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Chemical Contaminants in Gray Whales *(Eschrichtius robustus)* Stranded in Alaska, Washington, and California, U.S.A.

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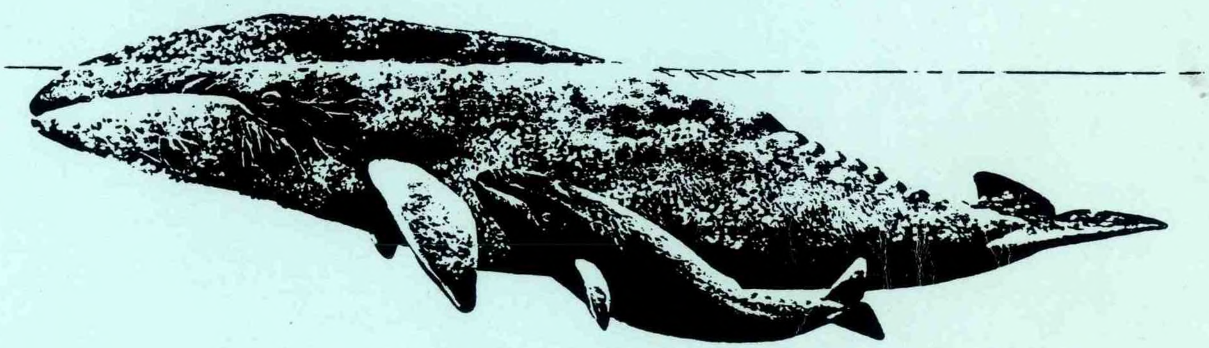

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Chemical Contaminants in Gray Whales *(Eschrichtius robustus)* Stranded in Alaska, Washington, and California, U.S.A.

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ABSTRACT

The concentrations of chlorinated hydrocarbons (CHs) such as polychlorinated biphenyls (PCBs), 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethanes (DDTs), 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethenes (DDEs), and chlordanes, and essential (e.g., zinc, selenium, copper) and toxic (e.g., mercury, lead) elements were measured in tissues and stomach contents from 22 gray whales (*Eschrichtius robustus*) stranded between 1988 and 1991. The stranding sites ranged from the relatively pristine areas of Kodiak Island, Alaska, to more urbanized areas in Puget Sound, Washington, and San Francisco Bay, California, with the majority of the sites on the Washington outer coast and in Puget Sound. The wide geographical distribution of the stranded whales allowed 1) an initial assessment of whether concentrations of chemical contaminants in these whales exhibited region-specific differences and 2) whether toxic chemicals that accumulate in sediments may have contributed to the mortality and stranding of gray whales near the more polluted urban areas. The concentrations of CHs in blubber (n = 22) showed no apparent significant differences among stranding sites. The summed concentrations of PCBs and DDEs in blubber ranged from 120 to 10,000 and 9 to 2,100 ppb (ng/g) wet weight, respectively. Additionally, no apparent significant differences were observed in the concentrations of CHs or selected elements in liver (n = 10) between whales stranded in Puget Sound and whales stranded at more pristine sites (Alaska, Washington outer coast and Strait of Juan de Fuca and Strait of Georgia). For example, the summed concentrations of PCBs and DDEs in liver ranged from 79 to 1,600 and 7 to 280 ppb, respectively, and the concentrations of the toxic elements, mercury and lead, ranged from 9 to 120 and 20 to 270 ppb, respectively. Analyses of stomach contents revealed low concentrations of CHs, but high concentrations (mean ± standard error, wet weight) of aluminum (1,700,000 ± 450,000 ppb), iron (320,000 ± 250,000 ppb), manganese (23,000 ± 15,000 ppb), and chromium (3,400 ± 1,300 ppb). Similar to concentrations in tissues, no significant differences were observed in concentrations of elements in stomach contents between whales stranded in Puget Sound and whales stranded at the more pristine sites. The relative

proportions of these generally nonanthropogenic elements in stomach contents of stranded whales were similar to the relative proportions in sediments, which is consistent with a geological source of these elements from the ingestion of sediment during feeding. Further, the concentrations of CHs in blubber of four whales repeatedly observed in Puget Sound for a time span of 33 to 67 days before they were found dead, were not significantly different from the concentrations in whales stranded on the Washington outer coast or Strait of Juan de Fuca. Thus, overall, the concentrations of anthropogenic chemicals in stranded gray whales showed little relation to the levels of chemical contaminants in sediment and biota in areas in proximity to the stranding sites. Further, the results showed that the concentrations of potentially toxic chemicals in tissues were relatively low when compared to the concentrations in tissues of marine mammals feeding on higher trophic level species, such as fish. The lack of data from apparently healthy gray whales, however, limits the assessment of whether the levels of anthropogenic contaminants found in tissues may have deleterious effects on the health of gray whales.

CONTENTS

PREFACE

Recent mass mortalities of marine mammals (e.g., bottlenose dolphin (*Tursiops truncatus*)) and the decline in populations of some species (e.g., Steller sea lion (*Eumetopias jubatus*)) have heightened the concern that environmental pollution may have a role in these events. To monitor exposure of marine mammal species to chemical contaminants and biological toxins and to collect additional biological data on the health of populations for the assessment of relationships between health and chemical contaminant exposure, the National Marine Fisheries Service (NMFS) has recently implemented the Marine Mammal Health and Stranding Response Program as authorized by the Ocean Act of 1992. The Environmental Conservation Division of the NMFS's Northwest Fisheries Science Center has the lead responsibility for the chemical contaminant monitoring component of the Program.

In the present study, the concentrations of selected chlorinated hydrocarbons (e.g., polychlorinated biphenyls, chlordanes, 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethanes (DDTs)), and certain essential (e.g., zinc, selenium, copper) and toxic (e.g., mercury, lead) elements were measured in tissues and stomach contents from gray whales (*Eschrichtius robustus*) that stranded at sites from Kodiak Island, Alaska, to San Francisco Bay, California. Gray whales make an annual round-trip migration between their breeding grounds in Mexican waters (along Baja California) and their feeding grounds in more northern waters from northern California to Alaska. Several of the gray whales sampled in this study were observed for prolonged periods in Puget Sound, Washington, where they later died. Gray whales feed primarily on benthic prey and use suction to engulf sediment and prey along the bottom, then filter out water and sediment through their baleen plates and ingest the remaining prey. This feeding method often results in the ingestion of sand and other bottom materials. Thus, the potential exists for exposure to sediment associated contaminants if gray whales feed in urban embayments of areas such as Puget Sound and San Francisco Bay. Accordingly, a concern was raised that such contaminant exposure could pose a threat to gray whales, which were recently removed from the List of

Endangered and Threatened Species. In response to this concern, NMFS initiated a study, the initial phase of which is presented here, to determine concentrations of a broad spectrum of chemical contaminants in tissues of gray whales stranded in both urban and nonurban areas along their migration route.

INTRODUCTION

Gray whale (*Eschrichtius robustus*) populations in the eastern North Pacific have increased at an annual rate of close to 3% since cessation of commercial exploitation and now number over 20,000 (Buckland et al. 1993, Reilly 1992), which is close to their historical population size. These marine mammals make an annual round-trip migration between their breeding grounds in Mexican waters (along Baja California) and their feeding grounds in more northern waters which range from northern California to Alaska (Rice and Wolman 1971). The southbound migration to the breeding grounds occurs in December and January along the West Coast and the northbound migration from February through May (Pike 1962). Gray whales generally fast during the breeding season in Mexico and during their migrations (Rice and Wolman 1971). Their body mass, overall fat content, girth, and blubber thickness are significantly lower during the northbound migration than during the southbound migration (Rice and Wolman 1971). Though the majority of gray whales feed in the Bering and Chukchi Seas in Alaska (Rice and Wolman 1971), some animals spend extended periods in the spring and summer feeding in coastal waters of California, Oregon, Washington, and British Columbia (Nerini 1984; Rice and Wolman 1971; Sumich 1984; Mallonee 1991; Patten and Samaras 1977; Darling 1984; Calambokidis et al. 1991, 1992). Up to 17 gray whales have been documented entering Puget Sound, Washington, in a year and some have spent up to 4 months in the area (Calambokidis et al. 1991, 1992, 1993). Some of these whales return in multiple years with two whales seen in Puget Sound in three consecutive years (Calambokidis et al. 1993). Further, between 1986 and 1991, 5 of 23 gray whales individually identified while alive in Puget Sound were subsequently found dead (Calambokidis et al. 1991, 1992). This high proportion of gray whale deaths may be due either to the whales entering Puget Sound in poor health or to the exposure to contaminants affecting the whales' health. There has not been adequate information to determine which factor explains the apparent high rate of gray whales deaths in Puget Sound.

Gray whales feed primarily on benthic prey, though feeding on pelagic prey has also been documented (Nerini 1984). The whales use suction to engulf sediments and prey from the bottom, then filter out water and sediment through their baleen plates and then ingest the remaining prey (Nerini 1984). This feeding method often results in the ingestion of sand and other bottom materials (Rice and Wolman 1971). The dominant prey of gray whales in feeding grounds in Alaska are ampeliscid amphipods (*Ampelisca macrocephala*) though a variety of other benthic prey items are also consumed (Rice and Wolman 1971, Nerini 1984). Recent studies of gray whale feeding in northern Puget Sound have revealed predation on ghost shrimp (*Callianassa californiensis*) (Weitkamp et al. 1992). Thus, the potential exists for exposure to sediment associated contaminants if gray whales feed in urban embayments.

There is increasing evidence that chemical pollution in coastal areas near urban centers may be responsible for a variety of deleterious biological effects in aquatic species, from liver tumors and reproductive dysfunction (infertility, spawning failure) in bottomfish that reside on contaminated sediments (Varanasi et al. 1992a) and altered immune function in juvenile salmon after only a brief residency in waters of polluted estuaries (Arkoosh et al. 1991) to reproductive dysfunction in marine mammals (DeLong et al. 1973, Duinker et al. 1979, Reijnders 1986). In Puget Sound, sediments in several urban and industrialized bays have elevated concentrations of anthropogenic chemicals (Krahn et al. 1986). Several field and laboratory studies have provided considerable evidence that anthropogenic compounds present in contaminated sediments are probable causative agents for hepatic tumors, related lesions, and reproductive dysfunction (Myers et al. 1987, Johnson et al. 1989, Casillas et al. 1991). Thus, the stranding of a gray whale near Port Angeles, Washington, on the Strait of Juan de Fuca in 1984 heightened public concern that chemical contaminants in sediments may have been responsible for its death. Chemical analyses, conducted in our laboratory, of tissues (liver, blubber, kidney, brain) and stomach contents of this whale revealed that the concentrations of chlorinated hydrocarbons (CHs) such as polychlorinated biphenyls (PCBs), 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethanes (DDTs), and a number of toxic elements (e.g., mercury and lead) were at levels well below toxicological concern and also well below the concentrations reported in most cetaceans and pinnipeds (Wagemann and Muir 1984). The only exception was that the concentrations of aluminum were relatively high in both the liver and brain of this gray whale. It was not possible, however, to compare the results with published values. There is little information on a broad spectrum of contaminants in gray whale tissues. Wolman and Wilson (1970) reported the presence of DDT and its metabolites in 6 of 23 gray whales taken off of San Francisco, California, during their northern and southern migrations. The concentrations of DDTs, 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethanes (DDDs), and 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethenes (DDEs) in blubber of these whales ranged from 22 to 360 ng/g wet weight, whereas it was reported that liver did not contain any of these chlorinated pesticides. Schaffer et al. (1984) reported concentrations of DDTs of 470 ng/g wet weight in blubber of a gray whale sampled in southern California in 1976. Total PCBs were not detected in the blubber (<230 ng/g wet weight).

In recent years, a number of gray whales have stranded in Puget Sound, as noted above, raising, once again, the concern that chemical pollution may have played a role in their deaths. However, demonstrating a causal link between pollution and strandings of marine mammals is particularly difficult because of inherent problems of availability of a sufficient number of tissue samples from both healthy and stranded animals and the inability to conduct controlled laboratory studies with live animals, particularly the large marine mammals. In addition to these sampling and experimental difficulties, the lack of detailed information on the biology and migration patterns of gray whales makes it very difficult to make a definitive assessment of the role of chemical pollution in their mortality. Nevertheless, the stranding of marine mammals and the increased public and scientific awareness of the potential impact of anthropogenic chemicals make it imperative that this issue be evaluated using the best possible strategy and state-of-the-art methodologies.

