr, Ni, and Pb were below the limits of detection for flame AAS extracts were reanalysed for Pb only using graphite furnace AAS. High concentrations of Hg and Pb were found in a number of animals from the Liverpool Bay area of the eastern Irish Sea. The highest Cd concentrations were found in an offshore species, the striped dolphin *Stenella coeruleoalba*, and this is thought to relate to prey preference. Elevated concentrations of Cu were found in a neonatal porpoise and a common dolphin foetus, relative to those found in their mothers, but this finding is also not thought to be pollution-related. Results from *post-mortem* investigations made on the majority of the animals are also presented.

KEY WORDS: Irish Sea, marine mammals, trace metals, Wales.

Law RJ, Stringer RL, Allchin CR, and Jones BR. 1996. Metals and Organochlorines in Sperm Whales (*Physeter macrocephalus*) Stranded Around the North Sea During the 1994/1995 Winter . Mar. Poll. Bull. 32(1):72-7.

ABSTRACT: Sperm whales, *Physeter macrocephalus*, samples of blubber were collected from seven animals stranded around the North Seas during the winter of 1994/1995. Samples were analyzed for organochlorine pesticides and metabolites along with a range of chlorobiphenyl congeners. One liver sample was also collected from one individual. Concentrations of Cr and Ni were low at 0.79 and 0.39 $mg \cdot kg^{-1}$ wet weight.

Alpha, beta and gamma-HCH, HCB and dieldrin were detected in all blubber samples. Residues of *cis* - and *trans*-chlordane and *trans*-nonachlor and both o,p' and p,p'-isomers of DDD, DDE and DDT were also detected in all samples. Compared to previous reports, concentrations of CBs were relatively low, ICES 7 = 1.6-3.1 $mg \cdot kg^{-1}$ wet weight with the predominant congener being CB 153. An accumulation of organochlorine pesticides and metabolites from oceanic food webs following their long-range transport from terrestrial sources have been represented from this data.
KEY WORDS: metabolites, metals, North Sea, organochlorine, *Physeter macrocephalus*, Sperm whales.

Le Boeuf BJ, and Bonnell ML. 1971. DDT in California Seal Lions. Nature 234:108-10.
ABSTRACT: Tissue samples, primarily blubber, were taken from California sea lions, *Zalophus californianus*, in 1970. DDT residues were present in all samples with mean concentrations in the liver being 17 $\pm$ 10ppm (n=7) wet weight. The potential danger of organochlorine pesticides to pinnipeds warrants a concern for not only the California sea lion population but also man, whose diet includes fish and cephalopods.
KEY WORDS: California, California sea lion, DDT, organochlorine pesticide, *Zalophus californianus*.

Lee JS, Tanabe S, Umino H, Tatsukawa TR, Loughlin TR, and Calkins D.C. 1996. Persistent Organochlorines in Steller Sea Lion (*Eumetopias jubatus*) from the Bulk of Alaska and the Bering Sea, 1976-1981. Mar. Poll. Bull. 32(7):535-44.
ABSTRACT: Organochlorine pesticides and polychlorinated biphenyls (PCBs) were determined in the blubber and liver of Steller sea lion collected from the bulk of Alaska and the Russian Bering Sea. PCBs were the predominant organochlorines in the blubber, ranging in concentration from 5.7 to 41 $g \cdot g^{-1}$ (lipid weight) in males and from 0.57 to 16 $g \cdot g^{-1}$ in females. Concentrations of DDTs (DDT and its metabolites) in blubber ranged from 2.8 to 17 $g \cdot g^{-1}$ in males and from 0.19 to 6.5 $g \cdot g^{-1}$ in females. The levels of chlordane compounds (CHLs) and hexachlorocyclohexanes (HCHs) were one to three orders of magnitude lower than those of PCBs and DDTs. The residue levels of PCBs, DDTs and CHLs in males increase with age, whereas in females they decreased sharply after maturity, suggesting the transfer of organochlorines in large quantities during lactation. Transfer rate of organochlorines through lactation was estimated to be 80% for PCBs and 79% for DDTs of the total body of adult female. Concentrations of organochlorines in the liver of the Steller sea lion from Alaska, on a lipid weight basis, were similar to those in the blubber. In addition, liver showed age-dependent accumulation of PCBs, DDTs and CHLs, similar to that in the blubber. The concentrations of all the organochlorines detected in the liver were clearly correlated with those in the blubber, indicating the lipophilic nature of organochlorines in accumulation and movement in the animal body. Residue levels of PCBs and DDTs in the liver of male Steller sea lions from the Bering Sea were significantly lower than those from Alaska, suggesting that Bering Sea animals have different foraging areas from the animals of the bulk of Alaska.
KEY WORDS: Alaska, Bering Sea, *Eumetopias jubatus*, foraging areas, organochlorines, Steller sea lion.

Lentfer JW, and Galster WA. 1987. Mercury in Polar Bears form Alaska. J. Wildl. Dis.

23(2):338-41.
ABSTRACT: Alaskan polar bear (*Ursus maritimus*) muscle and liver samples collected in 1972 were analyzed for total mercury. Bears north of Alaska had more mercury than bears west of Alaska. The only difference between young and adult animals was in the northern area where adults had more mercury in liver tissue than young animals. Levels were probably not high enough to be a serious threat to bears.
KEY WORDS: age, Alaska, mercury, polar bear, *Ursus maritimus*.

Lentfer JW. 1976. Environmental Contaminants and Parasites in Polar Bears. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration, Project Nos. W-17-4, W-17-5, Final Report. 22 pp.
ABSTRACT: Tissue samples from polar bears killed by Alaskan based hunters from 1967 through 1972 were examined for organochlorine hydrocarbons, PCBs, mercury and *Trichinella* larvae. Organochlorinated hydrocarbons including the DDT group, hexachlorobenzene, dieldrin and endrin were at such low levels (less than 0.1 ppm) they probably have a minimal effect on bears. The mean PCB level in fat was 1.9 ppm. This is a relatively low value compared to levels, apparently nonlethal, reported in some other mammals. Samples did not show differences in levels of organochlorinated hydrocarbons or PCBs between age groups of bears or hunting areas west and north of Alaska. Polar bears from the west hunting area contained slightly more than 4 micrograms per gram wet weight mercury in liver, and bears from the north area contained 30 micrograms per gram. Levels in liver were 100-175 times greater than in muscle. Levels in muscle were below maximum levels considered safe for human consumption. There is no known industrial use of mercury in Alaskan polar bear habitat, and food chains may acquire mercury from a geological source. Percent incidence of masseter muscle tissue with *Trichinella* larvae was 64.4, and mean number of larvae per gram in positive samples was 4.15. There was no significant difference in level of incidence or mean number of larvae per gram between sexes, age groups or west and north hunting areas.
KEY WORDS: contaminants, mercury, organochlorine hydrocarbons, parasites, PCB, polar bears.

Leonzio C, Focardi S, and Fossi C. 1992. Heavy Metals and Selenium in Stranded Dolphins of the Northern Tyrrhenian (NW Mediterranean). Sci. Total Environ. 119:77-84.
ABSTRACT: Heavy metal (Hg, Cd, Pb and Zn) and selenium levels were determined in striped (*Stenella coeruleoalba*) and bottle-nosed dolphins (*Tursiops truncatus*) stranded along the coast of Tuscany and Latium, Italy in the period 1987-1989. Lead and zinc concentrations were quite low and there was modest accumulation of cadmium in the kidney of both species. Mercury levels were very high especially in the liver where they reached peaks of 4400 ppm (dry weight) in the striped dolphin and 13,150 ppm (dry weight) in the bottle-nosed dolphin. Selenium levels were also high and were significantly correlated with mercury levels in some organs and tissues. The toxicological significance of the selenium-mercury interaction is discussed.
KEY WORDS: heavy metals, selenium mercury interaction, stranded dolphins.

Letcher RJ, Norstrom RJ, Lin S, Ramsay MA, and Bandiera SM. 1996. Immunoquantitation and Microsomal Monooxygenase Activities of Hepatic Cytochromes P4501A and P4502B and Chlorinated Hydrocarbon Contaminant Levels in Polar Bear (*Ursus maritimus*).

Toxicol. Appl. Pharmacol. 137(2):127-40.
ABSTRACT: Contamination of the Arctic ecosystem by anthropogenic compounds has resulted in exposure of polar bear (*Ursus maritimus*) to lipophilic chlorinated hydrocarbon contaminants (CHCs) accumulated through the marine food web. Liver samples were collected from 16 adult male polar bears in the Canadian arctic and subjected to chemical analysis for CHCs and metabolites, determination of alkoxyresorufin O-dealkylase activities, and immunoquantitation of cytochrome P450 (CYP) protein levels. We report on the relationships between the hepatic microsomal levels of immunoreactive CYP1A and CYP2B isozymes, catalytic activities, and hepatic CHC and metabolite concentrations in polar bear. We specifically explored the influence of several CHCs on the induction of hepatic CYP in polar bear and the potential use of immunoassay quantitation as a bioindicator of CHC exposure. Polychlorinated biphenyls (PCB) classed as CYP1A and mixed CYP1A/CYP2B inducers accounted for about 25% of the total PCB residues present (18,680 +/- 5053 ng/g lipid). CYP1A protein content correlated strongly with hepatic levels of PCBs, PCDDs (0.032 +/- 0.018 ng/g lipid), and PCDFs (0.011 +/- 0.007 ng/g lipid) and their corresponding toxic equivalents (TEQ, 0.377 +/- 0.182 ng/g lipid). Mono-ortho-CB-156, CB-157, andCB-105 were the predominant TEQ contributors. Correlations between CYP2B protein content and CHC residue levels in polar bear liver suggested that ortho-chlorine-substituted PCBs and chlordanes were the major contributors to CYP2B induction. CYP1A and CYP2B contents were therefore good indicators of CHC exposure in polar bear liver. Ethoxyresorufin, pentoxyresorufin, and benzyloxyresorufin O-dealkylase activities increased with increasing CYP1A protein content up to protein levels of approximately 5 pmol/mg, suggesting that all three activities were primarily CYP1A-mediated. These results were substantiated by antibody inhibition experiments. In summary, immunoquantitated CYP1A and CYP2B isozymes are a more reliable measure of exposure to CHC inducers than alkoxyresorufin O-dealkylase activities in polar bear.
KEY WORDS: bioindicator, Canadian arctic, CYP1A and CYP2B isozymes, lipophilic chlorinated hydrocarbon contaminants, PCBs, PCDDs, PCDFs, polar bear.

Lipscomb TP, Harris RK, Moeller RB, Pletcher JM, Haebler RJ, and Ballachey BE. 1993. Histopathological Lesions in Sea Otters Exposed to Crude Oil. Vet. Pathol. 30:1-11.
ABSTRACT: Following the *Exxon Valdez* oil spill in Prince William Sound, Alaska, sea otters (*Enhydra lutris*) that appeared to be contaminated with oil, that were in danger of becoming contaminated, or that were behaving abnormally were captured and taken to rehabilitation centers. Exposure to oil was assessed by visual examination when otters arrived at the centers. Degree of oil exposure was graded according to the following criteria: oil covering greater than 60% of the body-heavily contaminated; oil covering 30-60% of the body-moderately contaminated; oil covering less than 30% of the body or light sheen on fur-lightly contaminated. If there was no oil visible, otters were considered uncontaminated. Tissues from 51 oil-contaminated sea otters (14 males, 37 females) and from six uncontaminated sea otters (three males, three females) that died in rehabilitation centers were examined histologically. Among oil-contaminated sea otters, 19/46 had interstitial pulmonary emphysema, 13/40 had gastric erosion and hemorrhage, 11/47 had centrilobular hepatic necrosis, 14/47 had periportal to diffuse hepatic lipidosis, and 10/42 had renal tubular lipidosis. Histologic examinations were performed on tissues from five sea otters (three males, two females) found dead with external oil present 15 to 16 days

after the spill. Periportal hepatic lipidosis and renal tubular lipidosis were found in 3/5, and interstitial pulmonary emphysema was found in 1/5. Tissues from size apparently normal sea otters (four males, two females) collected from an area not affected by an oil spill were examined histologically, and none of these lesions were found. We conclude that interstitial pulmonary emphysema, centrilobular hepatic necrosis, and hepatic and renal lipidosis of sea otters were associated with exposure to crude oil. Gastric erosion and hemorrhage may have been associated with stress of captivity and/or oil exposure.
KEY WORDS: Crude oil, *Exxon Valdez* oil spill, interstitial pulmonary emphysema, petroleum hydrocarbon, sea otters.

Lockhart WL. 1995. Implications of Chemical Contaminants for Aquatic Animals in the Canadian Arctic: Some Review Comments. Sci. Total Environ. 160-161:631-41.
ABSTRACT: Chemical residue analyses have established beyond doubt that arctic ecosystems are contaminated with low concentrations of several contaminants. The sources of these vary, but for many, the principal source is atmospheric deposition as a result of widespread dispersal by air masses carrying materials from lower latitudes. The principal problem discussed here is how to determine whether there are biological implications associated with the contaminants. For the most part, concentrations are below those found in more temperate regions where similar questions have been asked. Little experimental toxicology has been done with arctic species, and relatively little has been done in environmental toxicology in general to express biological responses in terms of body residues. It is argued that chemical residue studies are not, in themselves, evidence of biological responses. The effects of greatest interest are those at ecological levels, but ecological surveys that might detect biological changes have little power to test for cause-effect linkages between the contaminants and the changes observed. The emerging approach of biomarkers or bioindicators seems to offer the greatest promise for efforts to determine whether arctic contaminants have biological implications.
KEY WORDS: Arctic, biomarker, contaminant, mercury, PCB, sediment.

Loughlin TR, Ballachey BE, and Wright BA. 1996. Overview of Studies to Determine Injury Caused by the *Exxon Valdez* Oil Spill to Marine Mammals. Proceedings of the *Exxon Valdez* Oil Spill Symposium. AFS, Bethesda, MD. Am. Fish. Soc. Symp. 18:798-808.

Lowry LF, and Fay FH. 1984. Seal Eating by Walruses in the Bering and Chukchi Seas. Polar Biol. 3:11-8.
ABSTRACT: Walruses (*Odobenus rosmarus*) feed primarily on benthic invertebrates, but they are known to eat seal (*Phocidae*) occasionally , ostensibly when the benthic foods are unavailable. We investigated reports of a marked increase in occurrence of seal-eating walruses in the Bering Strait region in the late 1970s by examining stomach contents of animals taken in the spring harvest by Eskimos. We also obtained relevant information during visual surveys of marine mammals in the region. Our findings from the stomachs indicated that seal eating was 10 to 100 times more common during the 1970s and early 1980s (0.6-3.0%, N = 645) than it had been in the previous three decades (0.07-0.20%, N = 4015). In addition, we observed walruses in possession of seal remains in 1978 and 1979, where we had not seen such a phenomenon before in the previous 25 years. We attribute the increased predatory interaction between seals and walruses partly to a larger walrus population and, especially in 1979, to unusually restrictive spring ice

conditions, which tended to cause greater than usual overlap of their distributions. Stomach contents of walruses take in the Chukchi Sea in summer, where the ranges of walruses and seals overlap broadly in all years, have indicated a similarly high rate of occurrence of seal eaters (8.6% in the 1960s, N = 35; 11.4% in 1983, N = 44). As a whole, our findings indicate that most of the seal eating is predation, rather than scavenging of carrion. They also indicate that it is not rare or aberrant but common behavior, and that it could exert a significant impact on seal populations in some areas.
KEY WORDS: benthic invertebrates, diet, *Odobenus rosmarus*, *Phocidae*, seal, walruses.

Luckas B, Vetter W, Fischer P, Heidemann G, and Plötz. 1990. Characteristic Chlorinated Hydrocarbon Patterns in the Blubber of Seals From Different Marine Regions. Chemosphere 21(1-2):13-9.
ABSTRACT: Samples of seal blubber from several marine regions (Arctic, Iceland, North Sea, Baltic, and Antarctic) were analysed for chlorinated hydrocarbon contamination. Varying concentrations of organochlorine compounds (PCB, DDT and its metabolites, HCB, and HCH-isomers) lead to characteristic residue patterns. Evaluation of the data demonstrated significant geographical differences in both level and pattern of the contaminants analyzed, thus giving an insight into the global distribution of organochlorine pollution.
KEY WORDS: chlorinated hydrocarbon contamination, global distribution, marine mammals, organochlorine compounds.

Mössner S, and Ballschmiter K. 1994. Separations of Alpha-hexachlorocyclohexane (alpha-HCH) and Pentachlorocyclohexene (PCCH) Enantiomers on a Cyclodextrin-phase (Cyclodex-B) by HRGC/ECD. Fresenius J. Anal. Chem. 348:583-9.
ABSTRACT: The separation of -hexachlorocyclohexane and of all eight possible pentachlorocyclohexene isomers into their enantiomers by high-resolution gas chromatography and electron capture detection was achieved by using permethylated -cyclodextrin in DB 1701 (Cyclodex B, J & W) as chiral stationary phase. The first step in the metabolism of 1,2,3,4,5,6-hexachlorocyclohexane (HCH) is the formation of 1,3,4,5,6-pentachlorocyclohexene-1 (PCCH). Various degradation experiments were carried out with alpha-, beta-, gamma-, and sigma-HCH. Whereas beta-HCH have no degradation products, the isomers alpha-, gamma-, and sigma-HCH degraded into various PCCHs and trichlorobenzenes, when using pyridine as dehydrochlorination reagent in xylene at 60C. Isomerization in to other HCH isomers was observed only for sigma-HCH. Enantioselective dehydrochlorination was observed for alpha- and gamma-HCH using the alkaloid (-)-brucine, R-(+)- or S-(-)-1-phenylethylamine as chiral base.
KEY WORDS: alpha-, beta-, gamma-, sigma-HCH, chiral stationary phase, pentachlorocyclohexene enantiomers.

Mössner S, Spraker TR, Becker PR, and Ballschmiter K. 1992. Ratios of Enantiomers of Alpha-HCH and Determination of Alpha-,Beta-,and Gamma-HCH Isomers in Brain and Other Tissues of Neonatal Northern Fur Seals (*Callorhinus ursinus*). Chemosphere 24(9):1171-80.
ABSTRACT: The ratios of the two enantiomers of alpha-HCH have been determined by high resolution gas chromatography using different chiral stationary phases of the

cyclodextrin-type in brain, blubber, liver, and lung tissues of neonatal Northern fur seals of different health status. The ratio of the two enantiomers (+)-alpha-HCH / (-)-alpha-HCH (tentatively assigned) varied from 1.8 to 28 in blubber and brain, respectively. Northern fur seal milk and cod liver oil were analyzed for comparison. In addition, the concentrations of alpha-, beta-, and gamma-HCH isomers in the fur seal samples were determined. The three isomers (alpha-, beta-, and gamma-HCH) gave a tissue specific distribution with a rather constant alpha-HCH / gamma-HCH ration of 4 2. Only the brain tissue gave an alpha-HCH / gamma-HCH ratio of 36 1.
KEY WORDS: brain tissue, capillary gas chromatography, enantiomeric ratio, HCH isomers, isomer ratio, neonatal Northern fur seals.

Mackey EA, Becker PR, Demiralp R, Greenberg RR, Koster BJ, and Wise SA. 1996. Bioaccumulation of Vanadium and Other Trace Metals in Livers of Alaskan Cetaceans and Pinnipeds. Arch. Environ. Contam. Toxicol. 30(4):503-12.
ABSTRACT: Concentrations for 38 elements are routinely measured in the marine mammal liver tissues archived in the National Biomonitoring Specimen Bank (NBSB). Results show that hepatic concentrations of vanadium, selenium, silver, cadmium, and mercury are positively correlated with age for beluga whales (*Delphinapterus leucas*) and of vanadium, selenium, cadmium, and mercury with length for ringed seals (*Phoca hispida*). Many researchers have reported linear correlations of hepatic selenium, cadmium, and mercury with marine mammal age; however, there is only one other report of a linear correlation of hepatic vanadium with marine mammal age. Vanadium levels are at or below detection limits (less than or equal to 0.01 μg/g) in liver tissues of U.S. east coast marine mammals from the NBSB but are present at levels ranging from 0.02 to 1.2 μg/g of wet weight in the tissues of Alaskan marine mammals. Although only three bearded seal (*Erignathus barbatus*) and three bow-head whale (*Balaena mysticetus*) liver samples have been analyzed, hepatic vanadium levels also increased with animal size for these species. The presence of relatively high levels of vanadium in the livers of these Alaskan animals may reflect a unique dietary source of vanadium, a unique geochemical source of vanadium, or anthropogenic input to the Alaskan marine environment.
KEY WORDS: Alaska, *Balaena mysticetus*, bioaccumulation, *Delphinapterus leucas*, *Erignathus barbatus,* heavy metals, liver, marine environment, marine mammals, *Phoca hispida*, tissues, trace elements, vanadium.

Malcolm HM, Boyd IL, Osborn D, French MC, and Freestone P. 1994. Trace Metals in Antarctic Fur Seal (*Arctocephalus gazella*) Livers from Bird Island, South Georgia. Mar. Poll. Bull. 28(6):375-80.
ABSTRACT: Samples of liver from 11 female Antarctic fur seals (*Arctocephalus gazella*) from Bird Island, South Georgia were analysed for 16 trace elements (Mg, Cr, Co, Cu, Zn, Rb, Sr, Mo, Cd, Sn, I, Ba, La, Ce, Hg, and Pb). The mean concentrations for each element ($mg \cdot kg^{-1}$ dry wt) was Mg, 727; Cr, 1; Cu, 263; Zn, 384; Rb, 7; Sr, 0.3; Mo, 1; Cd, 350; Hg, 215; Pb, 0.1. Levels of Co, Sn, I, Ba, La, and Ce were below the limits of detection. For the majority of elements, the measure concentrations were considerably higher than concentrations previously reported in seals. Significant Spearman correlation coefficients were obtained between Cd and Hg, Cd and Zn, Hg and Zn, Sr and Mo, age and Cd, and age and Hg. The toxicological significance of these concentrations is discussed.

KEY WORDS: Antarctic fur seals, *Arctocephalus gazella*, South Georgia, toxicology, trace metals.

Marcovecchio JE, Gerpe MS, Bastida RO, Rodriguez DH, and Moron SG. 1994. Environmental Contamination and Marine Mammals in Coastal Waters from Argentina: An Overview. Sci. Total Environ. 154(2,3):141-51.

ABSTRACT: Environmental contamination became an increasing global problem. Different scientific strategies have been developed in order to assess the impact of pollutants on marine ecosystems. The distribution of toxic contaminants in tissues of different marine mammal species - both cetaceans and pinnipeds - has been studied in many ecosystems, as well as several related ecological processes, like pollutant accumulation or transfer through the food web. A research program directed towards evaluating the occurrence of pollutants in marine mammals from the coastal waters of Argentina (southwestern Atlantic Ocean) has been developed since 1985, and includes the study of heavy metal contents in stranded or incidentally caught animals. The marine mammal species studied during this period were: the seals *Otaria flavescens* and *Arctocephalus australis*, and small cetaceans *Tursiops gephyreus*, *Pontoporia blainvillei*, *Kogia breviceps* and *Ziphius cavirostris*. In most of the cases, high contents of heavy metals (total mercury, cadmium, zinc, and copper) have been recorded. Moreover, liver showed the maximum capability for accumulation of heavy metals in all studied species. The biological and ecological characteristic of each species of the above-mentioned marine mammals (feeding habits, age, migratory pathways, or sex) contributed to the understanding of the metal sources. Considering the results as obtained during the study period it can be assumed that : (1) the global distribution of toxic contaminants also affects the southwestern Atlantic Ocean ecosystems, and (2) marine mammals could be appropriate bioindicator species in order to assess this kind of environmental problem.
KEY WORDS: bioaccumulation and biomagnification processes, bioindicator species, heavy metals, marine mammals, pollution, target tissues.