There has been considerable controversy around the role of pollutants in the deaths of gray whales in Puget Sound (Calambokidis 1992). Primary factors that have been cited to support a link to pollutants in these deaths has been the poor condition of the liver in some of these animals, the bottom-feeding behavior of this species, and the presence of contaminants in stomach contents and tissues (Fouty 1984). The basis for most of these conclusions has been challenged (Calambokidis 1992), but in the absence of better information, the question of the role of contaminants has largely been unresolved.

In the case of the recent gray whale strandings, tissue samples were collected from a total of 22 animals stranded at locations in Puget Sound, along the Strait of Juan de Fuca and Strait of Georgia, along the outer Washington Coast, on Kodiak Island, Alaska, and in San Francisco Bay, California, from 1988 through 1991. These sites represent a wide range of chemical contamination in bottom sediment, from the relatively pristine Alaskan waters to the urbanized areas of Puget Sound and San Francisco Bay (Varanasi et al. 1989a). We obtained stomach contents, liver, and blubber tissues from many of these animals with the assumption that the chemical profiles of CHs and essential and toxic elements in the stomach contents would reflect the most recent exposure, and the profiles in liver and blubber would reflect longer-term bioaccumulation of contaminants. The results from analyses of these samples should provide some insight into the relationship, if any, between chemical contamination at the site of stranding and concentrations and profiles of selected contaminants in various tissues. Moreover, to determine whether a particular group of contaminants preferentially accumulated in specific organs such as brain or kidney, these organs were also analyzed.

In the present study, we included measurements of CHs, selected toxic and essential elements (e.g., mercury, lead, zinc, copper) and polycyclic aromatic contaminants (PACs), which consisted primarily of polycyclic aromatic hydrocarbons and the dibenzothiophenes (Table 1). Because CHs such as PCBs, DDTs and chlordanes are among the most widespread and persistent chemical contaminants in the near coastal environment (Varanasi et al. 1992b) and because of their lipophilicity and resistance to metabolism, these pollutants tend to bioaccumulate in aquatic organisms, particularly in lipid-rich tissues of marine mammals. Several toxic and essential elements were measured because of their toxicological significance and their possible accumulation in certain tissues of marine mammals. For example, mercury is nephrotoxic in mammals and it has been suggested that aluminum may alter brain function (Goyer 1986). Additionally, because gray whales feed on benthic organisms, a feeding strategy unique among baleen whales, stomach contents were analyzed for CHs, selected toxic and essential elements, and PACs to provide insight into sources and levels of these compounds available through diet. Further, because of the extensive metabolism by mammals and fish of contaminants such as the polycyclic aromatic hydrocarbons (Varanasi et al. 1992b and 1989b, Lee et al. 1972, Stegeman et al. 1981), the parent compounds generally are not detected in tissues, but may be present in the stomach contents of bottom feeding gray whales. Stomach contents consist of benthic invertebrates that do not efficiently biotransform PACs, as well as incidentally ingested sediment; the sediments from many urban areas contain elevated levels of parent PACs (Varanasi et al. 1989a).

Overall, the findings from this study showed that the concentrations of chemical contaminants in tissues of bottom feeding gray whales were substantially lower than the concentrations measured in certain pinnipeds and toothed cetaceans (Odontoceti) whose diets consist largely of fish. The findings also showed that there were no statistically significant region-specific differences in tissue concentrations or profiles of CHs and selected elements.

METHODS

Sample Collection

Samples of blubber, liver, kidney, brain, and stomach contents were collected by various scientists (see Acknowledgments) from 22 dead, beached gray whales from March 1988 to June 1991 (Fig. 1, Table 2). It should be noted, however, that complete sets of tissue samples were not available for each whale. There was little information on the exact time of death; however, it was estimated that the time between death and necropsy ranged from days (1-2) to approximately 1 month; thus, the integrity of the gray whale tissue samples was poor in some cases due to the extended time between death and sampling. Five whales were stranded in the Puget Sound area, three on the Washington coast along the Strait of Juan de Fuca, one at Point Roberts along the Strait of Georgia, seven were stranded at sites along the Washington outer coast, four in San Francisco Bay, and two in Alaska. Fourteen of the whales were males and six were females; information on the sex of the Alaskan whales was not available. The ages of the whales were not determined. Twenty of the whales were measured and lengths ranged from 790 cm to 1,300 cm (Table 2).

More detailed biological information is available for 8 of the animals (CRC 334, CRC 397, CRC 398, CRC 401, CRC 395, CRC 402, CRC 332, CRC 337) than for the other 14. When considering this subset of eight whales, the sampling of all but one falls within the time period during or following the northbound migration. The single exception was whale CRC 395 sampled on 10 February 1991, which had been dead for several weeks, and had died during the period of the southbound migration. Four of these eight animals (CRC 334, CRC 397, CRC 398, CRC 401) had been individually identified while alive in Puget Sound using photographs of natural markings. They were first seen alive from 33 to 67 days prior to when they were found dead and were seen from 1 to 14 times while alive. All four were observed engaged in foraging behavior during one or more of these sightings. This technique of identifying and tracking gray whales has been used previously in biological studies of gray whales (Darling 1984, Calambokidis et al. 1991).

Analytical Methodologies

Chlorinated Hydrocarbons and Polycyclic Aromatic Contaminants

The analytical methodologies and quality assurance procedures for CHs and PACs were those used in the National Benthic Surveillance Project of NOAA's National Status and Trends Program (Krahn et al. 1988), except that the procedure for these analytes was modified to facilitate removal of interfering lipids, especially in blubber tissue. Briefly, tissue (1-3 g) and stomach contents (1-5 g) were macerated with sodium sulfate and methylene chloride. The methylene chloride extract was filtered through a column of silica gel and alumina, and the extract concentrated for further cleanup. The cleanup was done using size exclusion chromatography with high performance liquid chromatography (HPLC) (flow rate of 5 mL/min). A methylene chloride fraction containing the CHs and PACs was collected and then exchanged into hexane as the volume was reduced by evaporation to approximately 1 mL. The extracts were analyzed by capillary column gas chromatography (GC) with an electron capture detector for CHs. The PACs were determined by GC/mass spectrophotometry (MS) quantitation as outlined by Burrows et al. (1990). Chlorinated hydrocarbon peak identifications were confirmed on selected samples using GC/MS with selected ion monitoring.

Toxic and Essential Elements

The concentrations of 16 elements (Table 1) were determined using analytical methodologies and quality control procedures similar to those used in the National Benthic Surveillance Project of NOAA's National Status and Trends Program (Varanasi et al. 1989a). Briefly, thawed tissue (1.0-1.8 g) of liver, kidney, brain, and stomach contents was digested with 10 mL of concentrated ultra pure nitric acid for 2 hours at room temperature and subsequently heated in a microwave oven in a sealed Teflon bomb. The digestates were diluted with deionized water and the concentrations of elements were determined by atomic absorption spectrophotometry (mercury, arsenic, selenium, lead, iron, chromium, manganese, nickel, tin, silver) and inductively coupled argon plasma emission spectroscopy (copper, aluminum, zinc, cadmium, barium, strontium). In addition, the percent dry weight of the samples was determined by drying approximately 2 g of tissue in an oven (85°C) for 24 hours. After cooling the sample, the percent dry weight was calculated by dividing the weight of the dried tissue by the original wet sample weight and multiplying by 100.

Percent Lipid

To determine extractable lipids, an aliquot of the initial methylene chloride extract of tissue was filtered through filter paper containing approximately 5 g of diatomaceous earth as a filtering aid, and the solvent was removed from each sample using a rotary evaporator. After the solvent was removed, the mass of lipid was determined. The percent lipid was calculated by dividing the mass of lipid by the original sample wet weight and multiplying by 100. Using sea lion blubber (n = 5) and liver (n = 5) samples as test material, this procedure yielded results for total lipids comparable to those obtained using the method of Hanson and Olley (1963), a modification of the Bligh and Dyer (1959) method. The percent total lipids in the sea lion blubber determined by our method and the Hanson and Olley method were 84 ± 0.7% and 80 ± 2.2%, respectively, and for the sea lion liver were 2.7 ± 0.1% and 2.2 ± 0.2%, respectively.

Many studies of marine mammals report tissue concentrations of chemical contaminants on a wet weight basis, although the water content of tissues is highly variable and thus limits intertissue and interanimal comparisons. Herein, we discuss the data using the wet weight convention to compare to other literature values; however, percent lipid was determined for each sample and is reported in Appendix A. In addition, differences among studies in analytical methods and quality assurance measures make it difficult to rigorously compare contaminant concentrations in many cases.

Quality Assurance Measures for Toxic and Essential Elements, Chlorinated Hydrocarbons, and Polycyclic Aromatic Contaminants

Quality control procedures included the use of standard reference materials (SRMs) and certified reference materials (CRMs), which allowed an evaluation of the accuracy of the analytical methods (Tables 3 and 4). In summary, the grand mean recoveries (± standard deviation) for selected analytes were 85 ± 35% for CHs and 110 ± 45% for the PACs, and duplicate analyses of four gray whale samples agreed within ± 12%. The recoveries were calculated from the mean recoveries for certain analytes in SRM 1974, which was analyzed in the present study (CHs, n = 6; PACs, n = 2), and from previous analyses of SRM 1974 (CHs, n = 15; PACs, n = 103 for parent compounds and n = 88 for alkylated PACs). The concentrations (wet weight) of CHs and PACs in the method blanks (n = 6) analyzed with the samples were low and near the limit of detection (CHs: 0.2-1 ng/g, PACs: 0.5-2 ng/g).

The mean recovery of toxic and essential elements from the CRMs was 103 ± 64% (n = 29), and the analyses of replicate CRMs (n = 113) agreed within ± 29%.

Statistical Methodology

The data on chemical concentrations were analyzed by one-way or multi-way analysis of variance (ANOVA), with the factors being site of stranding, sex of the animal, and the year of stranding when appropriate. The statistical analyses were somewhat limited by the availability of samples; for example, blubber was available from all 22 animals, but liver was collected from only 10 animals and the sex of 2 whales was unknown. Further, the data for organic contaminants and essential and toxic elements were log transformed (log (x + 1)) to reduce deviations from normality. The results of the statistical analyses were very similar whether concentrations were expressed on a wet weight, lipid normalized weight or dry weight basis, thus only the results for the analyses using concentrations based on wet weight are discussed in detail.

RESULTS AND DISCUSSION

Percent Lipid

Lipid content of all tissue samples was measured because many of the anthropogenic contaminants measured in this study are lipophilic compounds. Blubber tissue generally has high lipid content in most marine mammals; the lipid content of blubber of many marine mammals is often found to be between 60% and nearly 100% (Aguilar 1985, Martineau et al. 1987, Geraci 1989, Henry and Best 1983). However, for most of the whales sampled in this study, the lipid content in blubber was relatively low, ranging from less than 1% to only 16%, with the exception of CRC 395 that had over 70%.

The low lipid content of these whales can potentially be attributed to three factors: 1) leaching of oil from the tissues after death, 2) poor nutritional condition because of fasting during the winter breeding season, and 3) poor nutritional condition due to ill health or other factors. Though some leaching of oil from tissues may have occurred, it appears unlikely that this could have accounted for the low lipid contents observed. All of the animals sampled were still intact and did not have visible oil leaching from the areas where the tissues were sampled.

Additionally, the most decomposed animal examined (CRC 395) had the highest lipid content. Part of the reason for the low lipid content is likely a result of the postbreeding season timing of the deaths. The only whale sampled that had died prior to the breeding season (CRC 395) was the only whale with a high lipid content in the blubber (70%). This individual was sampled in February and was very decomposed suggesting it had probably been dead at least a month. This finding, in addition to the fact that CRC 395 was sampled earlier than the other whales, would indicate that its death occurred during the period of the southbound migration from the feeding to the breeding grounds. Rice and Wolman (1971) report that northbound migrating whales (postbreeding season) have decreased weights, girths, blubber thicknesses, and oil content compared to southbound migrants (postfeeding season).