Martin JH, Elliott PD, Anderlini VC, Girvin D, Jacobs SA, Risebrough RW, Delong RL, and Gilmartin WG. 1976. Mercury-Selenium-Bromine Imbalance in Premature Parturient California Sea Lions. Marine Biology 35:91-104.

ABSTRACT: High premature birth rates have been observed in the rookeries of the California sea lion *Zalophus californianus* since 1968. The reasons for the premature pupping are complex, and, hence, not well understood, although leptospirosis infection and elevated PCB and DDT residues have been implicated. We were interested in determining what role trace and major elements played in these events. Livers and kidneys from 10 normal parturient and 10 premature parturient mothers and their pups were analyzed for Hg, Se, Br, Cd, Ag, Cu, Fe, Zn, Mn, K, Na, Ca, and Mg in order to detect differences that might exist between the two groups. A further objective was to establish how these elements varied in relation to each other in the normal and abnormal sea lions. Our results revealed that Hg, Se, Cd, and Br levels were significantly higher in livers of the normal mothers and that these elements were all in balance (highly correlated) with each other. This was especially true for Hg, Se, and Br. In mothers with high concentrations of these elements (e.g. Hg greater than 800 *u*g/g dry weight), atomic ratios of approximately 1Hg:1Se:1Br were observed. Atomic Se:Hg ratios were also near unity in the abnormal mothers; however, Br concentrations were always severely

depressed in these individuals. Normal full-term pups had higher hepatic levels of Hg and Se, and near-perfect 1:1 Se:Hg atomic ratios were almost always observed. In contrast, the livers of the premature pups appeared to be deficient in Hg, and, consequently, elevated Se:Hg ratios were always found. In almost all cases, the premature pups had increased concentrations of Na, Ca, and Br. Levels of these elements were correlated with their Se:Hg ratios. Amounts of Mn and Cu were reduced in the premature pups and negatively correlated with Se:Hg ratios. The results suggest that balance between elements is of more importance than absolute concentration when the possible effects of toxic elements are considered. It also appears that bromine may be important in the detoxification process involving Se and Hg and perhaps Cd as well; i.e., every mother that had Br in balance with Hg, Cd, and Se had a normal pup, while every mother that lacked sufficient Br had a premature pup. The question of whether Hg detoxifies Se is also raised. All the normal pups had Se:Hg atomic ratios of less than 2.2, while all the premature pups had reduced Hg amounts and Se:Hg ratios above 3.4.
KEY WORDS: California sea lions, heavy metals, premature birth rates, premature parturient, trace elements.

Martineau D, Beland P, Desjardins C, and Lagacé A. 1987. Levels of Organochlorine Chemicals in Tissues of Beluga Whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Quebec, Canada. Arch. Environ. Contam. Toxicol. 16:137-47.
ABSTRACT: High levels of organochlorine chemical (OC) were found in the blubber of 26 stranded carcasses of beluga whales from an isolated population in the St. Lawrence Estuary (Quebec, Canada). These compounds accumulated with age in both sexes, being consistently more concentrated in male tissue; high and variable concentrations were found in four juveniles. Lower levels in females are best explained through massive transfer to the newborn during lactation, resulting in juvenile OC concentrations equal to or higher than in adult males. Concentrations in the liver and kidney expressed on a lipid basis suggest dynamic OC exchange between tissues. The adipose tissue concentrations reported here were higher or equal to those found in some pinnipeds, in laboratory animals, and in domestic animals with severe reproductive failure. These findings suggest that OC contamination is a major factor in the on-recovery of the St. Lawrence beluga population over the last decades.
KEY WORDS: age accumulation, *Delphinapterus leucas*, organochlorine chemicals, stranded beluga whales, St. Lawrence Estuary.

Martineau D, DeGuise S, Fournier M, Shugart L, Girard C, Lagace A, and Beland P. 1994. Pathology and Toxicology of Beluga Whales from the St. Lawrence Estuary, Quebec, Canada. Past, Present, Future. Sci. Total Environ. 154(2,3):201-15.
ABSTRACT: An indigenous population of 450-500 beluga whales (*Delphinapterus leucas*) inhabiting the St. Lawrence Estuary has been exposed chronically for more than 50 years to a complex mixture of industrial pollutants including organochlorinated compounds (OC), polycyclic aromatic hydrocarbons (PAH) and heavy metals. From 1983 to 1990, we have necropsied 45 well preserved carcasses out of a total of 120 beluga whales reported dead over this period. Of these 45 animals, nine were affected by 10 malignant neoplasms. Fifteen animals (33%) were affected by pneumonia. Milk production was compromised in eight of 17 mature females (41%), by inflammatory changes (seven animals) and cancer (one animal) which affected the mammary glands.

Opportunistic bacteria were found in pure culture, and/or in significant amounts in at least two organs in 20 belugas (44%). The concentrations of both total PCBs and highly chlorinated PCB congeners were much higher in St. Lawrence animals than in Arctic beluga whales. OC-induced immunosuppression has been repeatedly demonstrated in a wide variety of animal species. Therefore, it is probable that the immune functions of St. Lawrence beluga whales are impaired. Benzo[*a*]pyrene adducts were detected in 10 of the 11 St. Lawrence beluga whales of which tissues (six livers, 10/11 brains) were analyzed by a method based on HPLC. No such adducts were found in four Arctic animals. Since benzo[]pyrene is one of the most potent chemical carcinogens known to man, these compounds might be responsible for some of the cancers observed in that population. Overall, our findings contrast vividly with those of others who found that cancers are exceedingly rare in free-ranging odontocete populations and that the major causes for mortalities in these populations are bacteria, parasites, and trauma.
KEY WORDS: beluga, cancer, cetaceans, contaminants, DDT, hydrocarbons, immunosuppression, organochlorines, pathology, PCB, polycyclic aromatic, whales.

Martineau D, Lagacé A, Massé R, Morin M, and Béland P. 1985. Transitional Cell Carcinoma of the Urinary Bladder in a Beluga Whale (*Delphinapterus leucas*). Can. Vet. J. 26:297-302.
ABSTRACT: A transitional cell carcinoma of the urinary bladder was found in a beluga whale stranded in the St. Lawrence middle estuary. Various organs of this animal were submitted to high resolution gas chromatography coupled with mass spectrometry analysis. High frequency of urinary bladder cancer in the human population of the same area and the presence of carcinogenic compounds in the marine environment of this animal are discussed. Concurrent isolation of *Edwardsiella tarda* from various organs of this whale is also reported.
KEY WORDS: carcinogens, cetaceans, *Edwardsiell tarda*, polycyclic aromatic hydrocarbons, transitional cell carcinoma, urinary bladder.

Martineau D, Lagace A, Beland P, Higgins R, Armstrong D, and Shugart LR. 1988. Pathology of Stranded Beluga Whales (*Delphinapterus leucas*) From the St. Lawrence Estuary, Quebec, Canada. J. Comp. Pathol. 98(3):287-311.
ABSTRACT: From June 1983 to May 1986, thirteen carcasses of stranded beluga whales from a polluted area of the St. Lawrence River, Canada were necropsied. High performance liquid chromatography was performed on the brains of three other animals to determine concentrations of benzo a pyrene (BaP). Two juvenile animals had severe multisystemic lesions one of which, a severe necrotizing dermatitis, was associated with a Herpesvirus-like particle. Four adults had five varieties of tumours. An adult had a systemic nocardiosis and a juvenile was affected by a non 0:1 Vibrio chlolerae septicemia. High concentrations of BaP adducts were found in the brains which were analyzed. Occurrence of BaP adducts in the brain of three whales of this population coincides with the high incidence of tumours. This and the previous finding of high concentrations of organochlorine in the tissues of these animals suggest an important role of industrial contaminants in the recent decrease of this population.
KEY WORDS: beluga whales, benzo-*a*-pyrene, organochlorine contaminants, St. Lawrence River, tumors.

Martoja R, and Viale D. 1977. Accumulation of Mercuric Selenide Granules in the Liver of

Odontocetes (Mammifers, Cetacea): A Possible Method of Detoxification of Methylmercury by Selenium. C R Acad. Sci. Hebd. Seances Acad. Sci. D 285(1):109-12.
ABSTRACT: In Mediterranean Cetaceans, concretions of pure mercuric selenide are found in the connective tissue of the liver. Their presence explains that high levels of mercury and selenium coexist with low level of methylmercury. The selenide could be produced parallel with demethylation of mercury, a process leading to the fossilization of mercury and partially of selenium under the form of a non biodegradable component.
KEY WORDS: cetaceans, detoxification, liver, methylmercury, selenium.

Mason CF, and Macdonald SM. 1993. Impact of Organochlorine Pesticide Residues and PCBs on Otters (*Lutra lutra*): A Study From Western Britain. Sci. Total Environ. 138(1-3):127-45.
ABSTRACT: A study of otter (*Lutra lutra*) populations and levels of organochlorine (OC) pesticide residues and PCBs in otter droppings (spraints) was made on eight stretches of river in three catchments in Wales and West Midland England. Population and contaminant levels were compared against target values. The otter populations (as measured by an index) remained stable on one stretch over 11 years, while they increased rapidly to equilibrium on four other stretches. The three stretches of rivers showed more erratic trends and on only one stretch did the index exceed, occasionally, the target value. Marking intensity at spraint sites was also lower at the three lowland sites. Concentrations of dieldrin, DDE and PCBs were significantly greater in spraint samples from the three lowland stretches. Over 50% of samples from the three lowland stretches had OC concentrations above the maximum allowable concentration, whereas most samples from the upland stretches had concentrations below the no effects level. It is suggested that the colonization, by otters, of their former lowland range is inhibited by OC contamination of their food chain but, if contaminant levels can be reduced, spread will occur rapidly.
KEY WORDS: *Lutra lutra*, otter, PCBs, pesticides, Wales.

Mason CF, and Macdonald SM. 1993. Impact of Organochlorine Pesticide Residues and PCBs on Otters (*Lutra lutra*) in Eastern England. Sci. Total Environ. 138(1-3):147-60.
ABSTRACT: A study of otter (*Lutra lutra*) populations and levels of organochlorine (OC) pesticide residues and PCBs in otter faeces (spraints) was made on rivers in East Anglia, England. Population and contaminant levels are compared against target values. It is thought that the native otter population was almost extirpated during the study period. The current population must derive largely, if not entirely, from captive-bred animals introduced since 1983. Its range has expanded little and population levels, measured a an index, were generally low. Concentrations of OC pesticides and PCBs were similar to those of lowland stretches of western rivers; however, samples had a smaller proportion of dieldrin and a greater proportion of PCBs. Overall 44% of samples had concentrations of contaminants exceeding the level of concern. It is considered that contamination, especially by PCBs, remains a factor influencing otter populations, which may not be viable in East Anglia without repeated releases of captive-bred animals.
KEY WORDS: England, *Lutra lutra*, otter, PCBs, pesticides.

Mason CF, and Macdonald SM. 1994. PCBs and Organochlorine Pesticide Residues in Otters (*Lutra lutra*) and In Otter Spraints From SW England and Their Likely Impact on

Populations. Sci. Total Environ. 144:305-12.
ABSTRACT: PCB and organochlorine pesticide residues were determined in otter (*Lutra lutra*) spraints (faeces) from nine catchment regions in SW England over the period 1989-1991. Results of analyses of tissues from 22 otters are also presented. Dieldrin occurred in the majority of spraint samples and p,p'-DDE and total PCBs in all. Lindane occurred mainly in samples collected in spring. Lindane was not found in otter tissues collected after 1991, but dieldrin, p,p'-DDE and PCBs were found in all tissues. Dieldrin and p,p'-DDE concentrations were strongly correlated in otter tissues, but there were no correlations with lindane or PCBs. Mean concentrations of contaminants varied widely between catchments. It was considered that PCBs were the compounds of most concern in influencing otter populations and that levels in spraints from one catchment were likely to be sufficiently high to exert a negative effect on populations. While levels of PCBs were elevated above background level in several other catchments and some individual otters had high levels of PCBs, it was considered that they were not sufficient to significantly hinder further population consolidation of otters in SW England.
KEY WORDS: *Lutra lutra*, otter, PCBs, pesticides.

Mason CF, and Madsen AB. 1993. Organochlorine Pesticide Residues and PCBs in Danish Otters (*Lutra lutra*). Sci. Total Environ. 133(1-2):73-81.
ABSTRACT: Tissues (71 liver, 2 muscle) of 73 otters found dead in Denmark between 1980 and 1990 were analyzed for organochlorine pesticide residues and PCBs. Geometric means of contaminant concentrations were generally low, but some otters had PCB concentrations considered to be of concern; a greater proportion of these came from isolated populations away from the main populations centre in Limfjord. Animals dying of unknown causes had greater concentrations of PCBs than those dying by drowning or in traffic accidents. Adults had significantly higher concentrations of PCBs. Contaminant concentrations were strongly intercorrelated. Concentrations of DDE and PCBs declined significantly during the study period. A sample of otter spraints (faeces) collected in 1990 had low concentrations of contaminants. It is concluded that current concentrations of organochlorine pesticide residues and PCBs are unlikely to pose a threat to otter populations.
KEY WORDS: Denmark, *Lutra lutra*, PCBs, pesticides.

May KI, Steoppler M, and Reisinger K. 1987. Studies in the Ratio Total Mercury/Methylmercury in the Aquatic Food Chain. Tox. Environ. Chem. 13:153-9.
ABSTRACT: A rapid and extremely sensitive method for the separation of inorganic mercury (Hg) from methylmercury (MeHg) and the simultaneous determination of both compounds by CVAAS has been developed. The determination limit of the total procedure for MeHg is approximately 0.2 ng/kg for aqueous samples. The determination of inorganic Hg and MeHg of some links of the aquatic food chain according to this method resulted in high percentages of inorganic Hg (84.7-85.7% of total Hg) and low percentages of MeHg (14.3-15.3% of total Hg) for algae. While already mussels show lower percentages of inorganic Hg (44.4-79.9% of total Hg), all fish samples yield by far the lowest percentages of inorganic HG (1-26.0% of total Hg) and as expected the highest percentages of MeHg (73.1-99% of total Hg). The ratio MeHg/total Hg found in fish even in fish of different species is approximately constant.
KEY WORDS: aquatic food chain, cold vapour AAS, environmental specimens,

inorganic mercury, ion exchange chromatography, methylmercury, sample preparation.

McFall J, Antoine SR, and Overton EB. 1986. Organochlorine Compounds and Polynuclear Aromatic Hydrocarbons In Tissues of Subsistence Harvested Bowhead Whales, *Balaena mysticetus*. Final Report to the North Slope Borough, Barrow, Alaska From the Center for Bio-Organic Studies, University of New Orleans, New Orleans, Louisiana. 17 pp.
ABSTRACT: Tissue samples were collected from selected subsistence harvested bowhead whales (*Balaena mysticetus*) during fall 1979 and spring 1980 and analyzed for PAHs. These animals belong to the western Arctic stock that inhabit the Bering, Chukchi and Beaufort Seas. The mean PCB concentrations in blubber samples was 0.212 $\pm$ 0.077ppm wet weight (n=7). The mean DDT concentrations was 0.032 $\pm$ 0.009ppm. Lindane, heptachlor epoxide, chlordane, nonachlor and dieldrin were also detected in the blubber samples. Overall pollutant levels were well below most of those reported for other baleen species.
KEY WORDS: Arctic, *Balaena mysticetus*, bowhead whales, organochlorine, PAHs, pollutants.

McFarland VA, and Clarke JU. 1989. Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis. Env. Health Perspect. 81:225-39.
ABSTRACT: Polychlorinated biphenyls (PCBs) as environmental contaminants often cannot be adequately described by reference to Aroclors or to total PCBs. Although there are 209 possible PCB configurations (congeners), perhaps half that number account for nearly all of the environmental contamination attributable to PCBs. Still fewer congeners are both prevalent and either demonstrably or potentially toxic. If potential toxicity, environmental prevalence, and relative abundance in animals tissues are used as criteria, the number of environmentally threatening PCB congeners reduces to about thirty-six. Twenty-five of these account for 50 to 75% of total PCBs in tissue samples of fish, invertebrates, birds, and mammals. A few PCB congeners that are sterically similar to 2,3,7,8-tetrachlorodibenzo-p-dixoin (2,3,7,8-TCDD) are directly toxic. Other PCB congeners, as well as those that are directly toxic, my also be involved in toxicity indirectly by stimulating the production of (inducing) bioactivating enzyme systems. The most consequential of these have the ability to induce aryl hydrocarbon metabolizing mixed-function oxidases (MFOs). A result can be an increased capacity for bioactivation of otherwise nontoxic foreign compounds such as certain polynuclear aromatic hydrocarbons (PAH) to cytotoxic or genotoxic metabolites. The effectiveness of specific PCB congeners as inducers of different types of cytochrome P-450 dependent MFO systems is determined by their stereochemistry. Although MFO induction is not a proximate cause, it is a strong correlate of certain kinds of toxicities. Structural patterns can thus be used to discriminate among PCB congeners on the basis of toxic potential, if not entirely on toxicity per se. Congeners that demonstrate 3-methylcholanthrene-type (3-MC-type) and mixed-type MFO induction have the greatest toxic potential. These congeners most closely resemble 2,3,7,8-TCDD in their structures and in their toxic effects. The larger group of phenobarbital-type (PB-type) inducers have considerably less potential for contribution to toxic effects. Weak inducers and noninducing congeners have the least potential for toxicity. Using the rationale described in this paper, we assigned the most environmentally threatening PCB congeners to four groups. Congeners

assigned to Group 1 are considered most likely to contribute to adverse biological effects attributable to PCBs in an environmental sample. Group 1A contains the three most potent (pure 3-MC-type-inducer) congeners, IUPAC numbers 77, 126, and 169. Six congeners, numbers 105, 118, 128, 138, 156, and 170 are assigned to Group 1B. These congeners are mixed-type inducers that have been reported frequently in environmental samples.

KEY WORDS: congener-specific analysis, environmental contaminants, marine animals, mixed-function oxidases, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, toxicity.

Meador JP, Varanasi U, Robisch PA, and Chan S-L. in press. Toxic Metals in Pilot Whales (*Globicephala melaena*) from Strandings in 1986 and 1990 on Cape Cod, MA. Can. J. Fish. Aquat. Sci.

ABSTRACT: Concentrations of As, Cd, Cu, Hg, Pb, and Se were measured in 17 adults and 8 fetal pilot whales. Total Hg and Se both occurred in very high concentrations in liver and kidney and in liver were significantly correlated with animal length (and each other) which indicated bioaccumulation over time. Methyl mercury, as a percentage of total Hg, varied inversely with total Hg indicating demethylation was occurring and a one-to-one molar association of Hg and Se was found which is believed to provide a protective mechanism against Hg toxicity. Arsenic concentrations were relatively low, however Cd concentrations were consistently very high in adult kidney. Lead in adult liver was also correlated with animal length indicating long term bioaccumulation. All non-essential elements were found in critical fetal tissues which indicates maternal transfer occurred. Cadmium in fetal kidney was over 30 times higher than either brain or liver, indicating early differential accumulation and supporting maternal transfer. Matched pairs of mother and fetus liver indicated no correlation of elements, which may due to the temporal nature of bioaccumulation and the immobility of some elements. These results were compared to other mammalian studies to evaluate the toxicological implication of observed tissue concentrations.

KEY WORDS: bioaccumulation, fetal pilot whales, heavy metals, mother/ fetus pair, toxicology.

Medvedev N, Panichev N, and Hyvarinen H. 1997. Levels of Heavy Metals in Seals of Lake Ladoga and the White Sea. Sci. Total Environ. 206:95-105.

ABSTRACT: Between 1990 and 1993 samples of hair, liver, kidney and muscle were collected from 28 ringed seals from Lake Ladoga, *Phoca hispida ladogensis*, 20 ringed seals, *Phoca hispida hispida*, and three bearded seals, *Erignathus barbatus*, from the White Sea for heavy-metal residue analyses in tissues. The concentrations of Hg, Cd, Pb, Cu, Ni and Zn were determined by atomic absorption spectrometry (AAS). The samples of hair and liver contained the highest mean levels of the elements analysed and the muscle contained the lowest mean heavy-metal concentrations. Age and sex differences in the accumulation of pollutants were found. Tissue of Ladoga ringed seal were to a greater extent contaminated with the heavy metals studies than the tissues of the White Sea pinniped.

KEY WORDS: accumulation, heavy metals, pollution, seals.

Metzger DM, and Skoch EJ. 1988. Heavy Metal Levels in Tissues of the Northern Fur Seal

Collected from Five Rookeries in the Pribilof Islands. In: Stoskopf, M.K.(Ed). International Association for Aquatic Animal Medicine (IAAAM) Proceedings 1988. 19:123-9.
KEYWORDS: Alaska, aluminum, cadmium, chromium, contamination, copper, heavy metals, iron, kidney, lead, liver, marine mammals, muscle, nickel, northern fur seal, selenium, titanium.

Middaugh J, Hlady WG, and Jenkerson SA. 1986. Cadmium in Walrus, Health Hazard and Risk Assessment St. Lawrence Island October 28-30, 1986. State of Alaska, Department of Health and Social Services, Division of Public Health, Section of Epidemiology .
KEYWORDS: Alaska, cadmium, contamination, heavy metals, kidney, liver, marine mammals, Pacific walrus, risk assessment.

Miles AK, and Hills S. 1994. Metals in Diet of Bering Sea Walrus: *Mya* sp. as a Possible Transmitter of Elevated Cadmium and Other Metals. Mar. Poll. Bull. 28(7):456-8.
ABSTRACT: Sources of high concentrations of cadmium and other metals in pinnipeds of the Bering Sea are unknown. Russia and US authorities are concerned because of the possible health hazard from consuming pinniped meat harvested for subsistence people. Therefore, the Pacific walrus, *Odobenus rosmarus divergens*, from four main areas along the ice front in the Bering Sea were shot humanely in April-May 1991 and stomach contents were examined for trace metals. *Mya* sp. and *Serripes groenlandica* were abundant invertebrates in walrus from Cape Navarin and had the highest mean concentration of cadmium (6.8 $mg \cdot g^{-1}$; range 2.5-12.0 $mg \cdot g^{-1}$). Concentration of cadmium, strontium and vanadium were significantly higher in *Echiurus echiurus* than in *S. groenlandica* or *Mactromeris polynyma* in walrus from the Nunivak Island area. *Serripes groenlandica* from the Nunivak Island area had significantly higher concentrations of copper (mean=4.76 $mg \cdot g^{-1}$) than from Cape Navarin (2.4 $mg \cdot g^{-1}$). In this study, the levels of cadmium and other metals detected were probably conservative estimates of whole body concentrations. Further studies should focus on *Mya* sp. and more widely distributed prey species to determine differences in cadmium levels in relation to habitat, total body burden and other characteristics of the organisms themselves.
KEY WORDS: cadmium, diet, invertebrates, *Mya* spp., Pacific walrus, pinnipeds, trace metals.

Mix MC. 1986. Cancerous Diseases in Aquatic Animals and their Association with Environmental Pollutants: A Critical Literature Review. Marine Environ. Res. 20(1 & 2):1-141.
ABSTRACT: This review of the literature on neoplastic or cancer-like disorders in fish and shellfish sets out to (1) summarize what is known of the occurrence of neoplastic diseases in indigenous populations of aquatic animals found in different geographic areas of the world; (2) critically evaluate existing reports so as to determine whether or not environmental pollutants are implicated as causal agents of the cellular disorders and (3) describe the current state of knowledge in the general areas of fish and shellfish metabolism and the use of aquatic animal models in studies of chemical carcinogenesis. Tumors and neoplasms have been described in fish and shellfish populations from many areas throughout the world. Although environmental pollutants have been suggested as

the cause of neoplasms in at least some cases, the existing evidence does not permit a firm conclusion. For fish, the quality of the reports and data reviewed varied considerably. There are rather good experimental data to suggest that cancer-like conditions in fish from certain areas of Puget Sound (Washington), the Fox River (Illinois) and Japan are associated with chemical contaminants in the environment. The data reported to support a chemical etiology for highly publicized tumors in fish from the Buffalo River, Torch Lake and Black River are not of a high quality. Most of the studies from those areas are compromised by inadequate experimental designs, and further research will be necessary to achieve a more complete understanding of the possible role, if any, of chemical pollutants in relation to the existence of tumors in fish from those areas. There are also reports providing impressive evidence that chemical pollutants are not associated with neoplasms in fish, even in those inhibiting environments known to contain mutagenic substances. Large surveys conducted from highly polluted aquatic systems in Yugoslavia (Sava River), Germany (Rhine and Elbe Rivers) and Australia (Port Phillip Bay) all reported negative results. Many other studies and surveys have produced data that neither supported nor refuted a pollution-neoplasm association. In contrast, to fish, there is little evidence that neoplasms of clams, oysters and mussels are associated in any significant way with environmental pollution. The most obvious conclusion, from reviewing the existing literature, is that much additional research is required before the relationship(s) between environmental pollution and neoplasms in indigenous aquatic species can be understood. There are several constraints associated with conducting credible field studies in this area, given the incalculable number of variables in natural environments. In the future, it may be advisable to place more emphasis on laboratory studies employing state-of-the-art methods to provide fundamental information that can be used to understand the nature and causes of neoplasms in aquatic species.

KEY WORDS: aquatic animals, cancer-like disorders, environmental pollutants, fish, neoplastic diseases, review, shellfish.

Miyazaki N. 1994. Contaminant Monitoring Studies Using Marine Mammals and the Need for Establishment of an International Environmental Specimen Bank. Sci. Total Environ. 154(2,3):249-56.

ABSTRACT: Many hazardous chemicals have polluted the environment of the earth. Among them, organochlorine compounds and heavy metals have dispersed worldwide. I reviewed the results of cooperative research based on specimens shared with colleagues at Ehime University, Japan: (1) bioaccumulation of organochlorine compounds (DDT, PCB, HHC, etc.) and heavy metals (Hg, Cd, Pb, etc.) from sea water to marine mammals through the food chain, (2) placental transfer of contaminants, (3) transfer of contaminants through lactation, (4) biological impacts of contaminants to marine mammals, and (5) the global movement of contaminants. This work was based on about 1200 specimens of marine mammals obtained from scientific research over 17 years during 1976-1992. Soft tissues were banked at -20C at Ehime University while related materials and information were deposited in the National Science Museum, Tokyo. These and other materials should be preserved in good condition in an international specimen bank for future global environmental monitoring studies, the examination of hazardous chemicals which are currently unknown, the future global environmental monitoring studies, the examination of hazardous chemicals which are currently

unknown, the reexamination of the same samples in future using more advanced equipment by different scientists, and the reaction to unknown environmental questions, etc. The need for the establishment of an International Environmental Specimen Bank for marine mammals and other marine organisms are recommended.
KEY WORDS: bioaccumulation, biological impact, food chain, global monitoring, heavy metals, marine mammals, organochlorine compounds, placental transfer, specimen bank, transfer through milk.

Morris RJ, Law RJ, Allchin CJ, Kelly CA, and Fileman CF. 1989. Metals and Organochlorines in Dolphins and Porpoises of Cardigan Bay, West Wales. Mar. Poll. Bull. 20(10):512-23.
ABSTRACT: Concentrations of seven metals (Cr, Ni, Cu, Zn, Cd, Hg, and Pb) and a range of organochlorine pesticides, individual chlorobiphenyl congeners, and total polychlorinated biphenyls (PCB) have been determined in tissues of dolphins, porpoises, seals, and a variety of food chain species and sediments from Cardigan Bay, West Wales. Elevated concentrations of metals were not seen in any of the animal tissues examined. Higher than expected levels of organochlorine compounds were found in tissues of dolphins and porpoises; these concentrations are not derived from local pollution, but come from the animals normal diet which did not show markedly elevated levels of organochlorines. The level of organochlorine bioaccumulation seen in some of the cetaceans analysed is much higher than found previously; this may have serious health implications for populations of those species around the coasts of NW Europe.
KEY WORDS: bioaccumulation, marine mammals, organochlorine pesticides, trace metals, West Wales.

Muir D, Becker P, Koczanski K, Stewart R, and Innes S. 1997. Spatial and Temporal Trends of Persistent Organochlorines in Marine Mammals from the North American Arctic. In: AMAP International Symposium on Environmental Pollution of the Arctic. Arctic Monitoring and Assessment Programme. Extended Abstract 1:121-3.
ABSTRACT: The objective of this study was to re-examine spacial trends of persistent OCs in ringed seal and beluga from Canadian waters, which were based on samples from the mid-80s, with new results from samples collected during the 1990s. In the case of beluga whales, we also wanted to compare the Alaskan Chukchi Sea populations and the isolated populations in Cook Inlet (AK) with Canadian arctic animals. The analysis of samples from the 1990s also permitted assessment of temporal trends at selected locations. The sum PCBs, sum DDT and sum CHL were significantly higher in female ringed seals from Hudson Bay than in the western and central Canadian archipelago. A distinct west-to-east spatial trend is apparent in male beluga whales with higher levels in the eastern stocks, especially Hudson Bay. Combined results of beluga whale blubber samples show no evidence of changes in sum DDT levels over a 23 year period.
KEY WORDS: beluga whale, marine mammals, North American Arctic, persistent organochlorine pollutants, spatial and temporal trends, ringed seal.

Muir DCG, Ford CA, Grift NP, Stewart REA, and Bidleman TF. 1992. Organochlorine Contaminants in Narwhal (*Monodon monoceros*) from the Canadian Arctic. Env. Poll. 75:307-16.
ABSTRACT: Organochlorine pesticides (DDT, chlordane, polychlorinated camphenes (PCCs), dieldrin, hexachlorocyclohexanes (HCH), mirex), polychlorinated biphenyl

congeners (PCBs) and chlorobenzenes (Cbz) were determined in blubber and liver of narwhal (*Monodon monoceros*) collected during 1982-83 from Pond Inlet on northern Baffin Island in the Canadian Arctic. PCCs were the predominate organochlorines in narwhal blubber, ranging in concentration from 2988 to 13228 $ng \cdot g^{-1}$ (wet wt) in males and from 1905 to 8388 $ng \cdot g^{-1}$ in females. PCCs consisted of two major components, an octachlorobornane and a nonachlorobornane with gas chromatographic retention times of 1.05 and 1.22, relative to 4,4'-DDE. PCB concentrations on blubber ranged from 2250 to 7290 $ng \cdot g^{-1}$ in males and from 894 to 5710 $ng \cdot g^{-1}$ in females. Seven PCB congeners (tetra-, penta-, and hexachlorobiphenyls) accounted for 45% of total PCB (PCB) in narwhal blubber. Narwhal had 1.4 to 8.6-fold higher ratios of tetra- and pentachlorobiphenyls to PCB -153 (2,2',4,4',5,5'-hexachlorobiphenyl), lower 4,4' -DDE/DDT ratios and lower proportions of *trans*-nonachlor to total chlordane components than reported for odontocetes living in more contaminated environments. Mean PCB concentrations in narwhal were 6 to 15-fold lower than in dolphins from the Canadian east coast and belugas from St. Lawrence River estuary, respectively, while PCC levels were from 4- to about 2-fold lower, and HCH, dieldrin and Cbz differed by <2- fold. The pattern of organochlorines in narwhal tissues suggests they are exposed to proportionally more volatile compounds, and may have less capacity to metabolize some of these compounds relative to odontocetes living nearer sources of these contaminants.
KEY WORDS: Canadian Arctic, contaminants, *Monodon monoceros*, narwhal whale, organochlorine pesticides.

Muir DCG, Ford CA, Norstrom RJ, and Simon M. 1989. Geographical Variation of Organochlorine Contaminants in Selected Canadian Arctic Marine Biota. Presented at the 7th International Conference of Comite Arctique International on Global Significance of the Transport and Accumulation of Polychlorinated Hydrocarbons in the Arctic, Oslo, Norway. 31 pp.

ABSTRACT: Canadian Arctic marine biota are contaminated by a broad range of organochlorine compounds originating in the mid-latitudes of the northern hemisphere. The major organochlorine contaminants found in Arctic marine fishes were polychlorinated camphenes (PCCs) which ranged in concentration from <100 to 3070 g/kg (lipid wt). Levels of PCCs and other organochlorines in marine fishes were low in comparison to Canadian east coast and Baltic fishes. PCCs were also prominent in blubber of ringed seal (*Phoca hispida*) but were undetectable in polar bear (*Ursus maritimus*) adipose tissue. PCBs, DDT- and chlordane-related compounds (CHLOR) predominated in ringed seal and polar bear fat. In male seals, total PCB congeners (PCB) ranged from a mean of 506 g/kg at Cumberland Sound to 1160 g/kg at Southhampton Island in northern Hudson Bay. Some geographical variation in seal PCB concentrations could be explained by the older mean age of animals, but amongst groups of similar age, hexachlorocyclohexane (-HCH) and mirex were significantly higher at Hudson Bay locations than at locations in the central and western Arctic. Biomagnification factors between seals and polar bears ranged from 0.3 for DDT to 7.4 for PCB. CHLOR and DDT levels in polar bear adipose tissue from western and northern Hudson Bay locations were more than two-fold higher than at eight other more northerly locations. PCBs were also generally higher in Hudson Bay than elsewhere while concentrations of hexachlorocyclohexanes were more evenly distributed. The geographic variation of organochlorines in northern Canadian marine biota inconsistent with other recent studies

showing an increase in contaminants from north-south, although age and sex differences in seals and dietary variability in polar bears also influenced the results.
KEY WORDS: Arctic biota, biomagnification, dietary variability, geographic variation, marine fishes, organochlorine contaminants, polar bears, polychlorinated biphenyls, ringed seal.

Muir DCG, Ford CA, Stewart REA, Smith TG, Addison RF, Zinck ME, and Béland P. 1990. Organochlorine Contaminants in Belugas, *Delphinapterus leucas*, from Canadian Waters. Can. Bull. Fish. Aquat. Sci. 224:165-90.
ABSTRACT: Concentrations of organochlorine compounds were compared in blubber samples from the six stocks of beluga whales (Delphinapterus leucas) in Canadian waters. Highest concentrations of PCB congeners (PCB), DDT-group (DDT), polychlorinated camphenes (PCCs), chlordane-related compounds (CHLOR), mirex and dieldrin were found in animals from the St. Lawrence estuary. Mean concentrations of hexachloro-cyclohexane isomers (HCH), total chlorobenzenes (Cbz), and CHLOR in females, showed few significant differences between any of the stocks. Mean concentrations of PCB in arctic male belugas ranged from 2.530.57 g/g in animals from Jones Sound to 4.650.94 g/g (wet wt) at Cumberland Sound. PCB, DDT and mirex concentrations were 25, 32 and 100-fold higher, respectively, in males from the St. Lawrence than average levels in arctic males. The St. Lawrence animals are clearly exposed to higher levels of PCBs as well as other pollutants than the arctic animals. Continued study of the St. Lawrence animals is needed because toxicological effects of organochlorines are more likely to occur in this stock before becoming apparent in other beluga stocks.
KEY WORDS: beluga whales, Canada, *Delphinapterus leucas*, organochlorine compounds, toxicological effects.

Muir DCG, Norstrom RJ, and Simon M. 1988. Organochlorine Contaminants in Arctic Marine Food Chains: Accumulation of Specific Polychlorinated Biphenyls and Chlordane-Related Compounds. Environ. Sci. Technol. 22:1071-9.
ABSTRACT: Polychlorinated biphenyl congeners (S-PCB) and chlordane-related compounds (S-CHLORO) as well as DDT, hexachlorocyclohexane, toxaphene, and chlorobenzenes were determined in pooled arctic cod (*Boreogadus saida*) muscle and polar bear (*Ursus maritimus*) fat and in the blubber and liver of 59 ringed seals (*Phoca hispida*) from the east-central Canadian Arctic. S-PCB concentrations ranged from 0.0037 mg/kg (wet wt) in cod muscle to 0.68 mg/kg in male seal blubber and 4.50 mg/kg in bear fat. Tri- and tetrachloro PCB homologues were the dominant PCBs in fish, while pentachloro/hexachloro and hexachloro/heptachloro congeners predominated in ringed seal blubber and polar bear fat, respectively. Chlordane compounds detected in seal blubber were oxychlordane, *cis*- and *trans*-nonachlor, and *cis*-chlordane as well as nine minor components of technical chlordane, including nonachlor-III (a nonachlor isomer). Toxaphene and HCH isomers were the major organochlorines in cod muscle with mean concentrations of 0.018 and 0.010 mg/kg, respectively. S-CHLOR/S-PCB ratios ranged from 0.6 in fish muscle and bear fat to 0.7-0.9 in seal blubber, much higher than observed in more southerly marine environments, suggesting a proportionally greater input of chlordane into the Arctic.
KEY WORDS: Arctic, arctic cod, *Boreogadus saida*, food chain, organochlorine, polar bear, *Ursus maritimus*.

Muir DCG, Segstro MD, Hobson KA, Ford CA, Stewart REA, and Olpinski S. 1995. Can Seal Eating Explain Elevated Levels of PCBs and Organochlorine Pesticides in Walrus Blubber from Eastern Hudson Bay (Canada)? Env. Poll. 90(3):335-48.

ABSTRACT: Walrus (*Odobenus rosmarus*) blubber samples from Inukjuak and Akulivik (East Hudson Bay), Foxe Basin (Igloolik and Hall Beach) and Loks Land (East Baffin Island) were analysed for PCB congeners (ortho and non-ortho substituted) and other persistent organochlorines (DDT, toxaphene, chlordanes, dieldrin, mirex), as well as chlorinated dioxins/furans, to document spatial trends in contaminants in Canadian Arctic marine biota. Samples from 19 of 53 individuals had concentrations of PCBs greater than 1000 $ng \cdot g^{-1}$ (wet wt); the remaining individuals had much lower concentrations (50-600 $ng \cdot g^{-1}$). Highest concentrations were found in samples from Inukjuak where average concentrations in blubber of females (N = 9) were 1450 1780 $ng \cdot g^{-1}$ CHLOR, 2160 925 $ng \cdot g^{-1}$ DDT and 4790 2380 $ng \cdot g^{-1}$ PCB. PCB and DDT concentrations greater than 1000 $ng \cdot g^{-1}$ were unexpected based on previous studies of walrus from Greenland and Alaska. Local contamination was ruled out because levels of all organochlorines were elevated in each animal from Inukjuak, and elevated levels were also found in animals from Akulivik and Loks Land. Walrus from Inukjuak had 13C and 15N values in muscle intermediate between those of ringed seals (*Phoca hispida*) and those of walrus from Akulivik with low organochlorine levels. There was a weak but significant correlation between 15N and (log)PCB. The Inukjuak walrus also had higher proportions of highly chlorinated PCB congeners, and higher DDE/DDT ratios than walrus from Igloolik or Akulivik. The results suggest that the walrus with elevated organochlorines are feeding at a higher trophic level than those with low levels and are probably utilizing ringed seals for a portion of their diet.

KEY WORDS: Canadian Arctic, marine mammals, *Odobenus rosmarus*, organochlorine pesticides, PCB congeners, walrus.

Muir DCG, Wagemann R, Grift NP, Norstrom RJ, Simon M, and Lien J. 1988. Organochlorine Chemical and Heavy Metal Contaminants in White-beaked Dolphins (*Lagenorhynchus albirostris*) and Pilot Whales (*Globicephala melaena*) from the Coast of Newfoundland, Canada. Arch. Environ. Contam. Toxicol. 17:613-29.

ABSTRACT: Polychlorinated biphenyl (PCB), DDT isomers (DDT), chlordane (CHLOR), toxaphene, chlorobenzenes and hexachlorocyclohexane isomers and seven elements (As, Cd, Cu, Hg, Pb, Se, Zn) were determined in tissues of 41 stranded pilot whales (*Globicephala melaena*) and 27 ice-entrapped white-beaked dolphins (*Lagenorhynchus albirostris*) from Newfoundland, Canada. Cadmium, Hg, As and Se were significantly higher in pilot whale kidney and liver than in dolphin tissues. Mercury in liver and blubber, and Cd in kidney of pilot whales were positively correlated with age. Cadmium levels in both species were much higher than reported for other cetaceans from Canadian east coast waters. Lead concentrations in dolphin kidney and muscle were 5 times higher than in pilot whales. Levels of PCB (sum of 49 congeners) in blubber samples ranged from 31 to 61 mg/kg (lipid wt) in female and male dolphins, respectively, and from 5.6 to 12 mg/kg in female and male pilot whales. DDT and toxaphene were present at similar levels to PCB while mean CHLOR (sum of seven components) ranged from 1.6 to 17 mg/kg in blubber of pilot whales ad dolphins, respectively. The presence of high levels of toxaphene in the blubber of both species was unexpected and may be due to increased use of this pesticide during the 1970s. Higher levels of all

organochlorine chemicals in blubber, as well as Pb in kidney and muscle, of dolphins than in pilot whales may reflect greater exposure to contaminants because of overwintering and feeding in Gulf of St. Lawrence waters.
KEY WORDS: Coast of Newfoundland Canada, heavy metals, organochlorines, stranded pilot whales, white-beaked dolphin.

Muir D, Grift B, and Ford C. 1987. Organochlorine Residues in Narwhal and Beluga Tissues. Preliminary Report, Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg :4 pp.
ABSTRACT: The objective of this study was to survey organochlorine contaminants in blubber and liver tissues of whales in Baffin Island. Tissues were collected from narwhal (*Monodon monoceros*) and beluga (*Delphinapterus leucas*) whales from Pond Inlet and Pangnirtung in 1983. Toxaphene was the dominant contaminant detected in blubber. PCB and DDT levels in narwhal blubber both averaged about 5 $mg \cdot g^{-1}$ and were 50 to 100-fold lower in narwhal liver. The results suggest that the estimate of 10 $mg \cdot g^{-1}$ for PCBs in whale oils consumer at Broughton Island was an overestimate.
KEY WORDS: Baffin Island, *Delphinapterus leucas*, marine mammals, *Monodon monoceros*, organochlorine contaminants, toxaphene.

Muir D, Grift B, and Ford C. 1987. Organochlorine Residues in Ringed Seal Blubber From N.W.T. Coastal Communities. Preliminary Report, Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, and Agassiz North Consultants, Winnipeg :4 pp.
ABSTRACT: The objective of this study was to survey organochlorine contaminants in blubber of Ringed seals, *Phoca hispida*, of the Northwest territories. Seal blubber samples were collected between September 1985 and June 1986 and analyzed for PCBs and other organochlorine contaminants. Ringed seals are potentially good monitors of contamination by organochlorines in the Arctic because of this position at the top of the marine food chain and because they are known to be relatively sedentary, inhabiting land-fast ice during most of the year. The results do not show any clear trends in contaminant levels between regions. Organochlorine levels are higher in waters influenced by surface runoff than in waters which have a greater influence from the Atlantic Ocean. Further studies of contaminant levels in whale need to be reported to further define levels of dietary contamination.
KEY WORDS: Arctic, dietary contamination, organochlorine contaminants, *Phoca hispida*, ringed seals.

Nakata H, Tanabe S, Tatsukawa R, Amano M, Miyazaki N, and Petrov EA. 1997. Bioaccumulation Profiles of Polychlorinated Biphenyls including Coplanar Congeners and Possible Toxicological Implications in Baikal Seal (*Phoca sibirica)*. Env. Poll. 95(1):57-65.
ABSTRACT: Isomer specific concentrations of individual polychlorinated biphenyls (PCBs) including toxic non ortho (IUPAC 77, 126, 169), mono ortho (105, 118, 156) and di ortho (137, 138, 153, 180) coplanar congeners were determined in the blubber of 40 Baikal seals (*Phoca sibirica*) and as their fish diet collected from Lake Baikal, Siberia. Residue levels of total PCBs in Baikal seals were noticeably high and comparable to those reported for seals from the North Sea, suggesting the recent usage of this compound in the watershed of Lake Baikal, Non, mono, and di ortho coplanar congeners were also

detected in Baikal seals and fish. An approach to estimate bioaccumulation profiles of PCB congeners revealed that the non ortho PCBs, IUPAC 77, 126 and 169 seemed to be less persistent than other congeners, Furthermore, selective biotransformation of PCB congeners having either meta para vicinal H atoms or both adjacent chlorinated meta para and ortho meta positions has been suggested. Comparison of 2,3,7,8 TCDD toxic equivalents (TEQ) of non , mono and di ortho coplanar congeners in Baikal seals with those for other marine mammals suggested higher enrichment of mono ortho congeners, particularly IUPAC 105 and 118, which contributed significantly to the total TEQs in Baikal seals. Results imply that the TCDD like toxicity is relatively serious in Baikal seals, because of the enrichment of these toxic PCB congeners in tissues.
KEY WORDS: Baikal seals, bioaccumulation, coplanar congeners, marine mammals, pollution, polychlorinated biphenyls.

Nendza M, Herbst T, Kussatz C, and Gies A. 1997. Potential for Secondary Poisoning and Biomagnification in Marine Organisms. Chemosphere 35(9):1875-85.
ABSTRACT: For selected priority pollutants, like organochlorine pesticides, PAHs and PCBs, and mercury and cadmium, the transfer along marine food chains was assessed based on monitoring data. Comparison of the acquired body burden for marine fish and the toxicity thresholds for predating marine birds and mammals provides evidence for the relevance of contaminant uptake with the food and the liability for secondary poisoning. As a consequence, contaminant residues in prey organisms (critical body burden) should be used for marine hazard and risk assessments. Evaluations solely from aquatic exposure concentrations are not adequate to account for potential secondary effects in marine ecosystems.
KEY WORDS: accumulation, critical body burden, cadmium, marine food chain, mercury, organochlorine pesticides, PAHs, PCBs, secondary posioning.