The lipid content of blubber from most of the whales sampled is lower than what would be expected as a result of their seasonal status alone. The difference in overall body oil yield of northbound and southbound migrants reported by Rice and Wolman (1971) was small (38.1% oil versus 39.6% oil, respectively). The overall percent oil in the body they reported for northbound migrants was much higher than the lipid content we found in the blubber of these animals. The low lipid content in the sampled whales appears to have likely been the result of poor nutritional condition from other than just the postbreeding season timing. It is difficult to verify the poor nutritional status of these animals from the gross examinations. Some animals showed below normal girths and blubber thicknesses (J. Calambokidis, pers. commun., June 1992). Blubber thickness, however, is a poor indicator of nutritional status in gray whales (Rice and Wolman 1971), with a thick fibrous layer remaining even in whales with no lipids. The girth of decomposing whales also could not reliably be used because of potential distortion due to bloating.

Chlorinated Hydrocarbons

The results show that all whales contained detectable levels of CHs in most tissues (Table 5 and Appendix A); however, the summed concentrations of CHs in blubber, liver, brain, and stomach contents of animals were generally less than 5,000 ng/g wet weight (parts per billion) with a high concentration of 20,000 ng/g wet weight in blubber of a whale (GLR 101) stranded along the Strait of Juan de Fuca (Fig. 1). The relatively low concentrations of lipophilic CHs in most of the whales may be related to the low lipid content in analyzed tissues. However, we found that the whale (CRC 395) having the highest lipid content in blubber did not have exceptionally or proportionately higher concentrations of these anthropogenic compounds. Moreover, whether the data on concentrations of CHs were based on wet weight or lipid content, the relationships with respect to contaminant concentrations did not change significantly or alter any of the conclusions with regard to region-specific differences in contaminant concentrations.

Blubber, liver, brain, and stomach contents were available from one whale (CRC 334, Hartstene Island). The highest summed concentrations (wet weight) of PCBs, DDTs, and chlordanes, and of dieldrin and hexachlorobenzene were observed in blubber and following in descending order were the concentrations in liver, brain, and stomach contents. This order does not strictly parallel the order of the total lipid content among the tissues and stomach contents; thus, the proportion of specific lipids (e.g., triglycerides and nonesterified fatty acids) in each compartment may better correlate with the concentrations of these lipophilic CHs in tissues and stomach contents.

The summed concentrations of PCBs were higher than other CHs, including DDT and its derivatives, in both blubber and liver tissues (Table 5) regardless of the site of the stranding, whereas the summed concentrations of DDT and its derivatives were generally higher than other chlorinated pesticides, such as the summed concentrations of chlordanes (Table 1). The same relationship between summed concentrations of PCBs and pesticides was observed in brain tissue obtained from whale CRC 334.

Information is not available on the levels of CHs in either sediment, invertebrates, or fish from the exact locations where the whales stranded. However, for Puget Sound in general, the range in summed concentrations of CHs in livers of adult English sole (*Pleuronectes vetulus*) is

200 to 14,000 ng/g (wet weight), with the lowest values for sole from relatively uncontaminated nonurban areas and highest values for areas such as the urban Duwamish Waterway (Johnson et al. 1988). Thus, the summed concentrations of CHs (110 to 2,500 ng/g) in these whale livers were comparable to those measured in livers of adult English sole from areas of relatively low contamination. In addition, in the San Francisco area where four of the whales stranded, the range of CHs in livers of starry flounder (*Platichthys stellatus*) and white croaker (*Genyonemus lineatus*) is 990 to 2,400 ng/g wet weight (Varanasi et al. 1989a) and the summed concentration of CHs (190 ng/g) in the one liver sample obtained from a whale stranded in San Francisco Bay was comparable to the values for fish livers from relatively uncontaminated sites.

A comparison of summed concentrations of PCBs and DDTs in tissues from these stranded gray whales to the values for baleen whales from other studies (Wagemann and Muir 1984), shows that the gray whales from this study had comparable or lower concentrations (wet weight) of these contaminants. For example, the ranges in summed concentrations of PCBs and DDTs in blubber of humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), and minke (*Balaenoptera acutorostrata*) whales were less than 10 to 7,000 and less than 10 to 23,000 ng/g wet weight, respectively, whereas the ranges in summed concentrations of PCBs in blubber of gray whale in the present study were 120 to 10,000 ng/g wet weight. In contrast, summed concentrations of PCBs and DDEs (major metabolite of DDTs) in toothed species, such as killer whales (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), range from 150 to 250,000 ng/g wet weight, and 550 to 640,000 ng/g wet weight, respectively (Calambokidis et al. 1984). The lower concentrations of these pollutants in baleen whales is consistent with the gray whales' primary food source being invertebrates which is in contrast to predatory seals, porpoises, and toothed whales (e.g., killer whales) which feed on organisms higher in the food chain, such as fish and other marine mammals.

Polycyclic Aromatic Contaminants

As discussed above, the extensive metabolism of PACs by marine mammals makes it nearly impossible to quantitatively assess exposure of these animals to PACs, which are widespread and toxicologically significant environmental pollutants (Varanasi et al. 1989b). Hence, in the present study, the only assessment of PAC exposure was by measurement of PACs in stomach contents, which contain sediment and also contain invertebrates that generally metabolize PACs much less than do mammals. The concentrations (wet weight) of PACs (Table 1, Appendix B) in stomach contents, which were available from eight of the whales sampled, ranged from 7 to 2,100 ng/g, with a mean value of 440 ng/g (Table 6). For Puget Sound, the range of concentrations (wet weight) of PACs in sediment is approximately 4 to 3,000 ng/g, with PACs in stomach contents of benthic fish ranging from 29 to 14,000 ng/g (Varanasi et al. 1989a).

In the future, the assessment of exposure to PACs can potentially be enhanced by the application of techniques developed for fish that measure metabolites of PACs in bile (Krahn et al. 1986) and tissues (Krone et al. 1992) and metabolites bound to hepatic DNA (i.e., DNA-xenobiotic adducts). Application of these techniques to marine mammal tissues and bile, however, is hampered by the often poor quality of the samples obtained and the absence of gall bladders in many marine mammals (e.g., cetaceans). For example, levels of DNA-xenobiotic adducts (Varanasi et al. 1989a) which represent the binding of potentially carcinogenic PACs to DNA may be a useful indicator of exposure to PACs, but only samples collected from tissues that have undergone minimal autolysis can be analyzed.

Toxic and Essential Elements

In the present study, the concentrations of 16 elements in liver, kidney, and stomach contents of whales stranded in all areas were generally low (Table 7). The only elements in stomach contents for which relatively elevated concentrations (wet weight) were found were as follows: aluminum (190,000 to 3,400,000 ng/g, n = 8); manganese (5,100 to 54,000 ng/g, n = 3), iron (5,800 to 810,000 ng/g, n = 3), chromium (360 to 11,000 ng/g, n = 8), and barium (310 to 24,000 ng/g, n = 5). Elevated concentrations of aluminum were also found in stomach contents of the whale stranded near Port Angeles in 1984. The mean concentration (± SE) of aluminum in stomach contents of these whales (n = 8) was 1,700,000 ± 450,000 ng/g wet weight, which is equivalent to 1.7% by weight with the highest value being 3.4%. These values are comparable to the concentration (4 to 9%) of aluminum found in marine sediments (Cerundolo et al. 1988 and Loreti 1988). Further, the high concentrations of aluminum in the stomach contents of these eight whales were also accompanied by correspondingly elevated values for iron and chromium (Table 7). Moreover, the mean ratios of the concentrations of iron and chromium to aluminum in stomach contents were comparable to the ratios in sediment and suspended particulate matter (Table 8). Thus, the findings of high concentrations of aluminum, chromium, and iron in stomach contents are consistent with ingestion of sediment in the natural feeding process of gray whales (Nerini 1984).

The high concentrations of aluminum in the stomach contents of the gray whales were accompanied by relatively high concentrations in liver and brain. In contrast to aluminum, barium, which was found in high concentrations in stomach contents, was not elevated in liver or kidney, indicating lower bioavailability of this element. Evaluating whether the concentrations of aluminum in tissues of gray whales are comparable to other marine mammals is not possible, because data on concentrations of aluminum in tissues of other marine mammals species are essentially nonexistent. However, the aluminum concentrations (2,300 ng/g) in brain of a gray whale in the present study and in the gray whale stranded in 1984 (8,800 ng/g) are within the range for some terrestrial mammals. For example, one review study (NRC 1980) listed the normal (control) concentrations (wet weight basis) of aluminum in the brain of rats as 7,100 ng/g, in cattle as 6,400 ng/g, and in sheep as 4,500 ng/g. These species may receive high concentrations of aluminum in their diet and hence their normal tissue burden may be higher than other species. Other control values of aluminum in various tissues for these species are 120 to 15,000 ng/g (liver) and 2,700 to 8,600 ng/g (kidney). These results were from toxicity studies in which aluminum was administered at dosages of 1,200,000 to 2,800,000 ng/g in water or food (NRC 1980). No effects were observed in cows and sheep fed these dosages of aluminum for 84 and 77 days, respectively. The range in control levels of aluminum indicates a broad range in the tolerance to aluminum in mammals, and hence demonstrates the importance of comparing concentrations for stranded animals to values in apparently healthy gray whales. These results, together with the fact that gray whales ingest sediment as part of feeding, would suggest that the concentrations of aluminum in tissues of gray whales reported here are within the normal physiological range. This can be confirmed, however, only by measuring tissue concentrations of aluminum in healthy gray whales.

The highest concentrations of mercury in livers were observed in the whales stranded on Hartstene Island (CRC 334) in south Puget Sound and near Lyre River (GLR 101) on the Strait of Juan de Fuca (100 ng/g and 120 ng/g wet weight, respectively). The mean concentrations (± SE) (wet weight) of mercury in liver and kidney (56 ± 12 ng/g, n = 10 and 34 ± 6 ng/g, n = 10, respectively) of the gray whales sampled in this study were relatively low when compared to the data for other cetaceans (Wagemann and Muir 1984). For example, the range of concentrations of mercury in liver of minke whales, a baleen whale, were found to range from 61 to 390 ng/g wet weight (Honda et al. 1987), while the range in mean concentrations of mercury in liver of porpoises and narwhal (*Monodon monoceros*) from several studies was 700 to 31,000 and in kidney 680 to 3,600 ng/g wet weight (Wagemann and Muir 1984). However, the range (nondetectable to 500 ng/g) of concentrations of mercury in the stomach contents of gray whales were within the range of concentrations (20 to 1,700 ng/g) found in stomach contents of porpoises and seals (Fujise et al. 1988 and Yamamota et al. 1987). As noted above, gray whales feed on benthic invertebrates and in the process ingest sediment that can be contaminated with toxic elements such as mercury. In contrast, porpoises and seals feed on higher trophic level organisms and would not ingest much sediment during feeding. Thus, the lower concentrations of mercury in gray whale liver and kidney compared to porpoises and seals would appear to indicate that mercury associated with sediment was not readily bioaccumulated by gray whales.

The concentrations of nickel, copper, zinc, cadmium, and lead in liver and kidney (Table 7) were similar among gray whales from different regions. Additionally, the concentrations of these elements in gray whales were comparable to the concentrations in liver of minke whales harvested between 1980 and 1985 (n = 135) in Antarctica (Honda et al. 1987) where the concentrations (wet weight) of nickel, copper, zinc, cadmium, and lead ranged from 20 to 430 ng/g, 6,900 to 25,500 ng/g, 74,300 to 175,000 ng/g, 6,600 to 100,000 ng/g, and 80 to 1,900 ng/g, respectively. Further, several other elements were present at low concentrations in the gray whales in this study. For example, the mean concentrations of silver and tin in liver and kidney were less than 40 ng/g wet weight, while the mean concentrations of selenium in liver and kidney were less than or equal to 2,000 ng/g wet weight. The concentrations of selenium reported (Wagemann et al. 1983) for narwhal liver and kidney (4,000 ± 1,800 and 3,100 ± 850 ng/g wet weight, respectively) are slightly greater than the concentrations of selenium in these stranded gray whales (Table 7).