Newman JW, Vedder JM, Jarman WM, and Chang RR. 1994. A Method For the Determination of Environmental Contaminants in Living Marine Mammals Using Microscale Samples of Blubber and Blood. Chemosphere 29(4):671-81.
ABSTRACT: As a part of a study examining the possible effects of organochlorine compounds on juvenile northern elephant seals (*Mirounga angustirostris*), blubber and blood samples were taken from animals present on the Ano Nuevo (California rookery, and from animals admitted for rehabilitation at The Marine Mammal Center (Sausalito, CA). Blubber samples were collected from immobilized seals. A pre-cleaned 6 mm K-medic biopsy punch was used to extract the blubber from a 1 cm incision near the hip, near the dorsal mid point. Blood samples were taken from the extradural vein; two mL of serum was analyzed for organochlorine compounds. Blubber samples (approximately 0.1g) were ground with Na2SO4 and extracted with 20 mL hexane: methylene chloride (1:1). Sera samples were extracted using commercially available disposable C18 columns. The extracts were separated on a micro-Florisil column, and analyzed by HRGC-ECD. Lipid determination in the serum was obtained by colorimetric analysis with 20 microliters samples. Results from the analysis of replicates and standard reference materials showed good recoveries, precision, and accuracy for both the blubber and blood methods.
KEY WORDS: blood, blubber, environmental contaminants, HRGC-ECD, marine mammals, northern elephant seal.

Noda K, Ichihashi H, Loughlin TR, Baba N, Kiyota M, and Tatsukawa R. 1995. Distribution of Heavy Metals in Muscle, Liver and Kidney of Northern Fur Seal (*Callorhinus ursinus*) Caught Off Sanriku, Japan and from the Pribilof Islands, Alaska Env. Poll. 90(1):51-9.
ABSTRACT: The concentrations of iron, manganese, zinc, copper, cadmium, and mercury were determined in muscle, liver and kidney of 67 northern fur seals (*Callorhinus ursinus*) collected off Sanriku, Japan, and from the Pribilof Islands, Alaska. Almost all the elements except cadmium were highest in liver. Cadmium levels in kidney were higher than those in liver and muscle for all animals analyzed. Concentrations of mercury increased significantly with age in muscle and liver and cadmium levels in muscle, while manganese concentrations decreased with age in muscle and kidney. The kidney also showed decreased copper concentration with age. Cadmium concentrations of the northern fur seals in this study were higher than the other otariids, reflecting a predominantly squid diet. Concentrations of manganese and mercury were found to be higher in the fur seals caught off Sanriku than in animals from the Pribilof Islands, while those of zinc and cadmium were found to be lower. Variable concentrations of cadmium might have been attributed to those in seawater. Discriminant analysis of heavy metal concentrations was used to identify habitat. Sixty-three of 67 animals (94%) were correctly classified using this technique. Heavy-metal concentrations in tissues may provide a useful method to elucidate the primary feeding grounds of fur seals.
KEY WORDS: Alaska, *Callorhinus ursinus*, feeding grounds, heavy metals, Japan, northern fur seal, Probilof Islands, Sanriku.

Norstrom RJ, and Muir DCG. 1994. Chlorinated Hydrocarbon Contaminants in Arctic Marine Mammals. Sci. Total Environ. 154:107-28.
ABSTRACT: By 1976, the presence of chlorinated hydrocarbons contaminants (CHCs) had been demonstrated in fur seal (*Callorhinus ursinus*), ringed seal (*Phoca hispida*), hooded seal (*Cystophora cristata*), bearded seal (*Erignathus barbatus*), walrus (*Odobenus rosmarus divergens*), beluga (*Delphinapterus leucas*), porpoise (*Phocoena phocoena*) and polar bear (*Ursus maritimus*) in various parts of the Arctic. In spite of this early interest, very little subsequent research on contaminants in Arctic marine mammals was undertaken until the mid-1980s. Since that time, there has been an explosion of interest, resulting in a much expanded data base on contaminants in Arctic marine mammals. Except in the Russian Arctic, data have now been obtained on the temporospatial distribution of PCBs and other contaminants in ringed seal, beluga and polar bear. Contaminants in narwhal (*Monodon monoceros*) have also now been measured. On a fat weight basis, the sum of DDT-related compounds (S-DDT) and PCB levels are lowest in walrus (<0.1 g/g range). Levels are an order of magnitude higher in beluga and narwhal (1-10 g/g range). It appears that metabolism and excretion of S-DDT and PCBs may be less efficient in cetaceans, leading to greater biomagnification. Polar bears have similar levels of PCBs as cetaceans (1-10 g/g), but with a much simpler congener pattern. DDE levels are lowest in polar bear, indicating rapid metabolism. Effects of age and sex on residue levels are found for all species where this was measured. Among cetaceans and ringed seal, sexually mature females have lower levels than males due to lactation. Although PCB levels in adult male polar bears are about twice as high as females, there is only a trivial age effect in either sex apart from an initial decrease from birth to sexual maturity (age 0-5). Comparison of levels of S-DDT and PCBs in Arctic beluga and ringed seal with those in beluga in the Gulf of St. Lawrence

and ringed seal in the Baltic Sea, indicate that overall contamination of the Arctic marine ecosystem is 10-50 times less than the most highly contaminated areas in the northern hemisphere temperate latitude marine environment. Geographic distribution of residue levels in polar bears indicates a gradual increase from Alaska east to Svalbard, except PCB levels are significantly higher in eastern Greenland and Svalbard. Information on temporal trends in somewhat contradictory. S-DDT and PCB levels declined in ringed seal in the Canadian Arctic throughout the 1970s, whereas polar bear data indicated levels in the late 1960s were lower than in the 1980s. Interpretation is confounded by insufficient data on sex, age and condition of the early samples, and lack of intermediate time points for polar bear. Application of gas chromatography-mass spectrometry techniques in the 1980s has resulted in the identification of many previously unmeasured contaminants in Arctic marine mammals. HCH, HCB, dieldrin and a number of chlordane-related compounds were first reported in polar bear and ringed seal from the Canadian Arctic. Polychlorinated camphenes (PCCs) have been found in polar bear, ringed seal, beluga and narwhal. The major PCCs have been identified as a octochloro- and nonachlorobornane found in technical toxaphene. Geographic distribution of HCH, HCB, dieldrin, chlordane and PCC residues in the Arctic is more even than that of S-DDT and PCBs. Low levels (<20 pg/g) of 2,3,7,8-TCDD and other PCDD and PCDF congeners have been identified in ringed seal and polar bear. Geographic distribution of TCDD is the most non-uniform of the CHCs. Highest levels occurred in the high Arctic and Spitxbergen. TCDD-like non-*ortho* and mono-*ortho* PCBs have been measured mainly in ringed seal, beluga and narwhal. TCDD toxic equivalent concentrations are highest in narwhal and beluga, in the order of 100-500 pg/g, and are dominated by PCBs. TCDD equivalents in ringed seal are about 10 times lower than in beluga and narwhal, but TCDD itself makes a proportionately larger contribution. Recently, g/g levels of tris(4-chlorophenylmethanol) and methylsulphone metabolites of PCB congeners and DDE have been identified in polar bear tissues.

KEY WORDS: Arctic, chlorinated hydrocarbon contaminants, marine mammals, polar bear.

Norstrom RJ, and Simon M. 1990. Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans in Marine Mammals in the Canadian North. Env. Poll. 66:1-19.

ABSTRACT: Polychlorinated dibenzo-*p*-dioxins (PCDDS) and dibenzofurans (PCDFs) were determined in pooled samples of ringed seal (*Phoca hispida*) blubber, beluga (*Delphinapterus leucas*) blubber and polar bear (*Ursus maritimus*) liver and fat from several areas throughout the Canadian north and compared to mean PCB and HCD levels in the same samples. All seal samples, and all but one polar bear sample, had detectable 2,3,7,8-TCDD at concentrations ranging from 2 to 37 ng/kg, but TCDD was not found in beluga blubber (<2ng/kg). All seal samples and one of three beluga samples contained 2,3,7,8-TCDF at levels of 2 to 7 ng/kg, but TCDF was not found in any bear sample. TCDF must therefore be cleared rapidly by polar bears. No other PCDF congeners were found at detection limits of 4 to 8 ng/kg. OCDD concentrations in seal blubber and polar bear samples ranged from not detected (<8 ng/kg) to 43 ng/kg. No apparent biomagnification of TCDD, OCDD or TCDF occurred from seal to bear fat, similar to previous findings for DDT and unlike PCBs and HCB which biomagnified 6- to 17-fold. Highest concentrations of 2,3,7,8-TCDD and OCDD in seals and bears were found in central Canadian Arctic Archipelago, and lowest were found in Hudson Bay, the reverse

of PCB concentration distribution. The reason for higher levels of TCDD and OCDD in the Arctic than in the sub-Arctic is suggested to be trans-polar movement of aerosols with combustion-related origins in Eurasia. Levels of 2,3,7,8-TCDF were more evenly distributed throughout the North, and were positively correlated with PCB, but not with HCB or 2,3,7,8-TCDD levels in seals.

KEY WORDS: beluga whale, biomagnification, Canadian north, dibenzofurans, marine mammals, polar bear, polychlorinated dibenzo-p-dioxins, ringed seal.

Norstrom RJ, Muir DCG, Ford CA, Simon M, Macdonald CR, and Béland P. 1992. Indications of P450 Monooxygenase Activities in Beluga (*Delphinapterus leucas*) and Narwhal (*Monodon monoceros*) from Patterns of PCB, PCDD and PCDF Accumulation . Marine Environ. Res. 34:267-72.

ABSTRACT: Selective accumulation of PCDDs, PCDFs and PCB congeners was investigated in beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*) and several species at the same trophic level in two areas of Canada. There was a much higher relative abundance of *meta-para*-unsubstituted PCBs in the cetaceans compared with other species. This suggests that activity of cytochrome P450 monooxygenase enzymes causing CYP2B-type metabolism was relatively low in beluga and narwhal. Lower relative levels of 2,3,7,8-TCDD occurred in beluga from both areas, and selective reduction of toxic non-ortho PCBs occurred in the highly PCB-contaminated St. Lawrence beluga. These compounds are potent inducers of cytochrome P450 CYP1A-type enzymes, suggesting that such an enzyme with the capability of metabolizing TCDD-like substrates is present in beluga and narwhal. SIMCA principal components analysis of PCB congener patterns showed that the two cetaceans were in a statistically significant different class than the other species. Variables (congeners)with the greatest separation power between classes were mainly those defined by the selective metabolism rules.

KEY WORDS: beluga whale, cytochrome P450 monooxygensae enzyme, marine mammals, narwhal whale, PCB congeners, PCDD, PCDF, selective metabolism.

Norstrom RJ, Schweinsberg RE, and Collins BT. 1986. Heavy Metals and Essential Elements in Livers of the Polar Bear (*Ursus maritimus*) in the Canadian Arctic. Sci. Total Environ. 48:195-212.

ABSTRACT: Polar bear (*Ursus maritimus*) livers (67) from six Management Zones in the western and central Canadian Arctic were analysed for 22 elements. Several, Ba, Be, Co, Mo, Ti, V and Zr, were near the detection limit in all cases. Baseline data were obtained for the remaining elements, Ag, As, Ca, Cd, Cu, Fe, Hg, K, Mg, Mn, Na, P, Se, Sr and Zn. No statistically significant effect of age, sex or geographical location was found for any of the elements, except Cd, Hg and Se, for which age and geographical location effects were found. The frequency distribution of Zn levels was bimodal. The second peak in the distribution appeared to be related to elevated levels of Cu. The average level of Cu was 104 $mg \cdot kg^{-1}$ (dry wt.), higher than other marine mammals. Average levels of Cd were significantly higher in the eastern zones, but were always <1.0 $mg \cdot kg^{-1}$ (dry wt.), significantly lower than their prey species. This may be due to the preference of polar bears for eating seal skin and fat which is low in Cd. Mercury levels tended to be higher in the western zones bordering the Beaufort Sea, which may be related to a higher proportion of bearded seal in their diet. Mean Hg levels ranged from

20 mg kg^{-1} in the eastern zones to 70 mg·kg-1 in the western zones. Levels of mercury in the eastern zones were related to age by the expression : Hg (mg·kg^{-1} dry wt.) = 15.7 + 8.0 Age (years). Mercury levels in the most northerly zone near Melville Island were very high: Hg (mg·kg-1 dry wt.) = 18.4 + 27.5 Age (years). Levels of Hg and Se were very highly correlated, with a molar ration of 1.27:1, Hg/Se.
KEY WORDS: Canadian Arctic, diet, essential elements, heavy metals, polar bear, *Ursus maritimus*.

Norstrom RJ, Simon M, Muir DCG, and Schweinsburg RE. 1988. Organochlorine Contaminants in Arctic Marine Food Chains: Identification, Geographical Distribution, and Temporal Trends in Polar Bears. Environ. Sci. Technol. 22:1063-71.
ABSTRACT: Contamination of Canadian arctic and subarctic marine ecosystems by organochlorine (OC) compounds was measured by analysis of polar bear (*Ursus maritimus*) tissues collected from 12 zones between 1982 and 1984. PCB congeners (S-PCB), chlordanes (S-CHLOR, mainly oxychlordane), DDT and metabolites (S-DDT), chlorobenzenes (S-CBz), hexachlorocyclohexane isomers (S-HCH), and dieldrin were identified by high-resolution gas chromatography-mass spectrometry. Nonachlor-III, a nonachlor isomer in technical chlordane, was positively identified for the first time as an environmental contaminant. S-PCB and S-CHLOR accounted for >80% of the total organochlorines in adipose tissue. Six PCB congeners (IUPAC numbers 99,153, 138, 180, 170, and 194) constituted approximately 93% of S-PCB in polar bears. Levels of most OCs were lowest in the high Arctic, intermediate in Baffin Bay, and highest in Hudson Bay. Levels of -HCH were elevated in zones influenced by surface runoff. Levels of S-CHLOR were four times higher and levels of the other OCs were two times higher in adipose tissue of bears from Hudson Bay and Baffin Bay in 1984 than in adipose tissue archived since 1969 from these areas; levels of S-DDT did not change.
KEY WORDS: Canadian arctic, geographical distribution, marine ecosystems, organochlorine contaminants, polar bear, *Ursus maritimus*.

O'Hara TM, and Fairbrother AF. 1996. Risk Assessment of Cadmium in Arctic Wildlife . Technical Support Document :40 pp.
ABSTRACT: This document provides the technical support and detailed risk assessment for a health advisory on the consumption of Arctic wildlife organ meats (liver and kidney) due to cadmium accumulation. Eskimos traditionally have hunted arctic wildlife and marine mammals, from small seals to large baleen whales. These animals represent a nutritious food source and, more importantly, have significant cultural value. Unfortunately these animals also appear to accumulate high levels of environmental contaminants in their tissues, due to their feeding habits as well as to their unique physiology that allows them to adapt to the harsh arctic environment. Therefore, the amount of meat eaten by North Slope residents could be limited, but not completely avoided, in order to avoid consuming contaminants at levels known to be hazardous to human health. This Advisory provides information about the amount of cadmium in tissues of arctic wildlife and guidelines for individuals to limit consumption to reduce health risks as they see fit.
KEY WORDS: Arctic wildlife, cadmium accumulation, environmental contaminants, risk assessment.

O'hara TM, and Fairbrother AF. 1995. Risk Assessment of Cadmium in Selected Arctic Wildlife of Northern Alaska: Health Advisory. Unpublished :11 pp.
ABSTRACT: This report describes many of the health related and cultural reasons in consuming caribou, marine mammals and cold water fish of Alaska. The intentions are to allow the consumer to make an educated choice as to the amount of cadmium exposure and the associated risks that can be tolerated. A health advisory is discussed in order to address cadmium in wildlife and the potential risk.
KEY WORDS: Alaska, cadmium, caribou, fish, health advisory, marine mammals, risk assessment, selenium.

O'Shea TJ, and Brownell Jr. RL. 1994. Organochlorine and Metal Contaminants in Baleen Whales: A Review and Evaluation of Conservation Implications. Sci. Total Environ. 154(2-3):179-200.
ABSTRACT: The literature on organochlorine and metal contaminants in tissues of baleen whales includes data for approximately 1000 individuals in 10 species from various oceans of the world. Concentrations of these contaminants in tissues of baleen whales are low. Sources of variation organochlorine concentrations in whales include age, sex, region of exposure, and feeding habits. Concentrations of DDT and PCBs in baleen whales appear higher in the northern hemisphere than in the southern oceans, perhaps due to greater contamination of northern ecosystems and a higher incidence of fish in the diet. However, maximum concentrations are generally lower in tissues of baleen whales than in other marine mammals species, both on global and local scales. This is predictable based on the general distribution , habitats and trophic levels of baleen whales. We reviewed laboratory studies on the effects of selected organochlorine contaminants on direct mortality and impaired reproduction in other mammals, and critically examined observations attempting to link organochlorines to reproductive and population effects in marine mammals. There is no firm basis to conclude that the contaminants reviewed herein have affected baleen whale populations. Although more information on contaminants in baleen whales would be of value, as a matter of priority, research and management actions should focus on reducing human-caused mortality and increasing habitat carrying capacity for these species.
KEY WORDS: marine mammals, metals, mortality, organochlorines, PCBs, reproduction, whales.

Oehme M, Schlabach M, Hummert K, Luckas B, and Nordoy ES. 1995. Determination of Levels of Polychlorinated Dibenzo-p-dioxins, Dibenzofurans, Biphenyls, and Pesticides in Harp Seals from the Greenland Sea. Sci. Total Environ. 162(2-3):75-91.
ABSTRACT: The levels of polychlorinated dibenzo-p-dioxins (PCDD), dibenzofurans (PCDF), biphenyls (PCB) and compounds of the DDT group were determined in individual seal blubber and brain samples from ten male and one female harp seals caught in the Greenland Sea. No data from this region and from harp seals have been reported before. The age of the animals varied between 1 and 18 years. PCDD/PCDF concentrations in the blubber (4-10 pg/g TEQ wet weight (w.w.), Nordic model) were somewhat lower than in ringed seals from the Arctic. Non-ortho substituted PCB (CB 77, 126, and 169) showed TEQ few cases CB 169 was the most abundant congener. P,p-DDE (averaged 760 ng/g w.w.) and di-ortho substituted PCB concentrations (2560 ng/g w.w. expressed as sigma PCB) in the blubber were comparable to those found in ringed

seals from the European and Canadian Arctic. Levels of PCDD/PCDF in brain correspond to the detection limit (about 0.1-0.6 pg/g w.w.) for most congeners. With one exception, PCB amount in brain (w.w.) were one to two orders of magnitude lower. A highly significant correlation was found between age, p,p'-DDE and di-ortho PCB as well as between single PCDD and coplanar PCB congeners. No relationship was observed between levels of PCDD/PCDF, age and di-ortho-PCB.
KEY WORDS: Arctic, dioxins, harp seals, organochlorines.

Oehme M, Schlabach M, Kallenborn R, and Haugen JE. 1996. Sources and Pathways of Persistent Polychlorinated Pollutants to Remote Areas of the North Atlantic and Levels in the Marine Food Chain: A Research Update. Sci. Total Environ. 186(1-2):13-24.
ABSTRACT: A summary is given of research conducted by our laboratory since 1991 on the dispersion and pathways of persistent organochlorines (POCs) to remote regions of the Northern North Atlantic. This review includes data not previously published and an overall interpretation of our results. Levels of polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls and pesticides in marine mammals and sediments from these areas are presented and discussed. Special attention is given to the levels of polychlorinated bornanes (toxaphene), to date the most heavily used insecticide worldwide. Finally, temporal trends are presented.
KEY WORDS: marine mammals, North Atlantic, organochlorines, toxaphene.

Olsson M. 1978. PCB and Reproduction Among Baltic Seals. Finnish Game Res. 37:40-5.
KEY WORDS: mammals, pesticides/ pollution, polychlorinated biphenyls.

Olsson M. 1972. PCBs in the Baltic Environment. In: PCBs and the Environment, Volume III, Washington, D.C., Department of Agriculture, Commerce H.E.W., and Interior Chapter 7:181-208.
ABSTRACT: This chapter is an overview of the Baltic Sea and the pollutant levels that are found in this large body of water. All nations that surround the Baltic are industrialized countries, which creates pollutant problems for the organisms that live here. There is a large diversity of fresh and marine water species that inhabit all areas of the Baltic. Studies have been intense since 1969, determining levels of polychlorinated biphenyls and DDTs. Fish, porpoise, seals and birds have been analyzed for these pollutants and their effects have been reported. Seal and otter populations have declined in the Baltic and reproductive rates have lowered. Investigations have led to a preliminary hypothesis regarding effects of DDT and PCBs. Nations around the Baltic have become aware of the potential danger of environmental pollution and among the various pollutants, how important persistent bioaccumulative substances are. International organizations, such as the Helsinki Commission, ICES, and The Gulf of Bothnia are becoming concerned about these environmental problems and are aware that more studies need to be implemented. More importantly, the sudden discovery of how rapidly a large marine area like the Baltic can be polluted and how long it takes before the ecological inflictions are discovered have been learned. Several years of information and international negotiations are necessary before an agreement on worldwide limitation imposed on the use of any pollutant.
KEY WORDS: Baltic Sea, bioaccumulation, bird, environment, fish, marine mammals, otter, pollution, polychlorinated biphenyls, porpoise, reproductive rates, seal, seasonal

variation.

Overton EB, Byrne C, McFall JA, Antoine SR, and Laseter JL. 1983. Preliminary Observations on Tissue Pollutant Levels in Subsistence Harvested Bowhead Whales (*Balaena mysticetus*). Paper SC/35/PS17 Presented to the International Whaling Commission Scientific Committee, June 1983. 11 pp.

ABSTRACT: The objectives of this research are to produce data of a baseline nature on the identities and levels of anthropogenic and petroleum-type chemicals in samples of subsistence harvested bowhead whales (*Balaena mysticetus*) collected off Alaskas north slope. This data will be used to facilitate an assessment of the effects of mans activities associated with offshore resource development. Low levels of PCBs, DDTs and unsubstituted polynuclear aromatic hydrocarbons were identified in the blubber samples. Overall pollutant levels were below most of previous reports of other cetacean species.

KEY WORDS: Alaska, anthropogenic and petroleum-type chemicals, bowhead whales, organochlorine contaminants.

Overton EC, Byrne C, McFall J, and Antoine S. 1985. Tissue Levels of Trace Organic and Heavy Metal Pollutants in Subsistence Harvested Bowhead Whales, *Balaena mysticetus*. In: T.F. Albert (Ed). Third Conference on the Biology of the Bowhead Whale (*Balaena Mysticetus*) :134-41.

ABSTRACT: The objectives of this study were to produce data of a baseline nature on the identities and levels of anthropogenic and petroleum-type chemicals in tissues samples taken from subsistence harvested bowhead whales that were collected off Alaskas north slope. These data will be used to facilitate an assessment of the effects of mans activities associated with offshore resource development. Since the chemical information will constitute a baseline data resource for the bowhead, analytical techniques were used that allowed for the screening of a broad spectrum of organic chemicals and selected heavy metals. The following parameters were investigated:

1. Quantification of the 13 U.S. Environmental Protection Agency designated priority pollutant trace metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, sliver, thallium, and zinc) and barium.
2. Identification and quantification of commonly used chlorinated pesticides and chlorinated synthetic organic chemicals (such as DDT and the PCBs).
3. Identification and quantification of the saturate and aromatic hydrocarbons commonly associated with petroleum exploration and production (such as the normal and isoprenoid saturates, and the two to four ring parent ad alkyl polynuclear aromatic hydrocarbons).

Major results of the study were that the bowheads burden of anthropogenic lypophilic chemicals is concentrated primarily in the animals blubber. Low levels of the PCBs, DDTs and polynuclear aromatic hydrocarbons were identified in the blubber samples. Further, low levels of heavy metals were detected primarily in organs such as the liver and kidneys. Overall pollutant levels were well below most of those reported in other cetacean samples collected from around the world.

KEY WORDS: anthropogenic and petroleum-type chemicals, bowhead whales, chlorinated pesticides, offshore resource development, organic metals, trace metals.

Paludan-Müller P, Agger CT, Dietz R, and Kinze CC. 1993. Mercury, Cadmium, Zinc, Copper

and Selenium in Harbour Porpoise (*Phocoena phocoena*) from West Greenland. Polar Biol. 13:311-20.

ABSTRACT: Muscle, liver, kidney and skin samples taken from 78 harbour porpoises (*Phocoena phocoena*) were analysed for mercury, cadmium, zinc, copper and selenium. The highest concentrations of mercury were found in the liver (geometric mean 4.17 g/g wet weight), whilst the highest concentrations of cadmium were in the kidney (g.m. 13.2 g/g ww). The levels of cadmium were more than ten times higher than in harbour porpoises from the North Sea and the British NW coast, whilst the mercury levels were about the same. The importance of the cadmium content in the prey is discussed, but this attempt did not revealed the differences. Very high levels of zinc (g.m. 359 g/g ww) and selenium (g.m. 28.6 g/g ww) were found in skin samples, respectively seven and ten times more than in liver. A significant correlation was found between age and the level of mercury and cadmium in all organs. The concentration of mercury and selenium in liver and skin samples and of cadmium and zinc in kidney samples were highly correlated.

KEY WORDS: harbour porpoise, heavy metals, *Phocoena phocoena*, West Greenland.

Pelletier E. 1985. Mercury-Selenium Interactions in Aquatic Organisms: A Review. Marine Environ. Res. 18:111-32.

ABSTRACT: Throughout the last decade, major research efforts have been directed towards the study of aquatic environment pollution. Nevertheless, the consequences of simultaneous interactions between two or more pollutants in the same aquatic organism are still poorly understood. This paper summarizes published work on mercury-selenium interactions in aquatic organisms. Mercury and selenium are naturally occurring is a 1:1 molar ratio in many aquatic organisms and especially in marine mammals. This particular occurrence is well known in laboratory animals and has been attributed to the Hg-Se antagonism. Nevertheless, there is no clear evidence for a natural joint bioaccumulation of Hg and Se in fish, crustaceans and molluscs except for marlin, which has the ability to tolerate very high concentrations of Hg and SE in its organs and tissues. In laboratory experiments, an antagonistic effect of selenium on the toxicity of mercury has been clearly shown for one marine alga species, but a synergy between Se and Hg has been observed for eggs. The rate of bioaccumulation of mercury in fish tissues was decreased in a freshwater ecosystem by the addition of selenite in low concentration. Interaction between selenium and mercury in aquatic organisms is real but the true antagonism between these two elements has not yet been clearly shown. Results are sometimes unrelated and contradictory. Possible avenues for progress in this area are discussed.

KEY WORDS: aquatic organisms, bioaccumulation, environmental pollution, mercury-selenium interactions, review.

Rawson AJ, Patton GW, Hofmann S, Pietra GG, and Johns L. 1993. Liver Abnormalities Associated with Chronic Mercury Accumulation in Stranded Atlantic Bottlenose Dolphins. Ecotoxicol. Environ. Safety 25:41-7.

ABSTRACT: Eighteen stranded Atlantic bottlenose dolphins (*Tursiops truncatus*) examined postmortem were sampled for histologic study. All cases were examined for ferric ion and lipofuscin. Ages were determined from tooth growth layers. Electron microscopic (EM) examination and X-ray spectroscopy (EDAX) were performed.

Chemical analysis for mercury was conducted on 12 of the animals by atomic absorption spectrophotometry. Nine animals were found to have excessive lipofuscin in both liver and kidney. Four of these nine animals also exhibited active liver disease (fat globules, central necrosis, lymphocytic infiltrates) whereas, of the animals without the excessive pigment, only one animal had an active liver lesion. EM and EDAX showed electron-dense amorphous material presumably within lysosomes to be Hg with no deposits on mitochondrial or nuclear membranes noted. Age relationship to portal pigment deposition was positive. Liver mercury concentrations ranged from 0.01 to 443 *u*g/g of wet weight with all animals having liver pigment yielding values of or above 61 *u*g/g, whereas all animals lacking pigment had values of or below 50 *u*g/g. The evidence suggests that the excessive pigment accumulation is related to toxic effects of Hg and presents as increased active liver disease.
KEY WORDS: age, Atlantic bottlenose dolphins, chronic mercury accumulation, ferric ion, histology, lipofuscin, toxic.

Ray S, Dunn BP, Payne JF, Fancey L, Helbig R, and Béland P. 1991. Aromatic DNA-Carcinogen Adducts in Beluga Whales from the Canadian Arctic and Gulf of St. Lawrence. Mar. Poll. Bull. 22(8):392-6.
ABSTRACT: Aromatic DNA adduct levels in liver tissues of beluga whales (*Delphinapterus leucas*) from two sites in the Canadian Arctic and from the St. Lawrence estuary (N.W. Atlantic Ocean) were determined using the highly sensitive 32P-postlabelling technique. Detectable levels of aromatic DNA adducts (16-158 nmole adducts/mole total nucleotides) were found in all animals tested. It is of interest that the average level of adducts in animals from the St. Lawrence estuary, which contains relatively high levels of contaminants including polycyclic aromatic hydrocarbons, was comparable to those found in animals from the two remote locations. These observations are of major significance in view of the controversy on the role of polycyclic aromatic hydrocarbons in producing cancer in beluga whales in the Gulf of St. Lawrence. (The point made is that PAH may not be the primary reason and other causes should be addressed.) Also given that the study was carried out on animals taken from regions known to be relatively clean and highly contaminated, the results are of major importance for the scientific and regulatory communities with interests in the use of biochemical monitoring techniques. Also, the presence of adducts in whales from the Canadian Arctic suggests the existence on non pollution-related mechanisms for genetic damage.
KEY WORDS: aromatic DNA adduct levels, beluga whales, contaminants, *Delphinapterus leucas*, polycyclic aromatic hydrocarbons.

Reijnders PJH. 1982. Diminished Fertility in Seals in the Netherlands, Possibly Resulting from Exposure to Large Amounts of Polychlorinated Biphenyls. Tijjdshcr.Diergeneesk 107(10):363-7.
ABSTRACT: The number of seals in the coastal waters of the Netherlands has been considerably reduced since 1950, in the Wadden Sea, it decreased from 3,000 to 500, in the Delta area, from 1,500 to merely a few animals. Studies on population dynamics during the period from 1974 to 1978 showed that reproduction among the seal population in the Netherlands Wadden Sea is too small compared with the stable population of Schleswig-Holstein. Investigations on the role of environmental factors in diminished reproduction centered on the factor water pollution. Analysis of the various contaminants

in the tissues of seals of the Netherlands, Schleswig-Holstein and Denmark, which were found dead, showed that particularly the concentrations of polychlorinated biphenyls in seals of the Netherlands were significantly higher than they were in German and Danish animals. The epidemiological and experimental findings on the characteristics of these contaminants, in conjunction with the high concentrations of polychlorinated biphenyls and the decrease in reproduction of seals in the Netherlands, led to the hypothesis that polychlorinated biphenyls are the cause of diminished fertility of seals in the Netherlands.
KEY WORDS: contaminants, environmental factors, Netherlands, polychlorinated biphenyls.

Reijnders PJH. 1994. Toxicokinetics of Chlorobiphenyls and Associated Physiological Responses in Marine Mammals, With Particular Reference to their Potential for Ecotoxicological Risk Assessment . Sci. Total Environ. 154(2,3):229-36.
ABSTRACT: For the conservation of marine mammals and their ecosystem, it is important to know whether or not they are exposed to intolerable levels of environmental pollutants. In some case studies on marine mammals, xenobiotics can be linked to reproductive and immunological disorders. Disturbed endocrine systems seem to be a common denominator, whereby metabolization systems dealing with xenobiotic as well as endocrine compounds are involved. Two sets of indicators are distinguished to evaluate the toxicity of organochlorine residues found in marine mammal tissues. These are (1) interactions of chlorobiphenyls with the cytochrome P450 enxyme system and (2) comparative physical and chemical blood parameters directly and indirectly obtained via functional immunoassays. Apart from the constitutive enzymes, the induction of each of the other 150 isoenzymes of the P450 system exhibits substrate (= compound) specificity and moreover organisms develop species and even organ specific induction profiles. Therefore, a specific enzyme profile for each compound in a given species/organ may exist. The biotransformation capacity, constitutive and/or induced, will be reflected in the extent to which biotransformation of the chlorinated biphenyls in question has occurred. This can be expressed in the ratio of the concentration of a given individual biphenyl to the concentration of a persistent reference individual biphenyl. Both these indicators will provide information on which compounds are most likely involved and to what extent. The directly obtained blood parameters include levels of vitamin A, steroid hormones and thyroxine. The blood parameters acquired via functional immunoassays include mitogen- and antigen-induced proliferative responses of peripheral blood mononuclear cells (PBMC) and natural killer (NK) activity. These parameters provide comparative information on the state of impact, inter alia immunocompetence, of environmentally exposed individual animals. It is concluded that both sets of indicators are a basis for a multiple response assessment in a nondestructive approach. They are, as such, important elements in a conceptual framework which allow prediction of the impact of pollution on marine mammals.
KEY WORDS: chlorobiphenyls, immunocompetence, marine mammals, physiological responses, risk assessment, toxicokinetics.

Renberg L, Sundstrom G, and Reutergardh L. 1978. Polychlorinated Terphenyls (PCT) in Swedish White-Tailed Eagles and in Grey Seals: A Preliminary Study. Chemosphere 6:477-82.
ABSTRACT: The present study was performed to investigate the presence of

polychlorinated terphenyl (PCT), an industrial chemical used for the same purposes as PCB, in grey seals and white-tailed eagles along the east coast and northern part of Sweden. The present results, indicate that a more thorough study on the presence of PCT in wildlife should be performed in which a larger material should be investigated, both as to periods of time, animal species, and geographical distribution of collected animals. Preliminary results indicated that the PCT components present were low-chlorinated, while previous studies indicated that the PCT present were of a high-chlorinated type. Therefore the degree of chlorination of the PCT should be taken into consideration for future studies. Preliminary studies have shown that PCT may be separated from PCB by chromatographic procedures.
KEY WORDS: chlorination, chromatographic procedures, grey seals, polychlorinated terphenyl, Sweden, white-tailed eagles.

Richard CA, and Skoch EJ. 1986. Comparison of Heavy Metal Concentrations Between Specific Tissues Sites in the Northern Fur Seal. International Association for Aquatic Animal Medicine (IAAAM) Proceedings 3:94-103.
KEYWORDS: Alaska, cadmium, chromium, contamination, copper, heavy metals, lead, marine mammals, nickel, northern fur seal, zinc and selenium.

Ridlington JW, and Whanger PD. 1981. Interactions of Selenium and Antioxidants with Mercury, Cadmium and Silver. Fund. Appl. Toxicol. 1:368-75.
ABSTRACT: Selenium has been known to counteract the toxicity of some heavy metals, and has created a situation in which an element known to be very toxic itself would counteract the toxicity of other elements, such as heavy metals. This protective effect of selenium against metal toxicity is further complicated by the well established metabolic interaction between selenium and vitamin E and other antioxidants. This paper will provide a discussion of these relationships and present a few possible mechanisms for these interactions. The relative effectiveness of selenium and vitamin E against heavy metals are divided into 3 classes, which is dependent upon the metal. Some of the synthetic antioxidants must also be taken into consideration with studies dealing with selenium and heavy metals. One test with rats indicated that the kidney was the only organ examined in which selenium may be promoting the conversion of methylmercury to inorganic mercury. Other results also indicate that selenium was most effective against methylmercury toxicity followed by DPPD, vitamin E and BHT (butylated hydroxy toluene). In the area of selenium-cadmium interactions, selenium has been proven to prevent the testicular damage due to cadmium, but also causes cadmium to accumulate at higher concentrations in this organ after treatments with selenium. In vitamin E deficient rats, the amount of selenide in liver was greatly reduced by silver treatment but this effect was not observed in vitamin E supplemented rats. The interactions between selenium and heavy metals is proposed here that more than one mechanism is involved in these interactions and several of these to various degrees could be involved with each metal.
KEY WORDS: antioxidants, heavy metals, interaction, mechanism, selenium, toxicity.

Romano TA, Felten SY, Olschowka JA, and Felten DL. 1993. A Microscopic Investigation of the Lymphoid Organs of the Beluga, *Delphinapterus leucas*. J Morphol 215:261-87.
ABSTRACT: Lymphoid organs from belugas, *Delphinapterus leucas*, ranging in age from less than one to 16 years, were harvested during a sanctioned hunt to investigate

morphology. The spleen is divisible into red and white pulp and a stroma consisting of a reticular network , a collagenous capsule, and trabeculae containing smooth muscle bundles. White pulp areas appear to be devoid of follicles and consist mainly of periarteriolar lymphatic sheaths (PALS), that are larger in younger than in older belugas. Definitive marginal zones between red and white pulp are difficult to discern in older belugas. Lymph nodes are similar to those of other mammals; they possess a follicular cortex surrounding a vascular medulla composed of lymphatic cords and sinuses. Smooth muscle is abundant in medullary region, usually in close proximity to sinuses. The expansive nodular mass at the root of the mesentery, often referred to as the pseudopancreas, is similar to lymph nodes in microscopic architecture. Pharyngeal tonsils and gut-associated lymphoid tissue (GALT) are found along the digestive tract and display an active morphology. Tonsils are comprised of lobules of follicles separated by vascular connective tissue. Epithelial-lined crypts communicate with the pharyngeal lumen. GALT consists of diffuse and follicular lymphocytes within the intestinal mucosa and submucosa. The thymus is well developed in the younger belugas, with lobules divisible into densely packed cortical zones of thymocytes and more loosely arranged medullary lymphocytes. Hassalls corpuscles are occasionally visible within the medulla. Cetaceans diverged evolutionary from other mammals over 55 million years ago. This study investigates changes in lymphoid organ morphology in a species that now inhabits a unique ecological niche. This study also lays the groundwork for functional investigation of the beluga immune system, particularly as it relates to differences between healthy and stranded animals.

KEY WORDS: beluga whales, *Delphinapterus leucas*, immune system, lymphoid organs, morphology, stranded.

Sanpera C, Capelli R, Minganti V, and Jover L. 1993. Total and Organic Mercury in North Atlantic Fin Whales: Distribution Pattern and Biological Related Changes. Mar. Poll. Bull. 26(3):135-9.

ABSTRACT: Total and organic mercury concentrations were determined in muscle, liver and kidney of thirty-six fin whales (*Balaenoptera physalus*) of the Northeast Atlantic. Age, sex and length relationships for both forms of metal were examined. Tissue concentrations were lower than those of toothed whales and seals. A slight increase with age was observed for total mercury concentrations in muscle and liver and organic mercury concentrations in liver, which suggests a low rate of excretion for the metal, even at low concentrations. No differences between sexes were found regarding mercury concentrations, nor to their accumulation pattern.

KEY WORDS: *Balaenoptera physalus*, fin whales, Northeast Atlantic, organic mercury, total mercury.

Schantz MM, Koster BJ, Wise SA, and Becker PR. 1993. Determination of PCBs and Chlorinated Hydrocarbons in Marine Mammal Tissues. Sci. Total Environ. 139-140:323-45.

ABSTRACT: Selected tissues (blubber, liver, kidney and muscle) from marine mammals, which were collected as part of the Alaska Marine Mammal Tissue Archival Project (AMMTAP), were analyzed for polychlorinated biphenyl (PCB) congeners and chlorinated pesticides. Concentrations of these compounds in the different tissues were compared and blubber was selected as the primary tissue for organic contaminant

analyses for the AMMTAP based on higher levels (1-2 orders of magnitude) in this tissue compared to liver, kidney, and muscle. Concentrations for 15 PCB congeners and 12 chlorinated pesticides are reported for 10 different animals of three species (northern fur seal, ringed seal and belukha whale) from five different sites.
KEY WORDS: chlorinated pesticides, chromatography, marine mammals, polychlorinated biphenyls (PCBs).

Seagars DJ, Bowlby CE, Burn D, and Garlich-Miller J. 1994. Metal Concentrations in Liver and Kidney Tissues of Pacific Walrus: 1991 *Zaslonovo* Bering Sea Research Cruise Samples. Text From a Poster Presented at the 45th Arctic Science Conference, Anchorage, AK and Vladivostok, Russia.10 pp.
ABSTRACT: Liver and kidney samples were collected from walrus taken in the Olyutorsky Bay, Cape Navarin and Gulf of Anadyr regions of Russia and from south of St. Lawrence Island and northwestern Bristol Bay in U.S.A., during the Spring of 1991. Tissues were analyzed for 19 elements including arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), methyl-mercury (meHg), selenium (Se), and zinc (Zn). Metal concentrations in female-fetus pairs were also compared along with samples of lower canine teeth taken for age determination. In the kidney samples, mean concentrations of As and Se were significantly higher and the mean concentration of Cd, Pb, Hg and Zn were significantly lower ($P<0.005$) than previous reports. In liver samples, the mean concentrations of As, Cd, Pb, Hg and Zn were significantly higher and Se was significantly lower ($P<0.005$) than previously reported. These significant differences in values from other reports may represent age-related, temporal or geographical variation in contaminant levels. Concentrations of Cd, Zn, Hg, meHg, and As (females) increased with age ($P<0.005$) in both the liver and kidney. Also, there were no significant correlations ($P>0.005$) between concentrations of key elements in female-fetus pairs. Although trace elements occur naturally in low levels of the marine environment, some levels of these elements found in walrus tissues could be toxic and raise a concern for the potential impact to walrus health. Therefore, the Fish and Wildlife Service in continuing studies to assess these effects on the animals health.
KEY WORDS: female-fetus pairs, marine mammals, Pacific walrus, Russia, trace metals.

Secord DC, Eaton RDP, Hewitt P, and Kidney B. 1978. Experimental Assessment of the Toxic Potential of Mercury in Seal Liver. IV Internation Congress on Circumpolar Health, Novosibirsk, Russia .

Sergeant DE, and Armstrong FAJ. 1973. Mercury in Seals from Eastern Canada. J. Fish. Res. Board Can. 30(6):843-6.
KEY WORDS: heavy metals, mammals, mercury, pesticides/ pollution.

Sericano JL, Safe SH, Wade TL, and Brooks JM. 1994. Toxicological Significance Of Non-, Mono- and Di-Ortho-Substituted Polychlorinated Biphenyls In Oysters From Galveston And Tampa Bays. Env. Tox. Chem. 13(1):1797-803.
ABSTRACT: Concentrations of non-ortho (77,126 and 169), mono-ortho (105 and 118) and di-ortho (128 and 138)-substituted PCB congeners were measured in oysters from Galveston and Tampa bays, and reported toxic equivalent factors were used to assess

their toxicity. Most of the relative toxicity encountered in the oysters analyzed during this study was due to the presence of planar non-ortho-PCBs (53.8-94.3%), particularly congeners 126. In contrast, the contribution of di-ortho-substituted PCB congeners to the total relative toxicity of the samples was negligible (<1%). On average, the contribution of each of these non-,mono-, and di-ortho-substituted PCB congeners to the total toxicity encountered in oysters from Galveston and Tampa bays were 126>118169105>77>>138>128 and 126>118>16977>105>>138>128, respectively. Based on the reported lower clearance rates of non-ortho- and mono-ortho-substituted PCB congeners compared to other congeners within the same chlorination level, contaminated oysters that are depurated in clean environments will lower their total PCB concentrations, but their original toxicity may not be proportionally reduced.
KEY WORDS: depuration, Gulf of Mexico, oysters, PCBs, toxicity.

Shaw GR, and Connell DW. 1984. Physiochemical Properties Controlling Polychlorinated Biphenyl (PCB) Concentrations in Aquatic Organisms. Environ. Sci. Technol. 18:18-23.
ABSTRACT: The uptake and bioaccumulation of PCBs by mullet and polychaetes have been shown to be influenced by two factors: (i) partition behavior, quantitatively measured by the partition coefficient between 1-octanol and water (p), and (ii) the adsorption characteristics of the PCBs onto a surface, estimated by chromatographic elution time on carbon and also by application of coefficients for chlorines in different substitution patterns giving a steric effect coefficient (SEC). The combination of these two factors, as log p elution time or log p SEC, gives a measure which is highly correlated with bioaccumulation. The results show that adsorption of PCB molecules onto a surface is influenced principally by their stereochemistry. Planar molecules are most efficiently adsorbed, and adsorption decreases as the molecule becomes less planar.
KEY WORDS: aquatic organisms, bioammumulation, PCB, stereochemistry, uptake.

Simmonds MP, Johnston P.A., and French MC. 1993. Organochlorine and Mercury Contamination in United Kingdom Seals. Vet. Rec. March, 20:291-5.

Simmonds MP, Johnston PA, French MC, Reeve R, and Hutchinson JD. 1994. Organochlorines and Mercury in Pilot Whale Blubber Consumed by Faroe Islanders. Sci. Total Environ. 149:97-111.
ABSTRACT: Some 22 000 pilot whales (*Globicephala melaena*) were taken in the Faroe Islands between 1970 and 1992. It is known that tissues from these animals are widely consumed by the islanders. The position of these animals at the apex of a direct marine food chain renders them liable to accumulate toxic chemicals, such as metals and organochlorines. Although the consumption of contaminating metals in pilot whale tissues has been studied, the significance of blubber as a dietary source of organochlorine compounds has not been fully considered. This study reports levels of organochlorine and mercury contamination the blubber of pilot whales taken in two Faroese kills. Published estimates of chlorine and mercury contamination in the blubber of pilot whales taken in two Faroese kills. Published estimated of pilot whale tissue consumption are used to evaluate dietary organochlorine intake in relation to established national and international guidelines and clinical studies conducted in the North American Great Lakes.
KEY WORDS: diet, Faroes, mercury, organochlorines, pilot whales, whaling.

Skoch EJ, and Metzger DM. 1985. Heavy Metal Levels in Tissues of the Northern Fur Seal Collected from Five Rookeries in the Pribilof Islands-1985. Marine Mammal Research Laboratory, John Carroll University, University Heights, Ohio .
KEY WORDS: Alaska, aluminum, cadmium, chromium, contamination, copper, heavy metals, iron, kidney, lead, liver, marine mammals, muscle, nickel, northern fur seal, selenium, titanium, zinc.