Regional Patterns in Contaminant Profiles

Analysis of variance was used to assess if there were significant differences in concentrations of CHs, PACs, or elements in animals from different regions. A summary of the statistical analyses for selected CHs and elements is given in Tables 9 and 10. First, the data for all tissues and CH analytes were analyzed for region-specific differences without controlling for either sex of the animal or year of sampling; subsequently, a three-way ANOVA was performed for blubber, which was sampled from all animals, to determine if there were region, sex, or year specific effects. While controlling for the variances of sex and year of stranding, there were no significant regional differences in the concentrations of CHs in blubber (wet weight or lipid normalized basis) in these gray whales (Table 8). These results are consistent with the concentrations of CHs in blubber, reflecting more chronic exposure rather than relatively recent exposure, even if it is assumed that animals were feeding actively at the site where they were stranded.

The concentrations of CHs (Table 5) and elements (Table 7) in liver of whales from Puget Sound were compared to the concentrations in whales from the other four areas combined because only a small number of liver samples (10) was available. The statistical analyses revealed no site differences for any of the analytes. Further, no significant differences in concentrations of CHs, PACs, or elements were found for stomach contents of animals from Puget Sound as compared to those from whales from all other sites combined, excluding whales from California for which no stomach content samples were obtained. The only exception was the finding of a significantly higher concentration of higher molecular weight PACs (Table 6) in stomach contents of whales from Puget Sound, which has several urbanized areas with high concentrations of sediment-associated PACs, as compared to whales from other sites. However, because no significant differences were found in concentrations of other anthropogenic contaminants (i.e., CHs) in stomach contents of these animals, which can contain large amounts of sediment, and because only a portion of sediment-associated PACs is known to be bioavailable (Varanasi et al. 1985, Farrington et al. 1983), the significance of higher levels of PACs in stomach contents of these animals is not known. It becomes important, therefore, that methodologies (DNA-xenobiotic adducts or PAC metabolites in tissues and bile) for measuring the level of exposure to PACs need to be validated for use in stranded marine mammals to assess PAC exposure. However, currently these biochemical measurements require relatively fresh tissue samples, thus complicating the task of assessing PAC exposure in stranded animals that have been dead for various periods of time and are exhibiting tissue autolysis.

Data on concentrations of a number of elements in liver, kidney, and stomach contents were also statistically evaluated (Table 10) to determine if there were significant differences between the concentrations for animals from Puget Sound in comparison to the values for whales from the Washington outer coast, Strait of Juan de Fuca and Strait of Georgia treated as a single group. No significant differences attributable to region of stranding were observed for any of these elements. These findings demonstrate that neither longer term exposure as reflected by concentrations in liver and kidney, nor short-term exposure, as reflected by concentrations of these elements in stomach contents, showed any regional specificity for whales that were stranded in Puget Sound as compared to those that stranded at other sites in Washington waters. Additionally, the finding of no significant stranding site related difference in concentrations of aluminum is consistent with a geological rather than anthropogenic origin of aluminum in stomach contents and tissues of gray whales, as discussed above.

A further assessment of whether whales spending time in more urban areas is related to tissue levels of chemical contaminants could be assessed for a subgroup of whales stranded in Puget Sound (Table 11). These four whales (CRC 334, CRC 397, CRC 398, CRC 401) were observed in Puget Sound from 33 to 67 days before they died, and all were observed exhibiting foraging behavior one or more times. One-way ANOVA of the concentrations of CHs in blubber of these four whales showed no significant difference in concentrations of CHs from the concentrations in gray whales stranded on the Washington outer coast or in the Strait of Juan de Fuca. These findings further support the conclusion that the concentrations of CHs in tissues of gray whales do not show a clear association to the environmental chemistry of areas in proximity to the stranding sites.

Although the benthic feeding strategy of gray whales that is unique among the baleen whales would suggest them as a sentinel species of environmental quality in specific regions, the present findings, the whales' extensive migrations, and their variable periods of fasting are factors that appear to limit their use in this regard. Recent studies on the biology of gray whales in Puget Sound have revealed that some individuals return to feed for extended periods in the same areas (Calambokidis et al. 1992, 1993). In 1992 for example, four gray whales that were observed feeding in Puget Sound were individuals that were returning for at least their second or third consecutive year (Calambokidis et al. 1993). So far none of the animals that has died and been examined has been any of the individuals known to have returned multiple years to Puget Sound. The relatively territorial marine mammals, such as harbor porpoises or harbor seals (*Phoca vitulina*), may be more appropriate as sentinel organisms in assessing regional differences in marine environmental quality. For example, a recent study (Calambokidis and

Barlow 1991) with harbor porpoises showed that the ratios of the concentrations of PCBs to DDEs in blubber were significantly different among porpoises from southern California (0.36 ± 0.03), Oregon (0.53 ± 0.06), and Washington (1.22 ± 0.17). In southern California, the levels of DDE in sediment are higher than in sediments from sites in Washington or Oregon (Varanasi et al. 1989a). In the present study, the mean PCB/DDE ratio in blubber of gray whales from Washington waters (6.4 ± 0.6) was very similar to that for gray whales from San Francisco Bay (5.4 ± 0.99), while the ratios in blubber of the two gray whales from Alaska were 6.0 and 16.7, thus indicating no marked regional differences. Further, the PCB/DDE ratio in gray whale blubber was markedly higher than in harbor porpoise from the Washington coast, indicating relatively lower concentrations of DDE in gray whales than in porpoise.

Sex-related Differences in Contaminant Profiles

Statistical analyses of concentrations of CHs in blubber, which was the only tissue available for all 22 animals, revealed no marked consistent difference between sexes in the concentration of persistent CH contaminants. The results showed significant differences ($P < 0.05$) between males and females only for mirex, and for the summed concentrations of DDEs and DDTs (Table 9). Findings from other studies (Cockcroft et al. 1989, Aguilar and Borrell 1988) suggest that there is enhanced excretion in sexually mature females of lipophilic CHs as a result of the redistribution of CHs that occurs during pregnancy and lactation. However, in the present study, tissues were obtained from only six females and only two were greater than 1,000 cm in length; the average length at sexual maturity of female gray whales is 1,200 cm (Rice and Wolman 1971). Thus, additional tissue samples from adult gray whales are needed before sex differences in concentrations of CHs can be fully evaluated.

Pattern of Accumulation of PCB Congeners

There are 209 possible PCBs that differ in the degree and position of substitution of chlorines on the biphenyl ring structure, and both factors are important in the toxicity of individual congeners. The PCB congeners (e.g., 3,4,3',4'-tetrachlorobiphenyl, 3,4,5,3',4',5'-hexachlorobiphenyl) that are isostereomers to the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) are particularly hepato- and immunotoxic (Safe 1990), while unidentified and more highly chlorinated congeners present in commercial PCB mixtures, such as Aroclor 1260, appear to be more carcinogenic (Kimura and Baba 1973). The profile of PCB congeners in tissues is, therefore, important in evaluating the toxic potential of PCBs. In the present study, the pattern of accumulation of PCBs by congener class (tri- to nonachloro) in stomach contents, liver, and blubber was examined. Because sex-specific differences in concentrations of some CHs were observed in this study and may be attributed to cyclic depletion of these lipophilic contaminants from females, we first examined profiles of PCBs by congener class in blubber of males and females (Fig. 2); no substantial differences among males and females were observed in these profiles (Fig. 2). Comparison of profiles of PCB congener classes among blubber, liver, and stomach contents was conducted for males only (Fig. 3), for which a larger number of samples was available. The results showed that in stomach contents of males, tetrachlorobiphenyls were present in the highest proportion ($40 \pm 3.5\%$). The proportion of trichlorobiphenyl was quite low and the proportions of penta- to nonachlorobiphenyls decreased with increasing degree of chlorination. However, in gray whale liver there was a shift towards PCB congeners with a higher degree of chlorination when compared to the pattern in stomach contents. Specifically, the proportion of tetrachlorobiphenyls was slightly lower and the proportion of heptachlorobiphenyls was slightly higher in liver compared to stomach contents, although relative ranking of the proportion of a congener class was similar in stomach contents and the liver (Fig. 3). Examination of PCB congener profiles in blubber compared to the profile for stomach contents showed a clearer trend towards preferential accumulation of PCBs with a higher degree of chlorination, as evidenced by a substantial increase in proportions of the more hydrophobic penta- and hexachlorobiphenyls, confirming that blubber is a storage depot of PCBs in gray whales and may reflect relatively chronic exposure, whereas liver shows a pattern reflecting more recent exposure. This finding is in concordance with the hypothesis that biphenyls with a lower degree of chlorination are more subject to oxidative metabolism and more readily excreted (Safe 1984, Birnbaum 1985, McFarland and Clarke 1989). Thus, the congeners retained in an organism chronically exposed to PCBs would exhibit a pattern of more highly chlorinated classes as compared to those in sediment, the main repository for hydrophobic contaminants in aquatic systems.

It should be noted that the blubber of gray whales shows PCB profiles with a higher proportion of less chlorinated congeners than profiles in blubber from fish-eating cetaceans and pinnipeds, or liver of benthic fish from urban areas. Specifically, in our analyses of blubber of cetaceans such as bottlenose dolphin from the Gulf of Mexico coast and harbor porpoise from the Atlantic coast or liver of English sole from Puget Sound, the predominant congeners are hexachlorobiphenyls (37 to 42%), followed by penta- and hepta- chlorobiphenyls, which are followed by lower proportions of tetra- and octa- chlorobiphenyls, with trichlorobiphenyls present at the lowest proportion (Tilbury, unpubl. data). The pattern in gray whale blubber showed that both tetra- and penta-chlorobiphenyls were present in higher or comparable proportions to those of the hexachlorobiphenyls. It appears, therefore, that differences in feeding strategy and possibly differential metabolic capacity of gray whales in comparison to other cetaceans and pinnipeds leads to profiles of PCBs in blubber exhibiting higher proportions of less chlorinated PCB congeners.

Metabolism is an important factor for excretion of highly lipophilic compounds, and the highly substituted congeners tend to be resistant to metabolism and subsequent excretion. The route of excretion shifts from urine to feces with increasing size and number of halogen atoms. Laboratory studies show that clearance of PCBs by invertebrates, fish, and terrestrial mammals occurs primarily through excretion into the digestive tract, followed by elimination with fecal material (Waid 1986). Therefore, bile in fish and mammals may be an important fluid in which to measure levels and profiles of CHs to understand further the mechanisms of excretion of these compounds. It would also be important to examine profiles of PCBs in other tissues such as reproductive organs, kidney, and brain to further understand the accumulation in extrahepatic tissues. In the present study, the pattern of PCBs in brain tissue (not shown) more closely resembled that in the blubber than the profile in liver; however, because only one complete set of tissue samples was available, no firm conclusions can be drawn with regard to the pattern of deposition of PCBs in this extrahepatic tissue.

CONCLUSIONS

The present findings for stranded gray whales sampled from several areas on the West Coast of the United States showed that the concentrations of a broad spectrum of anthropogenic contaminants were relatively low in all of the whales analyzed. Further, the results suggest that elevated concentrations of aluminum detected in stomach contents appeared to come from geologic and not anthropogenic sources. Moreover, the low tissue concentrations (wet weight) of toxic elements (e.g., mercury 56 ± 12 ng/g in liver) and CHs (e.g., summed concentrations of PCBs, 590 ± 140 ng/g in liver and $1,600 \pm 450$ ng/g in blubber; summed concentrations of DDEs, 100 ± 28 ng/g in liver and 310 ± 96 ng/g in blubber) would suggest that toxic chemical induced effects did not significantly contribute to the death of these whales. Results from studies with other marine and terrestrial mammals, as summarized by Wagemann and Muir (1984), indicate that concentrations (wet weight) of mercury in liver and summed concentrations of PCBs in blubber exceeding 100,000 ng/g and 50,000 ng/g, respectively, are levels of toxicological concern. However, the lack of samples from apparently healthy gray whales limits further assessment of the role of these or other anthropogenic factors in the mortality of the whales. Additionally, natural factors such as the increase in recent years in the population of these protected species (Rice et al. 1984) must also be considered when evaluating incidents of stranding or sightings in near coastal waters.

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TABLES

Table 1. Chlorinated hydrocarbon (CH) analytes, polycyclic aromatic compounds (PACs), and elements measured in samples from gray whales. The CH and PAC analytes within each group were summed for tabulation.