Smith DR, Flegal AR, and Estes JA. Lead in Sea Otters. U.S. Fish and Wildlife Service, Institute of Marine Sciences, University of California :4 pp.
KEY WORDS: age, Alaska, Aleutian Islands, California, contamination, marine mammals, sea otter, teeth.

Smith TG, and Geraci JR. 1975. Effect of Contact and Ingestion Crude Oil on Ringed Seals of the Beaufort Sea. Beaufort Sea Technical Report #5, 1975. 66 pp.
ABSTRACT: This paper attempts to evaluate the effects of crude oil on ringed seals primarily, and on harp seal whitecoat pups. Studies were conducted on both the effect of immersion in oil and ingestion of oil on wild and captive seals; there exist few experimental data on the effects of oil on mammals, and none on seals. From August 23-September 9, 1975, 96 seals, 32 of which were live, were caught in Browns Harbour, on the east side of Cape Parry. Fouling by fresh Norman Wells crude oil did not cause any mechanical damage to the body or plugging of the body openings. Also, no thermoregulatory problems were observed, including immersion studies on whitecoat harp seals. The ringed seals in the field study showed enzymatic and histological evidence of kidney damage. Eye irritation and damage was also a significant finding. Assumptions are made that continued exposure to oil may have resulted in more severe and permanent eye damage. The laboratory studies showed all ringed seals died within 71 minutes of exposure to oil, a situation suggestive of stress. Further investigations showed that the stress could be associated with prolonged moult and starvation and also related to age of the animal. Overall, the data suggest that an environmental disturbance, including a blowout, would not affect a seal population uniformly.
KEY WORDS: Browns Harbour, contaminants, crude oil, environmental disturbance, ingestion, ringed seals, whitecoat harp seal pups.

Smith TG, Geraci JR, and St. Aubin DJ. 1983. Reaction of Bottlenose Dolphins, *Tursiops truncatus*, to a Controlled Oil Spill. Can. J. Fish. Aquat. Sci. 40(1522-1525).
ABSTRACT: Three captive bottlenose dolphins, *Tursiops truncatus*, were observed in an ocean pen measuring 14 X 11 m, divided into three equal areas by oil-containment booms. Each dolphin was placed in the pen alone for 4 d with no oil present, and 2 d with dark-colored mineral oil in one of the areas. We noted their area of surfacing, underwater movements, dive times, and reactions. After a few brief contacts with the oil, dolphins completely avoided surfacing in the slick. The oil also acted as a temporary barrier restricting their underwater movement.
KEY WORDS: bottlenose dolphin, captivity, oil slicks, *Tursiops truncatus*, underwater movements.

Smith TG. 1987. The Ringed Seal, *Phoca hispida*, of the Canadian Western Arctic. Can. Bull. Fish. Aquat. Sci. 216:81 pp.

ABSTRACT: I studied ringed seals, *Phoca hispida*, during the years 1971 to 1983 from Holman in Amundsen Gulf, N.W.T. and several other localities in the southeastern Beaufort Sea. The highest densities of ringed seals (2.84/km2) were found in Prince Albert Sound, Amundsen Gulf. Each year this becomes an area of good stable landfast ice which is consistently used as a breeding habitat. Age structure of the catches indicates segregation of older animals occupying fast-ice areas in the winter and spring, with all age classes being present in the summer open-water period. In the autumn, young -of-the-year and adolescents move west along the coat of Amundsen Gulf and southeastern Beaufort Sea. Seals tagged in this study were recovered as far west as Point Barrow, Alaska and Injun, Siberia. Prime breeding ice in Amundsen Gulf is characterized by being stable with ice hummocks or pressure ridges which provide areas for accumulation of snow in which subnivean lairs are constructed. Lairs serve the dual function of providing protection from predators and as a thermal shelter. Both polar bears, *Ursus maritimus*, and arctic foxes, *Alopex lagopus*, kill seals in their lairs. Arctic foxes are the most important predators of ringed seal pups in the western Canadian arctic. Strong territoriality exists in the breeding habitat. A limited form of polygyny exists in the ringed seal breeding population; one make maintains a territory which includes several females with their sub-territories of birth-lair complexes. A significant decrease in the number of birth lairs found during dog searches was documented in 1974 and 1975. In 1975 it was also found that the number of lairs occupied by rutting males was severely reduced. Predation by arctic foxes was at a peak in the spring of 1973, one year prior to the highest fox trapping harvest yet recorded for the area. High fox predation continued in the springs of 1974 and 1975 even though the number of ringed seal pups born had been severely reduced. Ringed seal pups are born in mid April. Ovulation occurs on average, 21 May, with implantation of the blastocyst on 18 August. There is an active gestation of 241 says with a delay of implantation of 89 days. Females are sexually mature at 5.61 years with the mean age of first reproduction being attained at 7.67 years. The pup sex ratio at birth is 1:1. Mean reproductive rates in normal years are calculated as 0.56. In 1974 and 1975 ovulation rates were reduced to the low values of 0.41 and 0.38, respectively, compared to the mean ratio of 0.89 in other years. The index of body condition of adult seals was also significantly reduced on both 1974 and 1975. The length at birth of seals in this study area is calculated to be 632 mm (STL) with a foetal growth rate of 2.2 m/day; post-natal growth to weaning is 6.1 m/day; and post-weaning growth is reduced to a low of 0.099 mm/day for the remainder of the year. There is an indication of severe stunting in 4% and moderate stunting in 11% of the seals measured in this study. It appears to be related to date of birth and poor feeding conditions during the first year of life. Ringed seals feed on a variety of crustaceans during the open water season including *Parathemisto libellula*, *Thysanoessa raschii* and *Mysis oculata*. Arctic cod, *Boreogadus saida*, is the most important food of all ages of ringed seals during the ice covered period. There is evidence of feeding competition between adolescents and adults as shown by different prey items and diurnal feeding times. All age classes lose body condition from spring through to early September. Autumn feeding on arctic cod by groups of adult ringed seals occurs regularly, and this is an important time for the seals to regain body condition. It is also probably the proximate cause, through territorial exclusion, of the migration of young and adolescents westward along the mainland coast towards the Beaufort and Bering Seas. Survivorship values estimated from catch curves do not present either a clear or accurate picture of the annual changes in a ringed seal

population. They reflect the drastic reduction in recruitment documented from reproductive data and breeding habitat evaluation 1974 and 1975, but would not be sensitive enough to point to the nature of the change on their own. The inadequacy of a *klx* type life table in underlined by the changes in recruitment documented in this study, which violates the basic assumptions of population stability needed for such an analysis. The marked decrease in recruitment of 1974 and 1975 seems to be about equally influenced by reduced ovulations and increased pup mortality from fox predation. Many changes have occurred in the Canadian arctic in the past 20 years. The subsistence culture of the Inuit is being replaced by a cash-revenue economy. Modern Inuit depend on the sale of furs and seal pelts to finance their hunts which provide the main source of food for their growing population. Recent European anti-sealing campaigns have severely affected the ability of the Inuit to generate enough cash from hunting to pay their operating costs. Recent concerns of the Inuit and environmentalists involve the impacts of industrial development especially from the petroleum industry on seals. Oil spills, which have not yet occurred on a large scale are not thought to pose as serious a threat to seals as was once envisaged. Adult ringed seals are able to withstand and recover from immersion oil, but the effects on newborn seals would be more severe. Other oil-related impacts such as disturbance from ice-breaking tankers and underwater noise are more difficult to assess empirically. The effect of contaminants such as heavy metals and chlorinated hydrocarbons is not thought to be a major problem in the Canadian north. Integrated ecosystem research is needed to identify the mechanisms involved in regulation of marine mammal populations. This study has documented a significant reduction in ovulation in 1974 and 1975 which resulted in reduced recruitment. This was correlated to a significant reduction in body condition in the same years, but we have no quantitative information about fish or their availability, or on other levels of production in the ecosystem. New techniques including radio telemetry and satellite remote sensing are available and should be used to study ringed seals. The projected doubling of the Inuit population by the year 2000 will place more pressure on ringed seal populations, which will be increasingly used as human food.

KEY WORDS: chlorinated hydrocarbons, heavy metals, life history, oil-related impacts, *Phoca hispida*, ringed seal.

Smith TG, and Armstrong FAJ. 1975. Mercury in Seals, Terrestrial Carnivores, and Principal Food Items of the Inuit, from Holman, N.W.T. J. Fish. Res. Board Can. 32:795-801.

ABSTRACT: Total mercury analyses were made on liver and muscle of ringed and bearded seals, of caribou, and on muscle of Arctic char (the principal items in the diet of local people), of Arctic fox and sledge dogs (which feed mostly on ringed seal) and on wolves (predacious on caribou). About half of the 123 samples were also analyzed for methyl mercury, and some for selenium. Ringed seals showed mean total mercury levels of 27 ppm in liver and 0.73 in muscle. Bearded seals showed 143 in liver and 0.53 in muscle. In the livers, methyl mercury was a small fraction of the total being 5.6% in ringed and 0.38% in bearded seals. There were positive and significant correlations of mercury content with age and body weight. In Arctic cher, mean mercury was 0.049 ppm, and in caribou 0.20 in liver and 0.017 in muscle. In Arctic fox, values for liver and muscle were 0.77 and 0.32 and in sledge dogs 11.5 and 0.79 ppm. Seals form only part of the diet of the local people. Blood mercury levels have been reported for this community as being above average though not dangerously so. A change in diet, such as increased

consumption of seals, might change this.
KEY WORDS: Arctic char, bearded seals, carnivores, Inuit, ringed seals, total mercury.

Spraker TR, Frost D, and Calkins D. 1992. Histological Lesions Found in Several Marine Mammals Collected Following the T/V *Exxon Valdez* Oil Spill, March 1989. Proceeding Joint Meeting American Association of Zoo Veterinarians (AAZV)/ American Association of Wildlife Veterinarians (AAWV) :60 pp.
KEY WORDS: Alaska, contamination, *Exxon Valdez*, marine mammals.

St. Aubin DJ, and Geraci JR. 1985. How Do Bottlenose Dolphins, *Tursiops truncatus*, React to Oil Films under Different Light Conditions. Can. J. Fish. Aquat. Sci. 42(430-436).
ABSTRACT: In daylight, and again at night under a shading canopy, we observed the behavior of bottlenose dolphins (*Tursiops truncatus*) allowed to swim freely in a pool with three surface divisions, one of which contained either clear mineral oil, dark-tinted mineral oil, or a thin sheen of refined motor oil. Overall, they avoided oil both during the day and at night. The response broke down when we presented them with a thin sheen, especially at night; we suggest that such conditions represent the threshold for their ability to detect oil or their desire to avoid it. Irrespective of light conditions, the dolphins tactile sense played a more important role than vision in perceiving, and ultimately avoiding, oil. The strength of their basic reaction dampens our fear that they might be unknowingly subjected to prolonged or repeated exposure to oil at sea.
KEY WORDS: bottlenose dolphin, light conditions, oil detection, oil films, *Tursiops truncatus*.

St. Aubin DJ, Stinson RH, and Geraci JR. 1984. Aspects of the Structure and Composition of Baleen, and Some Effects of Exposure to Petroleum Hydrocarbons. Can. J. Zool. 62:1093-198.
ABSTRACT: The structure and composition of baleen from seven species of whales was studied using tensiometry, X-ray diffraction, and elemental analysis. Baleen was found to be composed principally of amorphous and -keratin. Hydroxyapatite (bone mineral, Ca10(PO4)6OH2) was present in all species. Certain elements, notably manganese, copper, boron, iron, and calcium were more highly concentrated in the fibers than in the matrix of the plate. The breaking strength of baleen plates from fin (*Balaenoptera physalus*), sei (*B. borealis*), and grey (*Eschrichtius robustus*) whales was comparable to that of buffalo horn, in the range of 2-9 x 106 N · m-2. The stiffness of baleen was somewhat less than that of other keratinized tissues. Treatment with 10% (v/v) trichloroacetic acid for 8 days removed most of the calcium salts, denatured -keratin and made fin whale plates stronger and stiffer. Exposure to gasoline for 1.5 h for 14 days, crude oil for 8 days, or tar for 21 days resulted in loss of trace elements from baleen, and inconsistent changes in keratin organization. After tar exposure, fin whale baleen plates were stiffer and stronger. We presume that at sea, baleen would be relatively resistant to damage by spilled oil.
KEY WORDS: baleen plates, hydrocarbons, keratinized tissue, tensiometry, whales.

Stern GA, Muir DCG, Segstro MD, Dietz R, and Heide-Jørgensen. 1994. PCB's and Other Organochlorine Contaminants in White Whales (*Delphinapterus leucas*) from West Greenland: Variations with Age and Sex . Medd Om Grønland, Bioscience 3:243-59.

ABSTRACT: Blubber samples from a total of 138 white whales from two locations in West Greenland waters (the Nuussuaq area (approximately 74N, 58W) and the Disko Bay area (approximately 69N, 85W)) as well as skin and kidney samples from 20 whales from Nuussuaq were analysed for PCB congeners and related organochlorines (hexachlorohexanes (HCH), chlorinated bornanes (CHB), chlordane (CHLORD), DDT related compounds (DDT), dieldrin and mirex). The large sample size permitted a detailed assessment of the variation of contaminant levels with age and sex. Mean concentrations of all major organochlorine (OC) groups (PCB, DDT, CHLORD, CHB) were not significantly different between the Nuussuaq and Disko Bay groups, for males or for females. After age 5.5, a consistent decline in concentration levels of all 4 major OCs was observed in females compared to only marginal differences in PCB, CHB, and CHLORD concentrations and a substantial increase in DDT in males. The observed decline in females in consistent with the age of attainment of sexual maturity and commencement of lactation. Residue levels in sexually immature animals (male and female) and male-female differences in mean concentrations of PCB and p,p'-DDE in adult animals are consistent with a lactation period of less than one year and point to a possible biennial breeding cycle. Young animals could be distinguished from adults, using principal component analysis, by higher proportions of lower chlorinated PCBs and more water soluble OCs such as p,p'-DDE which are preferentially transferred during lactation.
KEY WORDS: age, beluga, DDT, Greenland, lactation, organochlorine, paturition, PCB, sex, white whale

Stewart REA, Stewart BE, Stirling I, and Street E. 1996. Counts of Growth Layer Groups in Cementum and Dentine in Ringed Seals (*Phoca hispida*). Marine Mammal Science 12(3):383-401.

ABSTRACT: We compared counts of growth layer groups (GLGs) in the dentine of undecalcified, unstained cross-sections and in the cementum of decalcified, stained longitudinal sections of canine teeth from 144 ringed seals (*Phoca hispida*). Although there was a statistically significant correlation until approximately 10 GLGs, about 75% of paired readings at 10 cementum GLGs disagreed. After 10 GLGs, the number of GLGs in the cumemtum usually was greater. The maximum GLG count in cementum was 33, compared to a maximum in dentine of only 19. Interobserver differences in median counts were not statistically significant using cementum or dentine counts. Regression analysis revealed that for cementum in female seals, readers differed at higher counts ($P<0.05$), and for dentine, there was a constant difference of about 0.6 GLGs ($P<0.05$) for male seals and 1.1 GLGs ($P<0.05$) for female seals. Counting GLGs in the cementum of decalcified and stained longitudinal sections provided higher counts and more agreement between readers, and it was the better of the methods examined for aging ringed seals.
KEY WORDS: age estimates, cementum, dentine, growth layer group, *Phoca hispida*, ringed seal, teeth.

Stoneburner DL. 1978. Heavy Metals in Tissues of Stranded Short-Finned Pilot Whales. Sci. Total Environ. 9:293-7.

ABSTRACT: Selected tissues from four short-finned pilot whales that stranded at Cumberland Island National Seashore were analyzed for total cadmium, mercury and

selenium by neutron activation. Cadmium reached a maximum mean wet weight concentration of 31.4 ppm in the kidney tissues. Maximum mean wet weight concentrations of mercury, 230.9 ppm, and selenium, 44.2 ppm, were found in the liver tissues. The lowest concentration of each metal was found in the blubber. Postmortem examination showed that the whales had no food in their stomachs. The whales must have been utilizing metabolic reserves, contaminated with residual concentrations of heavy metals, prior to beaching. This utilization of reserves probably resulted in the high concentrations of cadmium, mercury and selenium found in the liver and kidney tissues. Since the heavy metal concentrations were three to four times greater in the stranded whales, as compared to apparently healthy whales of the same species, it is suggested that heavy metal toxicosis may have been a factor contributing to this particular stranding.
KEY WORDS: heavy metals, stranded short-finned pilot whales, toxicosis.

Subramanian A, Tanabe S, and Tatsukawa R. 1988. Estimating Some Biological Parameters of Baird's Beaked Whales Using PCBs and DDE as Tracers. Mar. Poll. Bull. 19(6):284-7.
ABSTRACT: Concentrations of PCBs and DDE in the blubber of Bairds beaked whales collected from the Pacific coast of Japan are reported. Comparison of the values of PCB/DDE ratios with those of other cetaceans from the Japanese coastal waters and open ocean areas of North Pacific indicates that these animals may not have any offshore distribution, as doubted by some biologists. The extent of the male-female differences in the levels of PCBs and DDE in the adults of this species is narrower than minke whale, Dalls porpoise and striped dolphin. Based on these values it is suggested that the lactational period for every parturition in Bairds beaked whales may be shorter than those of the other three species, i.e. less than 6 months.
KEY WORDS: Baird's beaked whales, *Berardius bairdii*, DDE, distribution, Japan, lactational period, migration pattern, PCB, pollutant levels.

Subramanian A, Tanabe S, and Tatsukawa R. 1988. Use of Organochlorines as Chemical Tracers in Determining Some Reproductive Parameters in *Dalli*-type Porpoise *Phocoenoides dalli*. Marine Environ. Res. 25:161-74.
ABSTRACT: Persistent organochlorines (PCBs and p,p'-DDE) in the bodies of *Dalli*- and *Truei*-type Dalls porpoises (*Phocoenoides dalli*) from the Bering Sea and the northwestern North Pacific were used as chemical tracers in evaluating some reproductive parameters of this species. In females the concentrations of organochlorines decrease consistently with age after 2 years. The results of isomer-specific analysis indicate that the lesser chlorinated biphenyls were preferentially eliminated from adult females. Elimination probably occurs mainly via lactation rather than through the placenta during gestation, since changes in congeners patterns in female porpoises follow closely the parturitional history of the female animals. The organochlorine data indicate that females of Dalls porpoise attain their sexual maturity at about 2 years of age and their first parturition occurs around 3 years. The active parturition period seems to be up to approximately 6 to 7 years of age and declines thereafter.
KEY WORDS: Bering Sea, Dalli- and Truei-type Dall's porpoises, isomer-specific analysis, lactation, North Pacific, parturition period.

Subramanian A, Tanabe S, Tatsukawa R, Saito S, and Miyazaki N. 1987. Reduction in the Testosterone Levels by PCBs and DDE in Dall's Porpoises of Northwestern North

Pacific. Mar. Poll. Bull. 18(12):643-6.

ABSTRACT: The increasing residue levels of PCBs and DDE in the blubber of *dalli*-type Dalls porpoises were found to have a negative effect on the testosterone levels in blood. Decrease in the levels of testosterone was statistically significant with increase in DDE concentrations. The results obtained suggest that the present levels of environmental contamination by persistent organochlorines can cause an imbalance of sex hormones and subsequent reproductive abnormalities in wild. The other hormone measured, aldosterone, which has no sexual function, was independent of the effects of both PCBs and DDE.

KEY WORDS: Dall's porpoise, DDE, organochlorines, PCB, reproductive abnormalities, testosterone, toxicological effects.

Szefer P, Czarnowski W, Pempkowiak J, and Holm E. 1993. Mercury and Major Essential Elements in Seals, Penguins, and Other Representative Fauna of the Antarctic. Arch. Environ. Contam. Toxicol. 25:422-7.

ABSTRACT: Concentrations of total Hg and major essential elements, Ca, Mg, Na, and K, were measured in the muscle, liver and kidney of three species of seals, crabeater seal (*Lobodon carcinophagus*), leopard seal (*Hydrurga leptonyx*), and Weddell seal (*Leptonychotes weddelli*) collected in the Antarctic. The muscle and liver of three species of penguins, i.e., gentoo penguin (*Pygoscelis papua*), Adelie penguin (*P. adeliae*), chinstrap penguin (*P. antarctica*), and other representative fauna were also analyzed for the elements. Distinct inter-tissue differences in the metal concentration were observed; liver had the greatest concentrations of Hg, kidney showed maximum concentration of Ca and Na, while muscle was characterized by the greatest content of Mg and K. Inter-specimen differentiation of concentrations among the same species was distinctly visualized for Hg but not for the major essential elements. The Hg concentration the seals analyzed are in keeping with those reported previously by other authors. Such comparison for Ca, Mg, Na, and K was impossible because of the lack of available literature data for their concentrations in marine seals. Numerous significant correlations were observed between concentrations of the several metals analyzed. There was no correlation between Hg, which is a non-essential element and both Zn and Cd which are essential and non-essential element, respectively in the liver or kidney of seals. However, there were significant correlations between concentration of Zn and the sum of molar concentrations of Hg + Cd in kidney ($r = 0.82$) and liver ($r = 0.76$). The results suggest that several control mechanisms operate to maintain physiologically required levels that decreases any effect of heavy metal toxicants such as Hg and Cd.

KEY WORDS: Antarctic fauna, inter-tissue differences, marine mammals, metals, total mercury.

Szefer P, Malinga M, Skora K, and Pempkowiak J. 1994. Heavy Metals in Harbour Porpoises from Puck Bay in the Baltic Sea. Mar. Poll. Bull. 28(9):570-1.

ABSTRACT: The harbour porpoise, *Phocoena phocoena*, occurs in coastal areas of the temperate and subarctic North Atlantic and North Pacific Oceans. The present study reports the levels of selected heavy metals in harbour porpoises collected at Puck Bay, Poland.

KEY WORDS: bioaccumulation, coastal waters, heavy metals, marine mamals, marine pollution, *Phocoena phocoena*, Poland, pollution effects, Puck Bay, water pollution.

Tanabe S, Iwata H, and Tatsukawa R. 1994. Global Contamination By Persistent Organochlorines and Their Ecotoxicological Impact on Marine Mammals. Sci. Total Environ. 154(2,3):163-77.

ABSTRACT: The present paper overviews the global contamination by persistent organochlorines and their ecotoxicological implications on marine mammals. The recent pattern of contamination by organochlorine residues in the coastal environment is prominent in tropical regions due to continuous usage in the low-latitude developing countries. The major emission source of organochlorines is probably the tropical belt and large quantities of volatized contaminants are dispersed through the atmosphere on global terms. Reflecting this, a considerable contamination was observed in open ocean tropical waters as well as in the Arctic and nearby waters. The study of the mass transfer of organochlorines at the air-water interface suggests that the oceanic water bodies, particularly animal groups receiving high concentrations of persistent organochlorines arising out of a worldwide contamination. They can amplify much greater amounts of toxic contaminants through feeding and also pass them in large quantities from one generation to the next through lactation. Unfortunately, these animals have a smaller capacity for degradation of these contaminants due to the specific mode of cytochrome P-450 enzyme systems. These drug-metabolizing enzyme systems may be related to the possible effects of persistent organochlorines, particularly coplanar PCBs. Furthermore, the residue levels of these contaminants in marine mammals are unlikely to decline in the near future. Considering all these facts, it may be concluded that marine mammals are one of the most vulnerable and possible target organisms with regard to long-term toxicity of hazardous man-made chemicals in the future.