CHs

DDEs	PCBs	Chlordanes
o,p'-DDE	trichlorobiphenyls	heptachlor
p,p'-DDE	tetrachlorobiphenyls	heptachlor epoxide
	hexachlorobiphenyls	alpha-chlordane
DDDs	pentachlorobiphenyls	trans-nonachlor
o,p'-DDD	heptachlorobiphenyls	
p,p'-DDD	octachlorobiphenyls	
	nonachlorobiphenyls	
DDTs	decachlorobiphenyl	hexachlorobenzene (HCB)
o,p'-DDT		lindane (gamma-BHC)
p,p'-DDT		dieldrin
		mirex
		aldrin

PACs

LACs (Lower molecular weight, 2-3 ring)	HACs (Higher molecular weight, 4-6 ring)
naphthalene	fluoranthene
C1-naphthalenes	pyrene
C2-naphthalenes	C1-fluoranthenes/pyrenes
C3-naphthalenes	benz[a]anthracene
C4-naphthalenes	chrysene
acenaphthylene	C1-chrysenes/benz[a]anthracenes
acenaphthene	C2-chrysenes/benz[a]anthracenes
fluorene	C3-chrysenes/benz[a]anthracenes
C1-fluorenes	C4-chrysenes/benz[a]anthracenes
C2-fluorenes	benzo[b]fluoranthene
C3-fluorenes	benzo[k]fluoranthene
phenanthrene	benzo[a]pyrene
C1-phenanthrenes/anthracenes	indeno[1,2,3-cd]pyrene
C2-phenanthrenes/anthracenes	dibenz[a,h]anthracene
C3-phenanthrenes/anthracenes	benzo[ghi]perylene
C4-phenanthrenes/anthracenes	
dibenzothiophene	
C1-dibenzothiophenes	
C2-dibenzothiophenes	
C3-dibenzothiophenes	

Elements

aluminum	copper	mercury
iron	zinc	lead
chromium	arsenic	tin
manganese	selenium	silver
nickel	cadmium	barium
		strontium

DDEs - 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethenes.
DDDs - 1,1-dichloro-2,2-bis (*p*-chlorophenyl) ethanes.
DDTs - 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethanes.
PCBs - polychlorinated biphenyls.

Table 2. Animal identification number (ID), collection site, date collected, sex, length, and tissues collected and analyzed from gray whales stranded in Washington (WA), Alaska (AK), and California (CA).

Animal ID	Collection site	Date collected	Sex	Length (cm)	Tissues analyzed
Puget Sound					
CRC 334	Hartstene Island, WA	6/3/90	male	1,200	blubber, liver, stomach contents, kidney, brain
CRC 397	Totten Inlet, WA	4/12/91	male	1,160	blubber, liver, stomach contents, kidney
CRC 398	Owens Beach, WA	5/8/91	male	1,170	blubber, liver, stomach contents, kidney
CRC 401	Port Susan, WA	6/26/91	male	1,170	blubber, liver, stomach contents, kidney
RCF 243	Manchester, WA	3/29/88	female	790	blubber
Washington Outer Coast					
CRC 395	Norwegian Memorial, WA	2/10/91	male	1,160	blubber
CRC 402	Ocean City, WA	6/30/91	male	1,250	blubber, liver, stomach contents, kidney
RCF 246	Ocean City, WA	4/18/88	male	855	blubber, liver
RCF 268	La Push, WA	5/23/90	female	845	blubber
RCF 269	Tahola, WA	5/16/89	male	1,110	blubber
RCF 271	Ruby Beach, WA	5/23/90	male	1,230	blubber
RCF 272	Queets, WA	6/10/90	female	850	blubber
Strait of Juan de Fuca and Strait of Georgia					
CRC 332	Eagle Point, WA	4/29/90	male	1,295	blubber, stomach contents, kidney
CRC 337	Sequim Bay	6/13/90	female	1,300	blubber
GLR 101	Lyre River, WA	6/16/90	male	1,250	blubber, liver, stomach contents, kidney
RCF 252	Point Roberts, WA	5/8/88	female	1,300	blubber
Alaska					
AKI 101	Kodiak Island, AK	6/27/89	*	*	blubber, liver, kidney
AKI 102	Tugidak Island, AK	5/22/89	*	*	blubber, liver, stomach contents, kidney
San Francisco Bay					
SFB 102	Point Richmond, CA	4/15/91	female	975	blubber, liver, kidney
SFB 103	Carquinez Strait, CA	3/23/91	male	1,006-1,067	blubber
SFB 105	Alcatraz Island, CA	4/18/91	male	1,067-1,219	blubber
SFB 107	Oakland, CA	5/2/91	male	1,250	blubber

* Data not available.

Table 3. Concentrations, ng/g wet weight, of selected chlorinated hydrocarbons and aromatic contaminants in the mussel *(Mytilus edulis)* tissue standard reference material SRM 1974.

Chlorinated hydrocarbons	Analyzed value (n = 6)	Noncertified value [a]
alpha-chlordane	3.2 ± 0.8	3.2 ± 0.2
trans-nonachlor	2.5 ± 0.5	2.6 ± 0.6
dieldrin	2.1 ± 1.3	1.0 ± 0.5
o,p'-DDE	1.8 ± 0.4	0.7 ± 0.1
p,p'-DDE	5.5 ± 1.6	5.9 ± 0.2
o,p'-DDD	1.8 ± 0.8	2.5 ± 0.9
p,p'-DDD	6.0 ± 2.6	8.4 ± 0.4
o,p'-DDT	0.8 ± 0.3	0.4 ± 0.2
p,p'-DDT	0.3 ± 0.2	0.3 ± 0.3
2,2',5-trichlorobiphenyl (no.18) [b]	4.3 ± 0.8	3.0 ± 1.0
2,4,4'-trichlorobiphenyl (no. 28)	19 ± 3.4	7.6 ± 0.4
2,2',3,5'-tetrachlorobiphenyl (no. 44)	11 ± 2.0	8.0 ± 3.0
2,2',5,5'-tetrachlorobiphenyl (no. 52)	17 ± 2.6	12 ± 5.0
2,3',4,4'-tetrachlorobiphenyl (no. 66)	24 ± 5.0	14 ± 0.6
2,3,3'4,4'-pentachlorobiphenyl (no.105)	5.2 ± 1.2	5.6 ± 0.4
2,3',4,4',5-pentachlorobiphenyl (no. 118)	17 ± 3.4	14 ± 0.6
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)	2.5 ± 0.5	1.9 ± 0.3
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)	21 ± 3.1	18 ± 1.0
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)	2.1 ± 0.8	1.7 ± 0.2
Aromatic contaminants	**Analyzed value (n = 2)**	**Certified and noncertified values**
fluorene	0.5 ± 0.7	1.5 ± 0.2 [c]
phenanthrene	5.5 ± 2.1	5.6 ± 1.4
fluoranthene	44 ± 2.1	33 ± 5.8
pyrene	42 ± 5.7	34 ± 3.7
benz[a]anthracene	5.5 ± 0.7	4.6 ± 0.4 [c]
benzo[b]fluoranthene	7.5 ± 2.1	6.5 ± 1.2
benzo[k]fluoranthene	5.0 ± 1.4	3.0 ± 0.1 [c]
benzo[a]pyrene	1.2 ± 1.1	2.3 ± 0.5
indeno[1,2,3-cd]pyrene	2.0 ± 0	1.8 ± 0.3
dibenz[a,h]anthracene	0.6 ± 0.1	0.4 ± 0.01 [c]
benzo[ghi]perylene	2.5 ± 0.7	2.5 ± 0.3

[a] Only noncertified values were available on the Certificate of Analysis from the National Institute of Standards and Technology.

[b] The accepted numbering system for polychlorinated biphenyl (PCB) isomers as developed by Ballschmiter and Zell (1980).

[c] Noncertified values.

DDEs - 1,1-dichloro-2,2-bis (p-chlorophenyl) ethenes.

DDDs - 1,1-dichloro-2,2-bis (p-chlorophenyl) ethanes.

DDTs - 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethanes.

Table 4. Concentrations, ng/g dry weight, of selected toxic and essential elements in certified reference materials (CRMs).[a]

Analytes	DOLT		LUTS	
	Analyzed value	Certified value	Analyzed value	Certified value
aluminum	b	-	c	-
iron	1,400,000 ± 53,000	710,000 ± 48,000	200,000 ± 21,000	78,000 ± 6,000
chromium	460 ± 170	400 ± 70	350 ± 60	530 ± 80
copper	b	-	96,000	110,000 ± 8,000
zinc	b	-	74,000	83,000 ± 5,400
arsenic	2,900 ± 200	10,000 ± 1,400	3,500 ± 790	19,000 ± 900
selenium	3,200 ± 320	7,300 ± 420	1,800 ± 160	4,300 ± 360
silver	c	-	8,600 ± 1,800	3,900 ± 330
cadmium	b	-	13,000	14,000 ± 1,000
mercury	300 ± 54	220 ± 37	130 ± 3	110 ± 15
lead	1,500 ± 340	1,400 ± 290	64 ± 8	69 ± 11
strontium	b	-	15,000	16,000 ± 1,900

Analytes	1566a	
	Analyzed value	Certified value
aluminum	64,000 ± 1,300	200,000 ± 12,000
iron	1,100,000 ± 40,000	540,000 ± 15,000
chromium	730 ± 50	1,400 ± 460
copper	57,000 ± 500	66,000 ± 4,300
zinc	680,000 ± 2,000	830,000 ± 57,000
arsenic	3,800 ± 280	14,000 ± 1,200
selenium	950 ± 130	2,100 ± 500
silver	3,500 ± 630	1,700 ± 150
cadmium	3,600 ± 20	4,100 ± 380
mercury	110 ± 150	64 ± 7
lead	350 ± 110	370 ± 10
strontium	9,600 ± 40	11,000 ± 1,000

[a] CRMs analyzed included DOLT-1 (Dogfish liver), LUTS-1 (Nondefatted lobster hepatopancreas, and 1566a (oyster tissue). The data for manganese and nickel were not available and there are no CRM certified values for barium and tin.

[b] The element was not analyzed for this CRM.

[c] The CRM was not certified for this element.

Table 5. Concentrations, ng/g wet weight, of chlorinated hydrocarbons (CHs) and percent (%) lipid in tissues and stomach contents of gray whales collected from sites in Washington, Alaska, and California.[a]

	Tissue	ΣPCBs	ΣDDE	ΣDDD	ΣDDT	HCB	Dieldrin	ΣChlordanes	ΣCHs [b]	% Lipid
Puget Sound, Washington	Blubber (n = 5)	1,800 ± 680 [c] (300 - 4,000)	350 ± 140 (54 - 730)	83 ± 40 (10 - 210)	96 ± 45 (11 - 260)	330 ± 130 (37 - 750)	160 ± 83 (11 - 440)	270 ± 110 (35 - 620)	2,900 ± 1,200 (460 - 6,800)	8.0 ± 5.1 (0.8 - 27)
	Liver (n = 4)	630 ± 70 (440 - 740)	140 ± 28 (63 - 180)	36 ± 6.7 (19 - 52)	1 ± 0.8 (nd - 2)	190 ± 17 (150 - 220)	63 ± 13 (30 - 92)	88 ± 12 (55 - 110)	1,200 ± 140 (760 - 1,300)	4.2 ± 0.1 (3.9 - 4.5)
	Stomach contents (n = 4)	130 ± 46 (73 - 270)	24 ± 13 (4 - 62)	4 ± 1 (2 - 8)	0.8 ± 0.2 (nd - 1)	29 ± 14 (10 - 70)	6 ± 3 (1 - 15)	10 ± 4 (2 - 22)	210 ± 81 (110 - 450)	1.3 ± 0.2 (0.8 - 1.8)
	Brain (n = 1)	420	100	21	4	110	47	51	760	11
Washington - Outer Coast	Blubber (n = 7)	1,200 ± 250 (360 - 2,300)	210 ± 62 (84 - 540)	71 ± 33 (10 - 260)	27 ± 9.5 (nd - 62)	290 ± 68 (66 - 560)	89 ± 22 (20 - 190)	190 ± 39 (52 - 360)	2,100 ± 430 (620 - 4,100)	17 ± 9.8 (0.6 - 73)
	Liver (n = 2)	940 ± 670 (270 - 1,600)	160 ± 120 (34 - 280)	22 ± 14 (8 - 35)	2 ± 1 (1 - 3)	200 ± 120 (77 - 320)	64 ±31 (34 - 95)	100 ± 68 (35 - 170)	1,500 ± 1,000 (460 - 2,500)	3.3 ± 1.1 (4.4 - 2.2)
	Stomach contents (n = 1)	160	44	6	nd	40	13	16	280	0.8
Strait of Juan de Fuca and Strait of Georgia	Blubber (n = 4)	3,200 ± 2,300 (120 - 10,000)	680 ± 490 (11 - 2,100)	140 ± 110 (4 - 470)	180 ± 110 (nd - 370)	850 ± 690 (17 - 2,900)	450 ± 380 (7 - 1,600)	650 ± 520 (15 - 2,200)	6,200 ± 4,700 (180 - 20,000)	5.0 ± 3.7 (1.0 - 16)
	Liver (n = 1)	370	80	17	1	110	40	61	690	4
	Stomach Contents (n = 2)	140 ± 10 (130 - 150)	29 ± 4 (25 - 33)	3 ± 2 (2 - 5)	nd -	34 ± 5 (29 - 39)	12 ± 0.5 (11 - 12)	12 ± 0.5 (11 - 12)	230 ± 10 (220 - 240)	1.6 ± 0 -

Table 5. Continued.

	Tissue	ΣPCBs	ΣDDEs	ΣDDDs	ΣDDTs	HCB	Dieldrin	ΣChlordanes	ΣCHs	% Lipid
Alaska	Blubber (n = 2)	680 ± 530 (150 - 1,200)	100 ± 96 (9 - 200)	22 ± 21 (1 - 42)	45 ± 43 (2 - 88)	47 ± 31 (16 - 78)	32 ± 28 (4 - 59)	72 ± 59 (13 - 130)	1000 ± 800 (200 - 1,800)	2.1 ± 1.2 (0.9 - 3.2)
	Liver (n = 2)	480 ± 400 (79 - 880)	39 ± 32 (7 - 71)	11 ± 11 (1 - 22)	0.6 (nd - 1)	43 ± 32 (11 - 75)	18 ± 16 (3 - 34)	28 ± 25 (4 - 53)	610 ± 500 (110 - 1,100)	2.2 ± 0.7 (1.5 - 2.9)
	Stomach contents (n = 1)	110	7	4	nd	14	2	5	150	1.7
California	Blubber (n = 4)	780 ± 140 (530 - 1,100)	160 ± 37 (63 - 230)	37 ± 8 (13 - 50)	20 ± 10 (2 - 41)	130 ± 30 (56 - 200)	52 ± 15 (17 - 85)	110 ± 23 (61 - 160)	1,300 ± 260 (750 - 1,900)	1.7 ± 0.3 (1.1 - 2.7)
	Liver (n = 1)	140	12	3	nd	23	5	11	190	1.4
Mean ± SE for all areas	Blubber (n = 22)	1,600 ± 450 (120 - 10,000)	310 ± 96 (9 - 2,100)	76 ± 24 (1 - 470)	68 ± 22 (1 - 370)	350 ± 130 (17 - 2,900)	160 ± 72 (4 - 1,600)	270 ± 97 (13 - 2,200)	2,800 ± 890 (180 - 20,000)	8.5 ± 3.4 (0.6 - 73)
	Liver (n = 10)	590 ± 140 (79 - 1,600)	100 ± 28 (7 - 280)	23 ± 5 (0.6 - 52)	1 ± 0.4 (0.4 - 3)	140 ± 31 (11 - 320)	46 ± 10 (3 - 95)	68 ± 16 (4 - 170)	970 ± 220 (110 - 2,500)	3.3 ± 0.4 (1.4 - 4.0)
	Stomach contents (n = 8)	140 ± 22 (73 - 270)	26 ± 7 (4 - 62)	4.3 ± 0.77 (2 - 8)	0.63 ± 0.2 (0.3 - 1)	30 ± 7 (10 - 70)	8 ± 2 (1 - 15)	10 ± 2 (2 - 22)	220 ± 40 (110 - 450)	1.4 ± 0.1 (0.8 - 1.8)
	Brain (n = 1)	420	100	21	4	110	47	51	760	11

Table 5. Continued.

	Tissue	ΣPCBs	ΣDDEs	ΣDDDs	ΣDDTs	HCB	Dieldrin	ΣChlordanes	ΣCHs	% Lipid
Port Angeles, Washington (1984)[d]	Blubber (n = 1)	55	6	0.8	nd	14	5	4	87	na
	Liver (n = 1)	210	55	10	nd	83	62	42	510	na
	Stomach contents (n = 1)	54	6	3	nd	6	21	13	130	na

[a] See Table 1 for the list of analytes.
[b] The concentrations of aldrin, lindane, and mirex ranged from nd - 100 ng/g wet weight. The values for ΣCHs are the summed (Σ) concentrations of CHs listed in Table 1.
[c] The data are presented as the mean ± standard error and the values in parentheses are the range of concentrations. The mean values do not include values for samples in which the concentrations of an analyte was below the limit of detection.
[d] These samples were analyzed previously (1984).
nd - indicates that the analyte was not detected above the limit of detection.
na - the sample was not analyzed for percent lipid.

Table 6. Sums of concentrations, ng/g wet weight, of polycyclic aromatic compounds (PACs) in stomach content samples from gray whales collected from sites in Washington and Alaska.[a]

Specimen	Number	ΣLACs	ΣHACs	ΣPACs[b]
Puget Sound, Washington	4	370 ± 250[c] (nd - 860)	390 ± 280[d] (7 - 1,200)	680 ± 490 (7 - 2,100)
Washington - Outer Coast	1	10	4	14
Strait of Juan de Fuca and Strait of Georgia	2	290 ± 270 (11 - 560)	88 ± 82 (6 - 170)	370 ± 360 (17 - 730)
Alaska	1	56	10	66
Mean ± SE for all areas	8	250 ± 130 (nd - 860)	220 ± 140 (4 - 1,200)	440 ± 250 (7 - 2,100)
Port Angeles, Washington (1984)[e]	1	-	-	140

[a] See Table 1 for list of analytes.
[b] The values of ΣPACs are the summed (Σ) concentrations of all PACs listed in Table 1.
[c] The data are presented as the mean ± standard error and the values in parentheses are the range of concentrations. The mean values do not include values for samples in which the concentrations of an analyte was below the limit of detection.
[d] Significantly ($P < 0.05$) different from the mean concentration (48 ± 41 ng/g wet weight) of all the other sites ($n = 4$) combined.
[e] These samples were analyzed previously (1984).

Table 7. Concentrations, ng/g wet weight, of selected toxic and essential elements and percent (%) dry weights in tissues and stomach contents of gray whales collected from sites in Washington, Alaska, and California [a]

Puget Sound, Washington

Tissue	Aluminum (Al)	Iron (Fe)	Chromium (Cr)	Manganese (Mn)	Nickel (Ni)	Copper (Cu)	Zinc (Zn)	Arsenic (As)
Liver (n=4)	32,000 ± 21,000 [b] (8,500 - 93,000)	4,200,000 (n=1)	110 (nd - 110)	3,000 (n=1)	350 (n=1)	12,000 ± 4,500 (5,700 - 25,000)	140,000 ± 8,500 (120,000 - 160,000)	520 ± 68 (390 - 700)
Kidney (n=4)	6,200 ± 3,600 (1,800 - 17,000)	150,000 (n=1)	93 ± 57 (10 - 260)	nd (n=1)	200 (n=1)	2,100 ± 210 (1,500 - 2,400)	41,000 ± 3,800 (32,000 - 47,000)	170 ± 19 (150 - 230)
Stomach contents (n=4)	1,490,000 ± 720,000 (190,000 - 3,400,000)	140,000 (n=1)	2,100 ± 1,100 (360 - 4,800)	11,000 (n=1)	240 (n=1)	9,100 ± 3,200 (3,000 - 15,000)	15,000 ± 8,400 (3,200 - 40,000)	4,700 ± 3,100 (640 - 14,000)
Brain (n=1)	2,300	39,000	60	nd	nd	2,400	10,000	nd

Tissue	Selenium (Se)	Silver (Ag)	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Strontium (Sr)	Tin (Sn)	Barium (Ba)
Liver (n=4)	2,600 ± 160 (2,300 - 3,000)	20 (n=1)	7,600 ± 1,200 (5,100 - 11,000)	63 ± 19 (10 - 100)	130 ± 24 (80 - 190)	320 ± 120 (n=3) (200 - 550)	nd (n=3)	37 ± 22 (n=3) (10 - 80)
Kidney (n=4)	1,400 ± 140 (1,200 - 1,800)	10 (n = 1)	5,100 ± 500 (3,700 - 6,100)	23 ± 3 (nd - 30)	50 ± 11 (30 - 80)	1,300 ± 180 (n=3) (1,000 - 1,600)	nd (n = 3)	93 ± 24 (n=3) (60 - 140)
Stomach contents (n=4)	750 ± 230 (420 - 1,400)	30 (n = 1)	370 ± 170 (40 - 840)	180 ± 110 (20 - 500)	1,600 ± 770 (300 - 3,300)	52,000 ± 49,000 (n=3) (1,900 - 150,000)	20 (n=3) (nd - 20)	2,000 ± 950 (n=3) (310 - 3,600)
Brain (n=1)	100	20	20	nd	60	na	na	na

Tissue	% dry weight
Liver (n=4)	21 ± 0.9 (19 - 23)
Kidney (n=4)	28 ± 0.8 (26 - 30)
Stomach contents (n=4)	22 ± 10 (7.5 - 50)
Brain (n=1)	37

Table 7. Continued.

Washington Outer Coast

Tissue	Al	Fe	Cr	Mn	Ni	Cu	Zn	As
Liver (n=2)	11,000 ± 6,700 (4,600 - 18,000)	1,400,000 (n=1)	130 (nd - 130)	3,000 (n=1)	nd (n=1)	13,000 ± 3,300 (9,400 - 16,000)	82,000 ± 7,000 (75,000 - 89,000)	260 ± 100 (160 - 360)
Kidney (n=1)	1,700	na	10	na	na	2,600	32,000	90
Stomach contents (n=1)	860,000	na	510	na	na	5,100	22,000	980

Tissue	Se	Ag	Cd	Hg	Pb	Sr	Sn	Ba
Liver (n=2)	2,300 ± 1,200 (1,100 -3,400)	10 (n=1)	3,200 ± 3,000 (210 - 6,200)	55 ± 25 (30 - 80)	130 ± 15 (110 - 140)	930 (n=1)	nd (n=1)	70 (n=1)
Kidney (n=1)	1,000	na	4,200	20	10	1,600	nd	140
Stomach contents (n=1)	470	na	690	30	140	360,000	nd	16,000

Tissue	% dry weight
Liver (n=2)	23 ± 0
Kidney (n=1)	25
Stomach contents (n=1)	31

Table 7. Continued.

Strait of Juan de Fuca and Strait of Georgia

Tissue	Al	Fe	Cr	Mn	Ni	Cu	Zn	As
Liver (n=1)	9,200	3,600,000	150	3,000	100	8,300	120,000	410
Kidney (n=2)	5,500 ± 3,900 (1,600 - 9,300)	88,000 ± 13,000 (75,000 - 100,000)	540 ± 470 (70 - 1,000)	nd -	210 (nd - 210)	3,100 ± 150 (2,900 - 3,200)	69,000 ± 9,500 (59,000 - 78,000)	230 ± 40 (190 - 270)
Stomach contents (n=2)	2,000,000 ± 1,100,000 (940,000 - 3,100,000)	410,000 ± 400,000 (5,800 - 810,000)	8,200 ± 2,800 (5,400 - 11,000)	30,000 ± 24,000 (5,100 - 54,000)	900 ± 560 (380 - 1,500)	37,000 ± 29,000 (8,000 - 66,000)	52,000 ± 33,000 (19,000 - 85,000)	6,200 ± 4,900 (1,300 - 11,000)

Tissue	Se	Ag	Cd	Hg	Pb	Sr	Sn	Ba
Liver (n=1)	2,100	20	3,100	120	110	na	na	na
Kidney (n=2)	1,600 ± 500 (1,100 - 2,100)	20 ± 10 (10 - 30)	4,400 ± 700 (3,700 - 5,100)	60 (nd - 60)	90 ± 10 (80 - 100)	na	na	na
Stomach contents (n=2)	1,400 ± 940 (430 - 2,300)	20 ± 10 (10 - 30)	290 ± 240 (50 -530)	85 ± 15 (70 - 100)	210 ± 110 (100 - 320)	na	na	na

Tissue	% dry weight
Liver (n=1)	24
Kidney (n=2)	26 ± 1.0 (25 - 27)
Stomach contents (n=2)	38 ± 13 (25 - 50)

Table 7. Continued.