KEY WORDS: chlordane compounds, coplanar PCBs, cytochrome P450 epizootic, DDTs, global contamination, hexachlorocyclohexanes, marine mammals, organochlorines, polychlorinated biphenyls.

Tanabe S, Kannan N, Ono M, and Tatsukawa R. 1989. Toxic Threat to Marine Mammals: Increasing Toxic Potential of Non-ortho and Mono-ortho Coplanar PCBs from Land to Ocean. Chemosphere 18(1-6):485-90.

ABSTRACT: Toxic non-, mono- and di-*ortho* coplanar PCB congeners were determined in terrestrial and marine mammals. The concentrations of coplanar PCBs were found to be higher in the order of di-*ortho*> mono-*ortho* > non-*ortho* congeners and were significantly higher than the levels of toxic dioxins and furans. The geographical distribution of these chemicals based on the relative abundance of coplanar PCB congeners with reference to total PCBs did not vary in terrestrial, coastal and open ocean mammals, whereas that of PCDFs and PCDDs apparently decreased from land to ocean. '2,3,7,8-T_4 CDD toxic equivalent analysis revealed that higher aquatic predators such as cetaceans receive a greater toxic threat from 3,3',4,4',5- and 2,3,3',4,4'-pentachlorobiphenyls than PCDFs and PCDDs.

KEY WORDS: geographical distribution, marine mammals, non-ortho and mono-ortho coplanar PCBs.

Tanabe S, Kumaran P, Iwata H, Tatsukawa R, and Miyazaki N. 1996. Enantiomeric Ratios of Alpha-Hexachlorocyclohexane in Blubber of Small Cetaceans. Mar. Poll. Bull. 32(1):27-31.

ABSTRACT: The enantiomeric ratio of alpha-hexachlorocyclohexane (alpha-HCH) in

blubber of 10 species of adult male small cetaceans has been determined by means of capillary gas chromatography using beta-cyclodextrin as a chiral stationary phase. The enantiomeric ratio of (+)-alpha-HCH/(-)-alpha-HCH ranged from 1.6 to 2.8, showing diverse values. Moreover, even in the same species, the ratios varied between animals collected from different localities. Dalls porpoise (*Phocoenoides dalli*) collected from the Bering Sea had enantiomeric ratios of 2.0-2.1 and others, from the North Pacific and Japan Sea, exhibited ratios ranging from 1.6-1.9. The ratios of beta-HCH concentration to total HCH concentration (beta-HCH/ ΣHCH) was linearly related to the enantiomeric ratios of alpha-HCH ($r= -0.46$, $p<0.005$). This may indicate that the metabolic capacity to degrade HCH isomers among cetaceans can be evaluated in terms of degradation of the (+)-alpha-HCH enantiomer. Present enantiomeric ratios were compared with earlier observations on various environmental samples and unbalanced degradation of environmental samples and unbalanced degradation of (+)- and (-)-alpha-HCH enantiomers was suggested in small cetaceans.
KEY WORDS: alpha-HCH, cetaceans, chiral stationary phase, enantiomeric ratio.

Tanabe S, Loganathan BG, Subramanian A, and Tatsukawa R. 1987. Organochlorine Residues in Short-Finned Pilot Whale: Possible Use as Tracers of Biological Parameters. Mar. Poll. Bull. 18(10):561-3.
ABSTRACT: Organochlorine (PCBs and p,p'-DDE) residues in the blubber of short-finned pilot whale (*Globicephala macrorhynchus*) from Ayukawa, the Pacific coast of Japan revealed clear age trends particularly in females. PCBs and DDE increased in concentration up to about 10 years age and declined with increasing age up to about 25 years. Again, after 25 years of age the concentration of PCBs and DDE increased with increasing age. Age-related biological parameters particularly the reproductive parameters are discernible from the organochlorine data, giving credence to the use of persistent organochlorines as excellent chemical tracers in biological and ecological studies of cetaceans.
KEY WORDS: chemical tracers, *Globicephala macrorhynchus*, organochlorine contaminants, reproductive parameters, short-finned pilot whale.

Tanabe S, Madhusree B, Ozturk AA, Tatsukawa R, Miyazaki N, Ozdamar E, Aral O, and Samsun B. 1997. Isomer-specific Analysis of Polychlorinated Biphenyls in Harbour Porpoise (*Phocoena phocoena*) from the Black Sea. Mar. Poll. Bull. 34(9):712-20.
ABSTRACT: The highly toxic coplanar PCBs and other isomers were determined in harbour porpoises and fish (porpoise diet) collected from the Turkish coastal water of the Black Sea, during 1993. The concentrations of total PCBs were found in the range of 5.0-34 ug·g-1 wet wt in the blubber of porpoises. Highly chlorinated members such as IUPAC Nos. 138, 153 and 180 were the dominant congeners consisting of 41% of the total PCB concentrations. The mean total 2,3,7,8-TCDD toxic equivalents (TEQs) of 13 coplanar PCBs including non-, mono- and di-*ortho* congeners were 1400 pg·g-1 wet wt in females. The IUPAC No. 118 was the most contributing congener occupying about 60% of the total TEQs. The most toxic non-*ortho* chlorine substituted coplanar PCBs such as IUPAC No. 77, 126 and 169 were minor contributors and accounted for 7.8, 4.2 and 0.7%, respectively, of the total TEQs. The activities of PB and MC-type enzymes were found to be low in Black Sea harbour porpoises, suggesting long term accumulation and possible toxic effects of PCBs in this species.

KEY WORDS: Black Sea, coplanar PCBs, harbour porpoise, PCBs, TEQs.

Tanabe S, Prudente M, Mizuno T, Hasegawa J, Iwata H, and Miyazaki N. 1998. Butyltin Contamination in Marine Mammals from North Pacific and Asian Coastal Waters. Env. Sci. Technol. 32(2)193-98.
ABSTRACT: Hepatic butyltin concentrations were determined in 63 cetaceans belonging to 14 species and four pinnipeds belonging to two species collected from North Pacific and Asian coastal waters. Butyltin compounds (BTs) including tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT) were detected in almost all the liver samples suggestive of its worldwide distribution. The elevated residues detected in coastal species and low concentrations found in off-shore species indicated a high degree of butyltin contamination in coastal waters than in the open sea. Mammals inhabiting waters of developed nations were found to contain higher BT concentrations compared with those collected from the waters proximal to developing countries. These observations strongly suggest serious BT contamination in the waters of developed countries than in developing nations at present. Among the samples collected off Japanese coastal waters, lower BT concentrations were found in pinnipeds compared with the cetaceans, suggestive of a possible difference in degradation capacities and excretory moulting between these two groups of animals. The estimated concentration ratio of BT in the liver of killer whale fetus to its pregnant mother was relatively low (0.015), indicative that transplacental transfer of BTs from the mother to her fetus is a deal less. Among the BT breakdown products, DBT was predominant in most of the liver samples analyzed, followed by TBT and MBT.
KEY WORDS: Asia, butyltin, cetaceans, coastal species, contamination, dibutyltin, marine mammals, North Pacific, tributyltin.

Tarpley RJ, Wade TL, and Haubold EM. 1994. Toxicological Studies in Tissues of the Beluga Whale (*Delphinapterus leucas*) Along Northern Alaska With an Emphasis on Public Health Implications of Subsistence Utilization . Draft and Unpublished Interim Report, Department of Wildlife Management, North Slope Borough, Alaska :85 pp.
KEY WORDS: Alaska, beluga whale, blubber, cadmium, contamination, heavy metals, kidney, liver, marine mammals, mercury, muscle, organochlorine pesticides, PCBs, selenium.

Taruski AG, Olney CE, and Winn HE. 1975. Chlorinated Hydrocarbons in Cetaceans. J. Fish. Res. Board Can. 32:2205-9.
ABSTRACT: DDT, PCBs, chlordane, and dieldrin levels were measured in blubber of 18 cetaceans, including humpback, sperm, dense-beaked, Atlantic and Pacific pilot whales, and five species of dolphins. All had significant residue levels ranging from 1.1 to 1023 ppm DDT (wet weight basis), and 0.7-147 ppm PCBs. These levels are high enough to justify efforts to reduce PCB contamination of the oceans and a continued ban on widespread use of DDT.
KEY WORDS: cetaceans, chlorinated hydrocarbons, DDT, marine mammals, PCB.

Taylor DL, Schliebe S, and Metsker H. 1989. Contaminants in Blubber, Liver and Kidney Tissue of Pacific Walruses. Mar. Poll. Bull. 20(9):465-8.
ABSTRACT: The Pacific walrus, *Odobenus rosmarus divergens* Illiger, is associated

with sea ice for most of the year and extensive oil and gas development, zinc mining and increasing levels of fin and shell fish fishing occurs within the animals range. Walrus tissues were collected from harvested animals in the Pacific periodically from 1981 through 1984 for chemical analyses. Also, samples were collected from walruses in Soviet waters in December of 1984. The maximum concentration of lead was 1.2ppm and was present in 16% of all liver samples. Cadmium and mercury occurred in all liver and kidney samples with maximum concentrations of mercury 50ppm in the liver and 99ppm in the kidney. Selenium and mercury showed a significant correlation in liver ($r=0.51$, $n=65$). Blubber was analysed for the presence of 14 organochlorines with dieldrin and oxychlordanes being the only 2 detected. Eicosan and pristane also occurred in blubber tissues in concentration >1ppm. Field personnel reported no obvious health problems from examinations of harvested animals but results indicate that the cadmium in liver samples are approaching hazardous levels and the cadmium in kidneys exceed these levels 3 fold. Also, effects of the observed reduced blubber thickness on concentrations of organochlorines and hydrocarbons is unknown.
KEY WORDS: accumulation, *Odobenus rosmarus divergens*, organochlorines, Pacific, Pacific walrus, trace metals.

Teigen SW, Skaare JU, Bjørge A, Degre E, and Sand G. 1993. Mercury and Selenium in Harbor Porpoise (*Phocoena phocoena*) in Norwegian Waters. Env. Tox. Chem. 12:1251-9.
ABSTRACT: Concentrations of mercury and selenium have been determined in liver and kidney of 92 harbor porpoises (*Phocoena phocoena*) caught along the Norwegian coast. The hepatic and renal mercury concentrations ranged from 0.26 to 9.9 and 0.15 to 3.5 $g \cdot g^{-1}$, respectively, whereas the corresponding selenium concentrations ranged from 0.74 to 14.2 and 0.60 to 8.6 $g \cdot g^{-1}$, respectively. No significant differences in mean concentrations of mercury and selenium were found between females and males within the same age classes. However, the concentrations were positively correlated with age. The present results revealed a decreasing mercury concentration gradient from south to north along the Norwegian coast. In all age classes, a significant, positive correlation between the concentrations of mercury and selenium was found in both liver and kidney, the molar mercury-to-selenium ratio being 0.9660 and 0.2151, respectively. Implications of these findings for the biochemical and toxicological behavior of mercury and selenium in the harbor porpoise are considered.
KEY WORDS: harbor porpoise, mercury, selenium.

Thompson DR. 1990. Metal Levels in Marine Vertebrates. In: Furness, R.W. and P.S. Rainbow (Eds). Heavy Metals in the Marine Environment. CRC Press, Inc. Boca Raton, Florida.:143-82.
ABSTRACT: The distribution of heavy metals, such as cadmium, mercury and lead, occurring in the marine environment have been studied in recent years. This chapter discusses the levels of both non-essential and essential elements in marine vertebrates. In this review, marine vertebrates are treated in the following subgroups: marine fish; seabirds, excluding sea ducks and divers; and marine mammals. The metal concentration data which have been presented in the various tables are not intended to be a complete record of all work on each respective group for a particular metal; the data included in the tables are a representative selection of work, used here to illustrate particular trends or differences, other work being referred to in the text. Unless otherwise stated, the data

presented in the various tables refer to samples made up of both male and female individuals, and age/length data are included only when accumulation effects of a particular metal are likely to be a factor.
KEY WORDS: heavy metals, marine fish, marine mammals, sea birds, vertebrates.

Tilbury KL, Stein JE, Meador JP, Krone CA, and Chan S. 1997. Chemical Contaminants in Harbor Porpoise (*Phocoena phocoena*) from the North Atlantic Coast: Tissue Concentration and Intra- and Inter-Organ Distribution. Chemosphere 34(9/10):2159-81.
ABSTRACT: Concentrations of chlorinated hydrocarbons (CHs), such as polychlorinated biphenyls (PCBs), were measured in subsamples taken from different anatomical locations of blubber and liver of three apparently healthy harbor porpoises (*Phocoena phocoena*) incidentally caught in a gill-net fishery along the northwest Atlantic coast; selected elements (e.g. mercury) were measured in subsamples of liver. The vertical distribution (skin to muscle) of contaminants within blubber was also determined. Additionally, the concentrations of CHs and elements were determined in individual samples of brain, lung, kidney, and testis to assess how the disposition of toxic chemicals may be dependent on the physiological characteristics of a specific organ. Statistical analyses of the results showed that the anatomical location of the blubber or liver sample had no significant effect on concentrations of either CHs in blubber and liver, or of selected elements in liver. However, there were statistical differences between strata of blubber (skin to muscle) for the concentrations of CHs. As expected, the results showed that the CH concentrations, based on wet weight, were considerably higher in the blubber than in the other tissues; however, the concentrations of CHs in the different tissues were more comparable when values were based on total lipid weight with the exception of the brain where lipid normalized concentrations were lower than in all other tissues. This lower relative accumulation of lipophilic contaminants in the brain tissue may be due to the presence of the blood-brain barrier, or due to a lower proportion of neutral lipids, such as triglycerides, as analysis for percent lipid and for the proportion of specific lipid classes showed.
KEY WORDS: chlorinated hydrocarbons, contaminants, harbor porpoise, northwest Atlantic coast, *Phocoena phocoena*.

Twitchell K. 1991. The Not-So-Pristine Arctic: From Plankton to Polar Bears, the Food Chain is Contaminated by Global Pollution. Can. Geo.:53-60.
ABSTRACT: This report discusses the conditions of the Canadian Arctic over the past 20 years. Scientists have detected an increasing variety of toxic contaminants in the North including pesticides, chemicals and heavy metals. These chemicals are not only broken down at a lower rate because of the environmental conditions of the Arctic but are also found in animals, such as marine mammals, at the top of the food chain, a primary diet of the Inuit and other northerners. A look at how these contaminants and toxins are being introduced into such a secluded area and how they are effecting the Inuit, Broughton Islanders and the wildlife communities in that region. Previous studies on contaminants such as organochlorines, PCBs and DDTs and their effects on marine mammals are discussed. Scientists are trying to determine whether specific contaminants are increasing in the Arctic or not and pinpoint the sources of pollutants. Once that is understood, more research and action can be implemented to control the use of these pesticides and contaminants.

KEY WORDS: Arctic, global pollution, human consumption, marine mammals, marine organisms, organochlorines, toxic contaminants.

Van Bressem MF, Van Waerebeek K, Garcia-Godos A, Dekegel D, and Pastoret PP. 1994. Herpes-like Virus in Dusky Dolphins, *Lagenorhynchus obscurus*, from Coastal Peru. Mar. Mam. Sci. 41(3):354-9.
ABSTRACT: Herpesviruses have been described from a wide variety of animal species ranging from fishes to mammals, in which they can cause severe disease. The family Herpesviridae comprises three subfamilies: the Alpha-, Beta- and Gammaherpesvirinae. After infection, herpesviruses remain latent in their natural hosts. Periodically shedding can occur following reactivation, triggered by different factors including stress and viral or bacterial diseases. Many herpesviruses are highly host specific, while others may affect a wide range of species. Among marine mammals they have been reported in pinnipeds and cetaceans.
KEY WORDS: biological stress, disease detection, disease transmission, herpesvirus, *Lagenorhynchus obscurus,* lesions, marine mammals, Peru, viral diseases, viruses.

van de Ven WSM, Koeman JH, and Svenson A. 1979. Mercury and Selenium in Wild and Experimental Seals. Chemosphere 8:539-55.
ABSTRACT: This paper describes the tissue distribution of inorganic mercury, organic mercury and selenium in Dutch and British seals as well as in seals which were dosed with methylmercury under experimental conditions. In the experimental animals, a time-related increase of both mercury and selenium was found in liver and kidney after the administration of methylmercury, while in the other tissues examined, e.g. brain, thyroid, blood, only the concentrations of mercury increased. In the wild seals, it was also demonstrated that the selenium concentrations showed a positive correlation with the concentrations of mercury. Atomic ratios of mercury and selenium were close to one in the wild seals as was also found in previous studies. However, atomic ratios above one were found in seals fed additional methylmercury. *In vitro* studies with liver homogenates of seals did not provide evidence for the presence of a biochemical demethylation mechanism nor for any effect of selenium on the demethylation process.
KEY WORDS: inorganic mercury, marine mammals, organic mercury, seals, selenium.

Vandal GM, Fitzgerald WF, Boutron CF, and Candelone JP. 1993. Variations in Mercury Deposition to Antarctica Over the Past 34,000 Years. Nature 362:621-3.
ABSTRACT: Polar ice contains a valuable record of past atmospheric mercury deposition, which can provide information about both the natural biogeochemical cycling of this toxic trace metal and the impact of recent anthropogenic emissions. But existing studies of mercury in polar ice and snow cores suffer from sample contamination and inadequate analytical procedures. Here we report measurements of mercury concentrations spanning the past 34,000 years from the Dome C ice core, Antarctica, using the stringent trace-metal clean protocols developed by Patterson and co-workers. Although this record does not extend into the industrial period, it provides an important baseline for future attempts to identify anthropogenic mercury in Antarctic ice and snow. We find that mercury concentrations were strikingly elevated during the last glacial maximum (18,000 years ago), when oceanic productivity may have been higher than it is today. As oceanic mercury emission is correlated with productivity, we suggest that this

was the principal pre-industrial source of mercury to Antarctica; mercury concentrations in Antarctic ice might therefore serve as a palaeoproductivity indicator for the more distant past.
KEY WORDS: Antarctica, mercury deposition, palaeoproductivity indicator, polar ice.

Varanasi U, Stein JE, Reichert WL, Tilbury KL, Krahn MM, and Chan S. 1992. Chlorinated and Aromatic Hydrocarbons in Bottom Sediments, Fish and Marine Mammals in US Coastal Waters: Laboratory and Field Studies of Metabolism and Accumulation. In: C.H. Walker, and D.R. Livingstone (Eds.) Persistent Pollutants in Marine Ecosystems :115 pp.
ABSTRACT: This overview focuses on the uptake and metabolism of PCBs and AHs with respect to their bioaccumulation and tissue distribution in benthic invertebrates and fish exposed to an urban sediment in the laboratory, as well as in organisms sampled from urban waterways. Samples are selected from a database originating from long-term monitoring of chemical contaminants in benthic fish and sediments. The original works from which these data are selected for discussion herein include various statistical treatments to evaluate correlations among parameters of exposure and to determine the statistical significance of the findings. In this review we will cite some of these findings, but will not include entire data sets that were used for statistical analyses. Finally, some recent findings on both the levels and relative proportions (profiles) of organochlorines in marine mammals-pinnipeds and cetaceans- will be described in relation to our results on profiles of these compounds in fish and bottom sediments where these marine mammals may have fed during their seasonal migration.
KEY WORDS: aromatic hydrocarbons, bioaccumulation, chlorinated hydrocarbons, fish, marine mammals, organochlorines, overview, polychlorinated biphenyls.

Vetter W, Luckas B, and Oehme M. 1992. Isolation and Purification of the Two Main Toxaphene Congeners in Marine Organisms. Chemosphere 25(11):1643-52.
ABSTRACT: The two most abundant toxaphene congeners in marine mammals and fish were isolated from 3.5 kg seal blubber. In a first step the tissue was decomposed by perchloric/acetic acid followed by extraction with petroleum ether. After destruction of the fat matrix with sulphuric acid, further purification and separation from other organochlorines was performed by reversed phase high performance liquid chromatography (HPLC). Remaining arylic impurities were removed after nitration by an additional HPLC clean up step. The purity and identity of the isolated congeners were controlled by mass spectrometry using different ionisation methods. Quantification of the purified isomers was carried out by flame ionisation detection using structure-related compounds.
KEY WORDS: HPLC, marine fish, marine mammals, mass spectrometry, organochlorines, toxaphene congeners.

Wade TL, Chambers L, Gardinali PR, Sericano JL, and Jackson TJ. 1997. Toxaphene, PCB, DDT, and Chlordane Analyses of Beluga Whale Blubber. Chemosphere 34(5-7):1351-7.
ABSTRACT: Beluga whales bioaccumulate organochlorines from their environment. Blubber samples of Beluga Whales from Alaskas north coast contain organochlorines, including Toxaphene (polychlorinated camphenes) PCBs, DDTs, and chlordane. Toxaphene was the organochlorine pesticide found in the highest concentration in all samples with the exception of the 6 year old male where PCBs were highest. The source

of these organochlorines is likely global distillation from lower latitudes. Males had higher concentrations than females and the oldest male had higher concentration than the younger male. Females exhibit a decrease in concentrations with age. The fetus had about 10% higher concentrations for all organochlorines compared to the mother. Trans-placental transfer of organochlorines and lactation lower the contaminant concentration in females. Older females have lower contaminate concentrations likely due to continual reproductive success. Consumption of older males will expose humans to higher levels of organochlorines.
KEY WORDS: Alaska, beluga whale, chlordane, DDT, organochlorines, reproductive success, toxaphene, trans-placental transfer.

Wagemann R, and Stewart REA. 1994. Concentrations of Heavy Metals and Selenium in Tissues and Some Foods of Walrus (*Odobenus rosmarus rosmarus*) from the Eastern Canadian Arctic and Sub-Arctic, and Associations between Metals, Age, and Gender. Can. J. Fish. Aquat. Sci. 51:426-36.
ABSTRACT: Atlantic walrus *(Odobenus* rosmarus rosmarus) harvested at Igloolik and Hall Beach (Foxe Basin) and Inukjuak and Akulivik (eastern coast of Hudson Bay) and clams (*Mya truncata*) and cockles (*Serripes groenlandicus*) collected at Igloolik were analyzed for heavy metals and Se. Pb was high in walrus from both Hudson Bay and Foxe Basin compared with other marine mammals, but levels were higher in animals from Hudson Bay than Foxe Basin showing a geographic trend of increasing concentrations from north to south. In some tissues of clams, Pb was also high, up to 3 μg/g (wet weight). Hg levels in walrus were low compared with those in other Arctic marine mammals; in liver, Hg showed a geographic trend similar to Pb. Cd in liver and particularly in kidney of walrus was high compared with other Arctic marine mammals and was higher in those from Foxe Basin than Hudson Bay. Associations among metals and between Hg and Se in liver, Hg and Cd in liver, Hg and Cd with age in kidney, Cd with Zn in liver and kidney, and Hg and Se in liver with gender.
KEY WORDS: age, Atlantic walrus, gender, geographic trend, heavy metals, marine mammals, *Odobenus rosmarus rosmarus*, selenium.

Wagemann R, Snow NB, Lutz A, and Scott P. 1983. Heavy Metals in Tissues and Organs of the Narwhal (*Monodon monoceros*). Can. J. Fish. Aquat. Sci. 40(2):206-14.
ABSTRACT: Sixty narwhals (*Monodon monoceros*) were sampled in the vicinity of Pond Inlet, N.W.T., during the summer of 1978 and 1979. Concentrations of Pb, Cu, Cd, Hg, Se, As, and Zn were measured in liver, kidney, muscle, and blubber. All elements except As were lowest in concentration in the blubber and highest in kidney and liver; Cd and Zn were generally higher in kidney than in liver, while the converse was true for Pb, Cu, and Hg. Cadmium levels in liver and kidney had high interanimal variability but were generally higher than would be expected based on existing marine mammal Cd content data. Certain metals were correlated with animal size and sex. Mercury in kidney, muscle, and blubber and Cd in muscle appear to accumulate during growth. A number of interelement associations with extremely high probabilities were found: among them, that between Hg and Se and Cd and Zn in liver and kidney tissues. The latter association is thought to be related to the presence of metallothionein. The data presented are discussed in terms of what little is known of the biology of the narwhal and represent a baseline for a resource organism which is harvested in an area already subject to mining

activity, the level of which is due to increase in the future.
KEY WORDS: heavy metals, metallothionein, *Monodon monoceros*, narwhals, resource organism.

Wagemann R, Stewart REA, Beland P, and Desjardins C. 1990. Heavy Metals and Selenium in Tissues of Beluga Whales, *Delphinapterus leucas*, from the Canadian Arctic and the St. Lawrence Estuary. Can. Bull. Fish. Aquat. Sci. 224:191-206.
ABSTRACT: Samples of liver, kidney and muscle tissue from beluga (*Delphinapterus leucas*) from five locations across the Canadian Arctic and the St. Lawrence Estuary were analyzed for copper, zinc, cadmium, mercury, lead and selenium. The St. Lawrence Estuary beluga had significantly higher levels of lead, mercury, and selenium and significantly less cadmium than most Arctic whales. Mercury was positively associated with selenium and age in all animals, and cadmium in kidney was positively associated with selenium and age. Copper concentrations declined with age. Whales from some Arctic sites appeared to have higher levels of cadmium than from other Arctic sites.
KEY WORDS: beluga whales, Canadian Arctic, *Delphinapterus leucas*, heavy metals, selenium, St. Lawrence Estuary.

Wagemann R, Stewart REA, Lockhart WL, Stewart BE, and Povoledo M. 1988. Trace Metals and Methyl Mercury: Associations and Transfer in Harp Seal (*Phoca groenlandica*) Mothers and Their Pups. Mar. Mam. Sci. 4(4):339-55.
ABSTRACT: Milk samples from the stomachs of harp seal pups were analyzed for C, Zn, Se, Cd and Hg, as were liver, kidney, and muscle from mother-pup pairs. Tissues were also analysed for MeHg. Milk contained, in addition to essential trace metals, Cd and Hg (57 ng/g and 6.5 ng/g respectively). Pups had mercury in all three tissues. The percent methyl mercury in liver of pups was higher than in liver of others. Mercury in muscle was mostly methyl mercury in both mothers and pups. Total mercury in liver of mothers but not pups was correlated positively with selenium. Estimates of ingested mercury by pups indicated they had acquired most of their mercury during gestation. Although mothers had cadmium in liver and kidney, it was not detected in tissues of pups. Cadmium did not transfer across the placenta, while mercury did. Tissue concentrations of Cu and Zn were higher in pups than mothers. The presence of metallothionein in pup tissues was postulated. A strong positive correlation of copper and selenium between mothers and pups indicated transfer of these elements from mother to pup in direct proportion to their concentrations in maternal liver and kidney.
KEY WORDS: contaminants, harp seal, methyl mercury, milk, mother-pup pairs, *Phoca groenlandicus*, placental transfer, trace metals.

Waldichuk M. 1989. Arctic Contaminants. Mar. Poll. Bull. 20(10):532-3.
ABSTRACT: The Tadousac Forum was held on September 26-30, 1988 in Canada with participants including 30 researchers. Topics discussed were a review on the status of the St. Lawrence beluga whales, *Delphinapterus leucas*, and the development of an action plan to protect these animals. A tributary of the upper St. Lawrence estuary receives effluents from a number of industries at its head and belugas concentrate organochlorines and other contaminants in their blubber from these industries. The structure and evolution of the St. Lawrence stock must be better understood and its habitats properly documented. Other topics included representatives of socioeconomic and environmental

groups, industry, universities and government agencies planning to promote the survival of the belugas. Public education, pollution control and research were priorities discussed at the Forum. A newsletter, entitled Beluga, will also be published on a regular basis by the Department of Fisheries and Oceans.
KEY WORDS: action plan, beluga whale, *Delphinapterus leucas*, pollution control, St. Lawrence, Tadousac Forum.

Wallace SD, and Lavigne DM. 1992. A Review of Chemical Contaminants in Harp (*Phoca groenlandica*) and Hooded (*Cystophora cristata*) Seals of the Northwest Atlantic. International Marine Mammal Association, Inc., Technical Report No. 92-01 :64 pp.
ABSTRACT: We reviewed and summarized the available information on chemical contaminants in harp (*Phoca groenlandica*) and hooded (*Cystophora cristata*) seals of the Northwest Atlantic Ocean. Organic and inorganic contaminants have been analyzed in various tissues of both species over the past 25 years, although considerably more research has been conducted on harp seals. Organic contaminants detected in harp seals include: dichlorodiphenyltirchloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), 6,6-dithiobis-2-naphthalenol (DDD), dieldrin, chlordane, heptachlor epoxide (HE), hexachlorobenzene (HCB), toxaphene, dichlorvos, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Inorganic contaminants detected in harp seals include: mercury (Hg) and its organic metabolite methyl mercury (HgCH3), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), selenium (Se), cesium-137 (Cs137) and strontium-90 (Sr90). Contaminants detected in hooded seals include: the organic contaminants DDT, DDE, DDD, aldrin, dieldrin, heptachlor, heptachlor epoxide, lindane (g-HCB), PCBs and PAHs, and the inorganic contaminant mercury and its organic metabolite methyl mercury. Concentrations of total DDT (TDDT), dieldrin, hexachlorobenzene, toxaphene, PCBs, mercury and lead in certain harp seal tissues were found to equal or exceed Canada Health and Welfare Action Levels (ALs) for fish and fish products, as did concentrations of TDDT, PCBs and mercury in samples from hooded seals. Concentrations of TDDT, dieldrin and PCBs in harp seals and concentrations of TDDT and PCBs in hooded seals were found to equal of exceed Canada Health and Welfare Maximum Residue Limits (MRLs) for beef products. Several harp seal studies and a few hooded seal studies have investigated relationships between contaminant levels and various biological and physical parameters. Generally, the reported trends appear similar to those observed in other marine mammals. Contaminant levels are usually higher in adults than in juveniles and neonates. Organic and inorganic contaminants are transferred from mother to foetus and neonate during gestations and lactation, respectively, often reducing the concentrations of contaminants in sexually mature females. In contrast, males generally accumulate contaminants with age. Most organic contaminants are lipophilic (fat-loving) and accumulate primarily in the blubber whereas inorganic contaminants are found foremost in the liver. Of exception, cadmium, an inorganic contaminant, occurs primarily in the kidneys. Contaminants appear to be distributed evenly throughout the blubber of harp seals; a single sample may, therefore, be representative of blubber concentrations. It is unclear whether changes in body condition influence concentrations of organic contaminants in harp seal tissues. Harp seals sampled in the Gulf of St. Lawrence may carry significantly higher levels of organic contaminants than those sampled off Newfoundland. In the Gulf, levels of DDT and PCBs reportedly decreased in male harp seals from 1971 to 1982 and in neonates from 1971 to 1973,

suggesting that inputs of DDT and PCBs to the Gulf of St. Lawrence may have declined. In general, there is a paucity of research on most chemical contaminants in harp and hooded seals. Efforts have focused primarily on DDT, dieldrin, PCBs seals but those have yet to be investigated. Comparative analyses among existing studies must be interpreted with caution due to differences in sample collection and analytical techniques. Further, a lack of relevant biological information in some studies precludes such comparison. The available material is useful, nonetheless, for indicating the presence and absence of contaminants in specific tissues. Standardized techniques for analyzing chemical contaminants are necessary to establish realistic baseline conditions from which to monitor contaminant levels in harp and hooded seal populations in the future.
KEY WORDS: chemical contaminants, harp seal, hooded seal, Northwest Atlantic, organic and inorganic contaminants, review, standardized techniques .

Wania F, and Mackay D. 1993. Global Fractionation and Cold Condensation of Low Volatility Organochlorine Compounds in Polar Regions. Ambio 22(1):10-8.
ABSTRACT: Organochlorine chemicals, including chlorinated pesticides and polychlorinated biphenyls, are found at appreciable concentrations in the polar regions, presumably as a result of long range atmospheric transport. Concentration data in arctic and antarctic air, snow, atmospheric deposition, fish and seals, measured by various investigators, are compiled and interpreted to determine latitudinal and temporal trends. It is suggested that the often surprisingly high concentrations are explained in part by the temperate-dependent partitioning of these low volatility compounds. A process of global fractionation may be occurring in which organic compounds become latitudinally fractionated, condensing at different ambient temperatures dependent on their volatility. We suggest that compounds with vapor pressures in a certain low range may preferentially accumulate in polar regions. Possible adverse effects of these potentially toxic compounds on the indigenous population and on the arctic ecosystem are discussed. It is concluded that there is a need to control or even ban certain chemicals which have a tendency to fractionate into the polar ecosystems.
KEY WORDS: adverse effects, condensing, marine organisms, organochlorine compounds, polar regions.

Warburton J, and Seagars DJ. 1993. Metal Concentrations in Liver and Kidney Tissues of Pacific Walrus: continuation of a baseline study. United States Fish and Wildlife Service, Region 7, Alaska, Marine Mammals Management. Technical Report R7/MMM 93-1:23 pp.
ABSTRACT: The U.S. Fish and Wildlife Service continued a 1981-1984 baseline study (Taylor et al. 1989) in 1986-1989 to evaluate contaminant levels in tissues of Pacific walrus harvested in the spring by Alaskan Natives. Samples from 56 walrus (32 males, 24 females) were collected in the villages of Diomede (n=21), Gambell (n=31), and Savoonga (n=4). Analyses were completed for 23 metalloids were conducted on 50 kidneys and 53 livers. All samples were from adult walrus (ages 11-32 years, x=19). Analyses were completed for 23 elements; special focus was on arsenic, cadmium, lead, mercury, selenium, and zinc. All tissues and samples had these six elements in detectable quantities. Mean cadmium concentrations were not significantly higher than those previously reported for walrus. However, mean cadmium concentrations continue to exceed levels (13 ng/kg wet weight) thought by the Environmental Protection Agency (EPA) to interfere with organ function in some animals. A positive correlation between

cadmium and age was found in both liver and kidney. Male and female tissues significantly differed in mean concentrations of arsenic (liver and kidney) and selenium (liver). It is uncertain what these results mean to the health of walrus.
KEY WORDS: Alaska, contaminant levels, metalloids, *Odobenus rosmarus divergens*, Pacific walrus, trace metals.

Watson M, and Russel RG. 1986. Preliminary Assessment: Cadmium in Walrus Liver and Kidney/Human Consumption. Letters in 1986 From Regional Administrator Robie G. Russel, U.S. Environmental Protection Agency .
KEY WORDS: Alaska, cadmium, contamination, EPA, marine mammals, risk assessment.

Weis IM, and Muir DCG. 1997. Geographical Variation of Persistent Organochlorine Concentrations in Blubber of Ringed Seal (*Phoca hispida*) from the Canadian Arctic: Univariate and Multivariate Approaches. Env. Poll.
ABSTRACT: Geographical variation of organochlorine (OC) concentrations in ringed seal (*Phoca hispida*) in the Canadian Arctic was studied using univariate and multivariate statistical techniques. The dataset consisted of 80 individual OC components (58 PCB congeners plus DDT- and chlordane (CHL)-related compounds, toxaphene, hexachlorocyclohexanes (HCH), chlorobenzenes (Cbz), and dieldrin) determined in 221 ringed seal blubber samples from 13 locations throughout the Canadian Arctic from the period 1983 to 1989. Mean concentrations of the major OC groups in ringed seal blubber (PCBs, DDT, CHL and toxaphene), adjusted for the age and sex of the seals, showed few significant geographical differences. Principal components analysis was used to examine geographical trends. Significant differences in mean factor scores for three of four principal components were found between sampling locations. Locations in the western and high Arctic could be distinguished from those in Hudson Bay by highest scores along principal component two which was associated principally with Cbz. PCB congeners with six or more chlorine substitutions declined with increasing north latitude while more volatile OCs (Cbz, HCH, less chlorinated PCBs) increased in the proportion of total OCs with latitude. Proportions of less chlorinated PCBs also decreased with increasing longitude, while slopes of regressions for more highly chlorinated PCBs increased significantly. The results were generally consistent with the cold condensation hypothesis in increasing proportions of more volatile OCs with increasing latitude and distance from sources.
KEY WORDS: Canadian arctic, geographical variation, organic contaminants, PCBs, ringed seals (*Phoca hispida*).

Weiss LD. 1992. Comments Concerning Mercury Contamination of Arctic Seafood. Draft of Unpublished Paper. University of Alaska, Anchorage, Department of Sociology :1-15.
KEY WORDS: Alaska, contamination, heavy metals, marine mammals, mercury, seal, walrus, whale.

Wells DE, and Echarri I. 1992. Determination of Individual Chlorobiphenyls (CB's), Including Non-ortho, and Mono-ortho chloro Substituted CB's in Marine Mammals from Scottish Waters. International Journal of Environmental Analytical Chemistry 47:75-97.

Westgate AJ, Muir DCG, Gaskin DE, and Kingsley MCS. 1997. Concentrations and Accumulation Patterns of Organochlorine Contaminants in the Blubber of Harbour Porpoises, *Phocoena phocoena*, from the Coast of Newfoundland, the Gulf of St. Lawrence and the Bay of Fundy Gulf of Maine. Env. Poll. 95(1):105-19.

ABSTRACT: Concentrations of 99 organochlorine compounds were measured in the blubber of 196 harbour porpoises, *Phocoena phocoena*, killed in commercial gill net fisheries in the western North Atlantic. PCBs and chlorinated bornanes (CHB) were the dominant contaminants in all porpoises. Mean concentrations (with standard deviations) of PCBs and CHBs from the three regions were as follows:
Bay of Fundy/Gulf of Maine, PCB males 17.3 +/ 11.2 μg/g, PCB females 11.4 +/ 4.8 μg/g, CHB males 11.5 +/ 6.6 μg/g, CHB females 8.4 +/ 5.3 μg/g; Gulf of St. Lawrence, PCB males 10.6 +/ 5.4 μg/g, PCB females 7.2 +/ 3.9 μg/g, CHB males 14.1 +/ 8.8 μg/g, CHB females 9.0 +/ 6.3 μg/g, southeast Newfoundland, PCB males 5.2 +/ 2.5 μg/g, PCB females 5.5 +/ 4.4 μg/g, CHB males 7.0 +/ 2.2 μg/g, CHB females 5.5 +/ 3.0 μg/g. The relative composition of the major contaminant groups found in male and female harbour porpoise blubber from the three locations varied. In order of decreasing concentration, porpoises from Fundy/Maine had PCBs > CHB > DDT > chlordanes (CHL), whereas Gulf of St. Lawrence and Newfoundland porpoises had CHB > PCB > DDT > CHL. Significant increases with age were observed for most contaminants in male harbour porpoises, and significant decreases were observed in females. Females lose about 15% of their contaminant burden per birth. PCB and DDT levels in porpoises from the Bay of Fundy are significantly lower than those recorded in the 1970s.
KEY WORDS: Bay of Fundy, chlorinated bornanes, contaminants, Gulf of Maine, harbour porpoise, organochlorine, PCBs, *Phocoena phocoena*.

White RD, Hahn ME, Lockhart WL, and Stegeman JJ. 1994. Catalytic and Immunochemical Characterization of Hepatic Microsomal Cytochromes P450 in Beluga Whale (*Delphinapterus leucas*). Toxicol. Appl. Pharmacol. 126:45-57.

ABSTRACT: Understanding the effects of environmental contaminants on cetaceans and other marine mammals will require information in the biochemistry of xenobiotic metabolism in these species. We characterized the hepatic microsomal cytochrome P450 system in beluga whales (*Delphinapterus leucas*) from the Canadian Arctic. The content of native P450 averaged 0.203 and 0.319 nmol/mg microsomal protein, cytochrome b5 content averaged 0.199 and 0.236 nmol/mg, and rates of NADPH-cytochrome c reductase were 79 and 76 nmol/min/mg, for females and males respectively. Ethoxyresorufin O-deethylase (EROD), pentoxyresorufin O-dependentylase (PROD), and benzo[a]pyrene (BP) hydroxylase (AHH) activities were significantly greater in males than in females, and were highly correlated with one another (r^2 between 0.853 and 0.912). HPLC analysis of *in vitro* BP metabolites revealed benzo-ring (7,8- and 9,10) dihydrodiols, consistent with activation of this compound, as well as 4,5-dihydrodiol, 3-OH-, 7-OH-, and 9-OH-BP and 1,6- and 3,6-quinones. Estradiol 2-hydroxylase activity did not differ between sexes, and rates did not correlate with those of the other activities. Antibodies against scup P450B (an apparent teleost CYP2B) and rat CYP2B1 did not recognize proteins in beluga liver microsomes, but there was a protein detected by antibodies to PB-inducible rabbit CYP2B4. Antibodies to ethanol and ketone-inducible rat CYP2E1 reacted with two proteins in beluga liver microsomes. Antibodies specific to hydrocarbon-inducible CYP1A1 and/or CYP2E1 forms showed a single protein band, apparently more closely

related to CYP1A1. The content of CYP1A was fivefold greater in male than in female beluga. CYP1A content was highly correlated with EROD, PROD, and AHH activities, suggesting that this P450 form is a primary catalyst for these reactions in beluga. CYP1A content and activity were highly correlated with the concentrations in blubber of non-*ortho* and mono-*ortho* PCB congeners, compounds that induce CYP1A in other mammals. These results indicate that a CYP1A is a catalyst for the metabolism or aromatic hydrocarbon pollutants in the beluga whale, and strongly suggest that this protein is induced in these organisms by environmental contaminants, including PCBs. The results support the measurement of CYP1A expression as a biomarker of exposure to induces in marine mammals. The full functional and evolutionary relationships of beluga CYP1A and of beluga proteins immunologically related to other P450 forms are uncertain.

KEY WORDS: aromatic hydrocarbon pollutants, cetaceans, CYP1A, cytochrome P450 system, environmental contaminants, marine mammals.

Yamamoto Y, Honda K, Hidaka H, and Tatsukawa R. 1987. Tissue Distribution of Heavy Metals in Weddell Seals (*Leptonychotes weddelli*). Mar. Poll. Bull. 18(4):164-9.

ABSTRACT: Tissue distributions of heavy metals were investigated in the Weddell seal collected around Syowa Station, Antarctica. Generally, the metal concentrations were high in liver and kidney and low in brain, blubber and skin. Fe in blood and spleen, Zn in bone, and Mn and Cd in pancreas and gastrointestinal organs were also relatively high. Wide variations of the metal concentrations indifferent bones were also observed. The concentrations of Fe and Cd were positively correlated with moisture content of the bones, while those of Mn and Zn increased with increase of Ca content in the bone. Majority of the metal burden the body existed in muscle and liver. A relatively high burden of Cd was in the kidney. Based upon these results, the suitability of the tissues of a seal for ecological and toxicological comparisons is discussed.

KEY WORDS: Antarctica, heavy metals, *Leptonychotes weddelli*, toxicology, Weddell seal.

Yamamoto Y, Masuda M, Kazusaka A, Imaoka S, Funae Y, and Fujita S. 1995. Purification and Characterization of a Form of Cytochrome P450 From Bear Liver Microsomes. Biochem. Pharmacol. 49(7):965-70.

ABSTRACT: A form of P450 [termed p450(b-1)] was purified from male bear liver microsomes. The specific content of the final P450(b-1) preparation was 11.26 microsomal/mg protein, and recovery was 0.20% of the microsomal P450. The apparent molecular weight of P450(b-1) was 54,000. The absorption spectrum of P450(b-1) indicated that this protein was a low- and high-spin mixed type P450 in the oxidized form. The carbon monoxide complex of reduced P450(b-1) showed an absorption peak at 450.5nm. The reconstituted system containing P450(b-1) catalyzed the metabolism of animopyrine, benzo[a]pyrene, 7-ethoxycoumarin, imipramine and propranolol, of which P450(b-1) most strongly catalyzed aminopyrine N-demethylation and imipramine N-demethylation. The N-terminal amino acid sequence of P450(b-1) was highly homologous to that of P450-D1 from liver microsomes of male beagle dogs. P450(b-1) showed similarities in spectral properties, N-terminal amino acid sequence, and catalytic activities to rat P450 2C11. P450(b-1) was immunochemically cross-reactive with anti-P450 2C11 antibody and very weakly cross-reactive with anti-P450 2E1 antibody, but did

not react with anti P450 1A1 or 2B1 antibodies. On the basis of these results, we suggest that P450(b-1) belongs to the P450 2C subfamily.
KEY WORDS: absorption spectrum, bear, cytochrome P450, liver, microsomes, P450(b-1).

Yediler A, Panou A, and Schramel P. 1993. Heavy Metals in Hair Samples of the Mediterranean Monk Seal (*Monachus monachus*). Mar. Poll. Bull. 26(3):156-9.
ABSTRACT: For the first time the concentrations of copper, zinc, mercury, cadmium and lead in hair samples of the Mediterranean Monk Seal, one of the worlds rarest mammals, were determined. The hair samples were collected in the absence of the animals from six calves located in the Ionian Sea, Greece. Our data suggest the importance of hair analysis as a useful indicator for heavy metals in these rare animals.
KEY WORDS: Greece, heavy metals, Mediterranean Monk seal, *Monachus monachus*.

Zeisler R, Demiralp R, Koster BJ, Becker PR, Burow M, Ostapszuk P, and Wise SA. 1993. Determination of Inorganic Constituents in Marine Mammal Tissues. Sci. Total Environ. 139/140:365-86.
ABSTRACT: Analyses of selected tissues from the Alaska Marine Mammal Tissue Archival Project (AMMTAP) have provided comprehensive information related to levels of 36 trace elements and methyl-mercury in marine mammal tissues. Liver, kidney and muscle tissues from two northern fur seals, four ringed seals and six belukha whales were analyzed. The bulk of the investigated tissues and additional tissues from a total of 65 marine mammals are banked in the AMMTAP. The results are compared to literature values for trace element concentrations in marine mammal tissues and their relevance to environmental studies is discussed.
KEY WORDS: instrumental neutron activation analysis, marine mammals, specimen banking, trace elements.