Alaska

Tissue	Al	Fe	Cr	Mn	Ni	Cu	Zn	As
Liver (n=2)	80,000 ± 70,000 (10,000 - 150,000)	na	250 (nd - 250)	na	na	5,400 ± 4,200 (1,200 - 9,600)	47,000 ± 46,000 (1,600 - 93,000)	210 ± 65 (140 - 270)
Kidney (n=2)	3,800 ± 1,000 (2,800 - 4,800)	na	20 ± 10 (10 - 30)	na	na	1,000 ± 580 (450 - 1,600)	40,000 ± 5,000 (35,000 - 45,000)	1,400 ± 1,300 (10 - 2,700)
Stomach contents (n=1)	2,900,000	na	2,100	na	na	55,000	41,000	1,600

Tissue	Se	Ag	Cd	Hg	Pb	Sr	Sn	Ba
Liver (n=2)	1,600 ± 600 (1,000 - 2,200)	na	1,500 ± 1,300 (200 - 2,700)	25 ± 16 (9 - 40)	170 ± 110 (60 - 270)	2,600 ± 1,800 (880 - 4,400)	nd -	62 ± 32 (30 - 94)
Kidney (n=2)	720 ± 380 (340 - 1,100)	na	1,400 ± 1,200 (140 - 2,600)	30 ± 0 -	10 (nd - 10)	1,500 ± 770 (770 - 2,300)	50 (nd - 50)	15 ± 5 (10 - 20)
Stomach contents (n=1)	1,400	na	1,700	80	350	410,000	nd	24,000

Tissue	% dry weight
Liver (n=2)	19 ± 3.5 (15 - 22)
Kidney (n=2)	27 ± 3.4 (23 - 30)
Stomach contents (n=1)	25

Table 7. Continued.

San Francisco Bay, California

Tissue	Al	Fe	Cr	Mn	Ni	Cu	Zn	As
Liver (n=1)	6,400	120,000	nd	na	na	630	46,000	47
Kidney (n=1)	5,100	84,000	nd	na	na	4,900	110,000	480

Tissue	Se	Ag	Cd	Hg	Pb	Sr	Sn	Ba
Liver (n=1)	350	nd	60	30	20	520	40	120
Kidney (n=1)	1,600	nd	5,400	60	80	1,300	30	160

Tissue	% dry weight
Liver (n=1)	18
Kidney (n=1)	21

Table 7. Continued.

Means for All Areas

Tissue	Al	Fe	Cr	Mn	Ni	Cu	Zn	As
Liver (n=10)	32,000 ± 15,000 (6,400 - 150,000)	2,300,000 ± 950,000 (120,000 - 4,200,000) (n=4)	160 ± 31 (nd - 250)	3,000 ± 0 - (n=3)	230 ± 130 (nd - 350) (n=3)	9,200 ± 2,200 (630 - 25,000)	99,000 ± 16,000 (1,600 - 160,000)	340 ± 62 (47 - 700)
Kidney (n=10)	5,000 ± 1,500 (1,600 - 9,300)	100,000 ± 17,000 (75,000 - 150,000) (n=4)	170 ± 110 (nd - 1000)	nd - (n=3)	210 ± 5 (nd - 210) (n=3)	2,400 ± 370 (450 - 4,900)	52,000 ± 7,800 (32,000 - 110,000)	440 ± 250 (10 - 2,700)
Stomach contents (n=8)	1,700,000 ± 450,000 (190,000 - 3,400,000)	320,000 ± 250,000 (5,800 - 810,000) (n=3)	3,400 ± 1,300 (510 - 11,000)	23,000 ± 15,000 (5,100 - 54,000) (n=3)	710 ± 400 (240 - 1,500) (n=3)	21,000 ± 8,800 (3,000 - 66,000)	28,000 ± 9,500 (3,200 - 85,000)	4,200 ± 1,800 (640 - 14,000)
Brain (n=1)	2,300	39,000	60	nd	nd	2,400	10,000	nd

Tissue	Se	Ag	Cd	Hg	Pb	Sr	Sn	Ba
Liver (n=10)	2,000 ± 300 (350 - 3,400)	17 ± 3 (10 - 20) (n=4)	4,300 ± 1,200 (60 - 6,200)	56 ± 12 (9 - 120)	120 ± 22 (20 - 270)	1,100 ± 560 (200 - 1,800) (n=7)	40 (nd - 40) (n=7)	61 ± 16 (10 - 120) (n=8)
Kidney (n=10)	1,300 ± 150 (340 - 2,100)	17 ± 7 (10 - 30) (n=4)	4,100 ± 550 (140 - 6,100)	34 ± 6 (nd - 60)	53 ± 11 (nd - 100)	1,400 ± 190 (770 - 2,300) (n=7)	40 ± 10 (nd - 50) (n=7)	87 ± 23 (10 - 160) (n=8)
Stomach contents (n=8)	950 ± 240 (420 - 1,400)	23 ± 7 (10 - 30) (n=3)	560 ± 190 (40 - 1,700)	120 ± 56 (20 - 500)	940 ± 450 (100 - 3,300)	180,000 ± 86,000 (1,900 - 410,000) (n=5)	20 (nd - 20) (n=5)	9,200 ± 4,600 (310 - 24,000) (n=5)
Brain (n=1)	100	20	20	nd	60	na	na	na

Tissue	% dry weight
Liver (n=10)	21 ± 0.9 (15 - 24)
Kidney (n=10)	26 ± 0.9 (21 - 30)
Stomach contents (n=8)	27 ± 5.6 (7.5 - 50)
Brain (n=1)	37

Table 7. Continued.

Port Angeles, Washington (1984)[c]

Tissue	Al	Cr	Ni	Cu	Zn	As	Hg	Pb
Liver	39,000	2,200	3,400	8,800	62,000	nd	nd	nd
Kidney	1,900	nd	250	5,700	34,000	nd	nd	nd
Stomach contents	1,100,000	3,300	1,800	9,600	18,000	nd	nd	nd
Brain	8,800	3,800	na	4,200	26,000	nd	nd	nd

[a] The toxic and essential elements analyzed are given in Table 1.
[b] The data are presented as the mean ± standard error and the values in parentheses are the range of concentrations. The mean values do not include values for samples in which the concentrations of an element were below the limit of detection.
[c] These samples were analyzed previously (1984).
nd - indicates that the analyte was not detected above the limit of detection.
na - the sample was not analyzed for this element.

Table 8. Aluminum (Al), iron (Fe), and chromium (Cr) ratios in stomach contents of gray whales and in suspended particulate matter and surface sediment.

	Al	:	Fe x 10	:	Cr x 1000
Gray whale stomach contents					
CRC 334	1	:	7.2	:	1.8
GLR 101	1	:	8.7	:	5.7
CRC 332	1	:	19	:	1.3
CRC 397	1	:	na	:	0.8
CRC 398	1	:	na	:	0.9
CRC 401	1	:	na	:	2.6
CRC 402	1	:	na	:	0.6
mean ± standard error			12 ± 3.8		1.9 ± 0.7
Suspended particulate matter					
Duwamish River (Feely et al. 1983)	1	:	7.4	:	1.1
North Pacific (Feely et al. 1981)	1	:	7.6	:	1.8
North Atlantic (Eggimann and Betzer 1976)	1	:	7.7	:	na
mean ± standard error			7.6 ± 0.1		1.4 ± 0.4
Surface sediment					
Duwamish River (Feely et al. 1983)	1	:	6.6	:	1.2
Elliott Bay	1	:	5.3	:	1.2
Columbia River at Astoria	1	:	5.4	:	0.6
Port Angeles	1	:	5.4	:	1.3
Henderson Inlet	1	:	6.8	:	1.6
mean ± standard error			5.9 ± 0.3		1.2 ± 0.2

na - the element was not determined for this sample.

Table 9. Summary of results of analysis of variance (ANOVA) of the effects of A) stranding site, B) the sex of the whale, and C) the year of the stranding, as appropriate, on the concentrations (wet weight basis) of selected CHs in blubber, liver, and stomach contents of gray whales. The values (P) are the levels of significance for each factor. Differences were considered significant at $P \leq 0.05$.[a]

ANOVA significance (P) level

Blubber (n = 20)[b]

Analyte \ Factors	Stranding site	Sex of animal	Year of stranding
hexachlorobenzene	0.46	0.32	0.22
Σchlordanes	0.46	0.09	0.23
dieldrin	0.72	0.16	0.38
mirex	0.64	0.01 [c]	0.34
ΣDDEs	0.14	0.01 [c]	0.08
ΣDDDs	0.56	0.32	0.17
ΣDDTs	0.35	0.01 [c]	0.32
ΣPCBs	0.34	0.07	0.20

Liver (n = 10)[d]

Analyte \ Factor	Stranding site
hexachlorobenzene	0.10
Σchlordanes	0.18
dieldrin	0.18
mirex	0.32
ΣDDEs	0.15
ΣDDDs	0.07
ΣDDTs	0.65
ΣPCBs	0.33

Stomach contents (n = 8)[d]

Analyte \ Factor	Stranding site
hexachlorobenzene	0.59
Σchlordanes	0.55
dieldrin	0.41
mirex	0.26
ΣDDEs	0.56
ΣDDDs	0.80
ΣDDTs	e
ΣPCBs	0.60

[a] Data were log-transformed (log (x+1)) to reduce heteroscedasticity in the variances.
[b] The Alaska whales were deleted from the data base because the sex of these animals was not known.
[c] Concentrations were greater in males than in females.
[d] Included data for all samples regardless of the sex of the whale for one-way ANOVA with the factor being the stranding site.
[e] No statistical analysis was performed because the concentrations of ΣDDTs were below the limit of detection in most of the whales (Table 5).

Table 10. Summary of results of analysis of variance (ANOVA) of the effects of stranding site on the concentrations (dry weight basis) of selected elements in liver, kidney, and stomach contents of male gray whales. The values (P) are the levels of significance for each factor. Differences were considered significant at $P \leq 0.05$.[a]

ANOVA significance (P) level

Liver (n = 7)

Analyte \ Factor	Stranding site
aluminum	0.32
cadmium	0.11
chromium	0.27
lead	0.51
selenium	0.31
copper	0.99
mercury	0.81
barium	

Kidney (n = 7)

Analyte \ Factor	Stranding site
aluminum	0.80
cadmium	0.70
chromium	0.43
lead	0.87
selenium	0.07
copper	0.47
mercury	b
barium	

Stomach contents (n = 7)

Analyte \ Factor	Stranding site
aluminum	0.49
cadmium	0.72
chromium	0.75
lead	0.01
selenium	0.56
copper	0.99
mercury	0.34
barium	b

[a] Data were log-transformed (log (x+1)) to reduce heteroscedasticity in the variances. The analyses were done with only data from male whales because only one sample of liver was available from female whales.

[b] Statistical analyses were not possible because $n \leq 2$.

Table 11. Mean concentrations, ng/g wet weight, of chlorinated hydrocarbons (CHs) and percent (%) lipid in blubber of gray whales observed feeding in Puget Sound before they died and in whales stranded along the Washington Outer Coast, and at sites on the Strait of Juan de Fuca and Strait of Georgia. [a]

		ΣPCBs	ΣDDE	ΣDDD	ΣDDT	HCB	dieldrin	Σchlordanes	ΣCHs [b]	% Lipid
Puget Sound, Washington	n = 4	1,700 ± 870	370 ± 170	68 ± 48	98 ± 57	220 ± 100	140 ± 100	240 ± 140	2,900 ± 1,500	3.4 ± 1.9
Washington - Outer Coast	n = 7	1,200 ± 250 [c]	210 ± 62	71 ± 33	27 ± 9.5	290 ± 68	89 ± 22	190 ± 39	2,100 ± 430	17 ± 9.8
Strait of Juan de Fuca and Strait of Georgia	n = 4	3,200 ± 2,300	680 ± 490	140 ± 110	180 ± 110	850 ± 690	450 ± 380	650 ± 520	6,200 ± 4,700	5.0 ± 3.7

a The CHs analyzed are given in Table 1.

b The concentrations of aldrin, lindane, and mirex ranged from nd - 40 ng/g wet weight. The values for ΣCHs are the summed (Σ) concentrations of the CHs listed in Table 1.

c The data are presented as the mean ± standard error and the values in parentheses are the range of concentrations. The mean values do not include values for samples in which the concentration of an analyte was below the limit of detection.

nd - Indicates that the analyte was not detected above the limit of detection.

n - Number of samples.

FIGURES

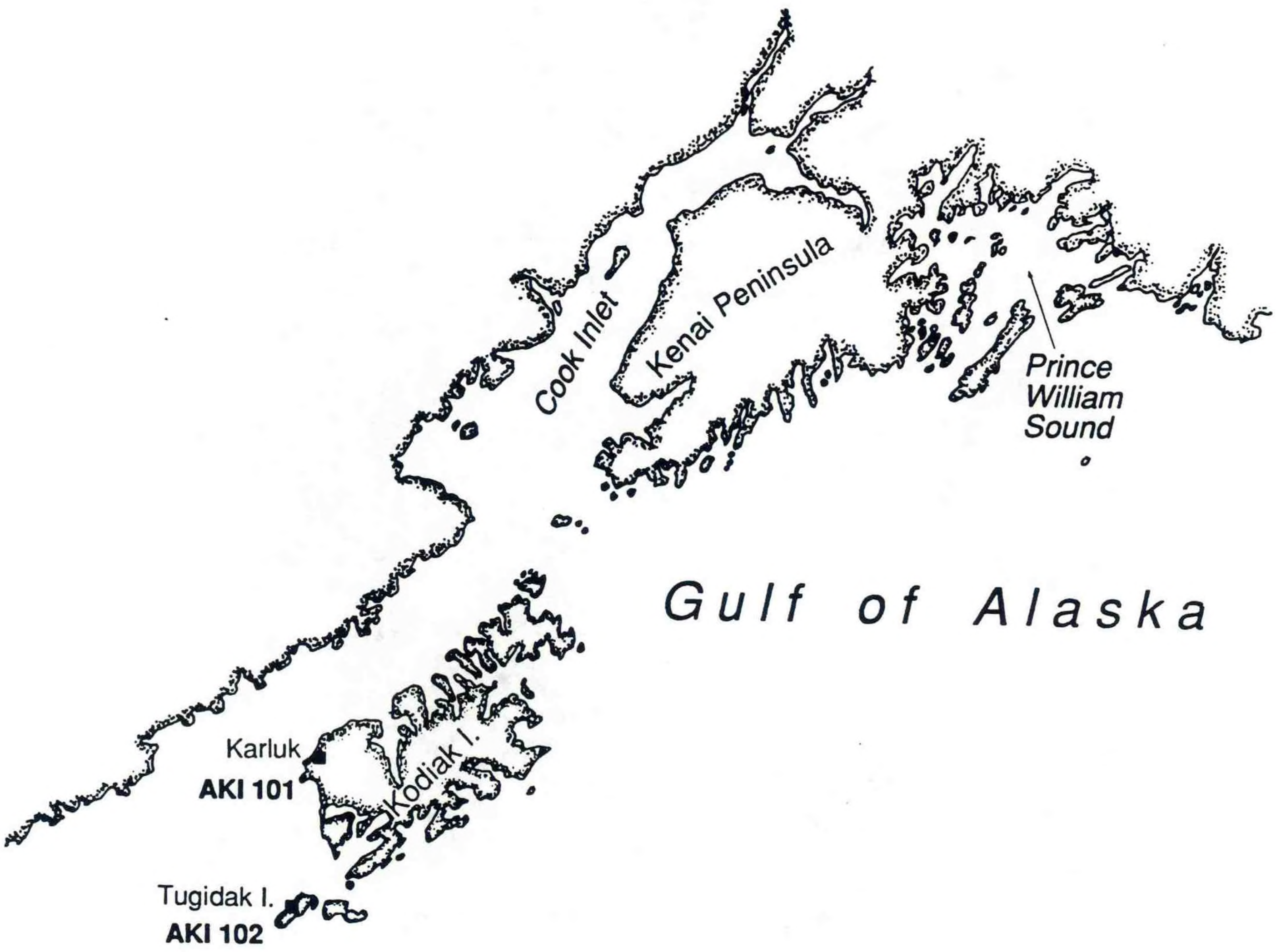

Figure 1A. Locations of stranding sites in Alaska. Stranding site is indicated by animal identification number.

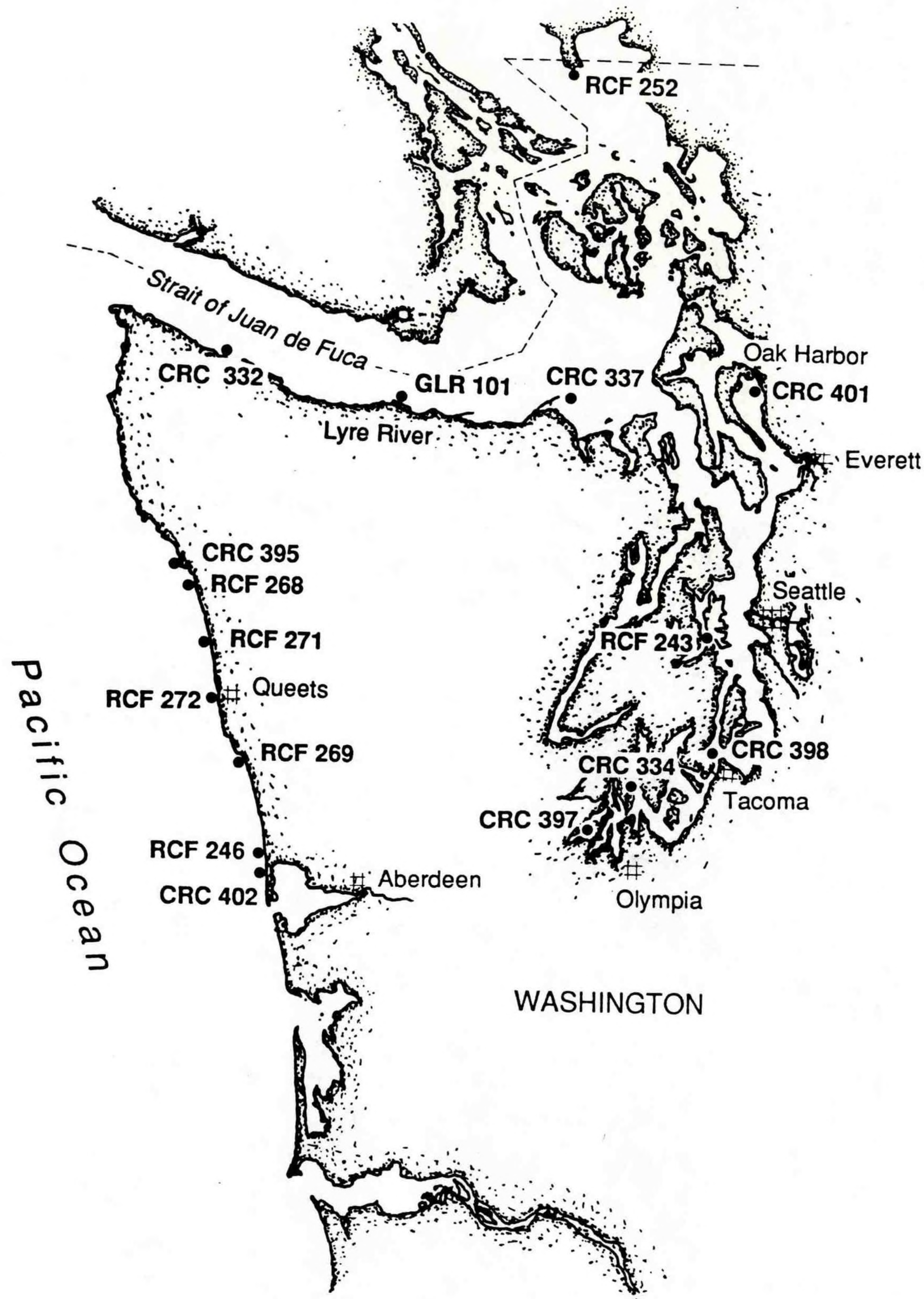

Figure 1B. Locations of stranding sites in Washington. Stranding site is indicated by animal identification number.

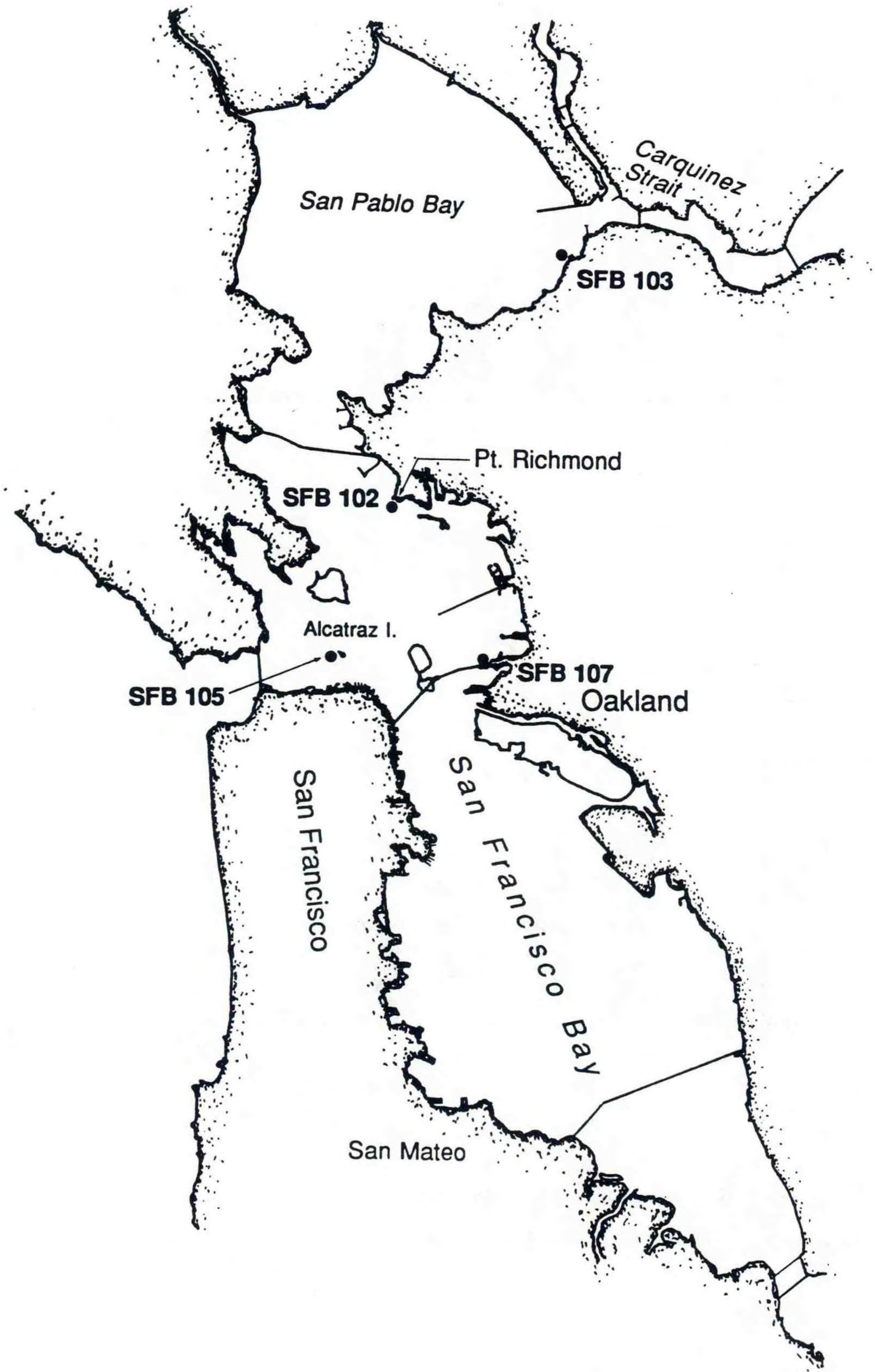

Figure 1C. Locations of stranding sites in California. Stranding site is indicated by animal identification number.

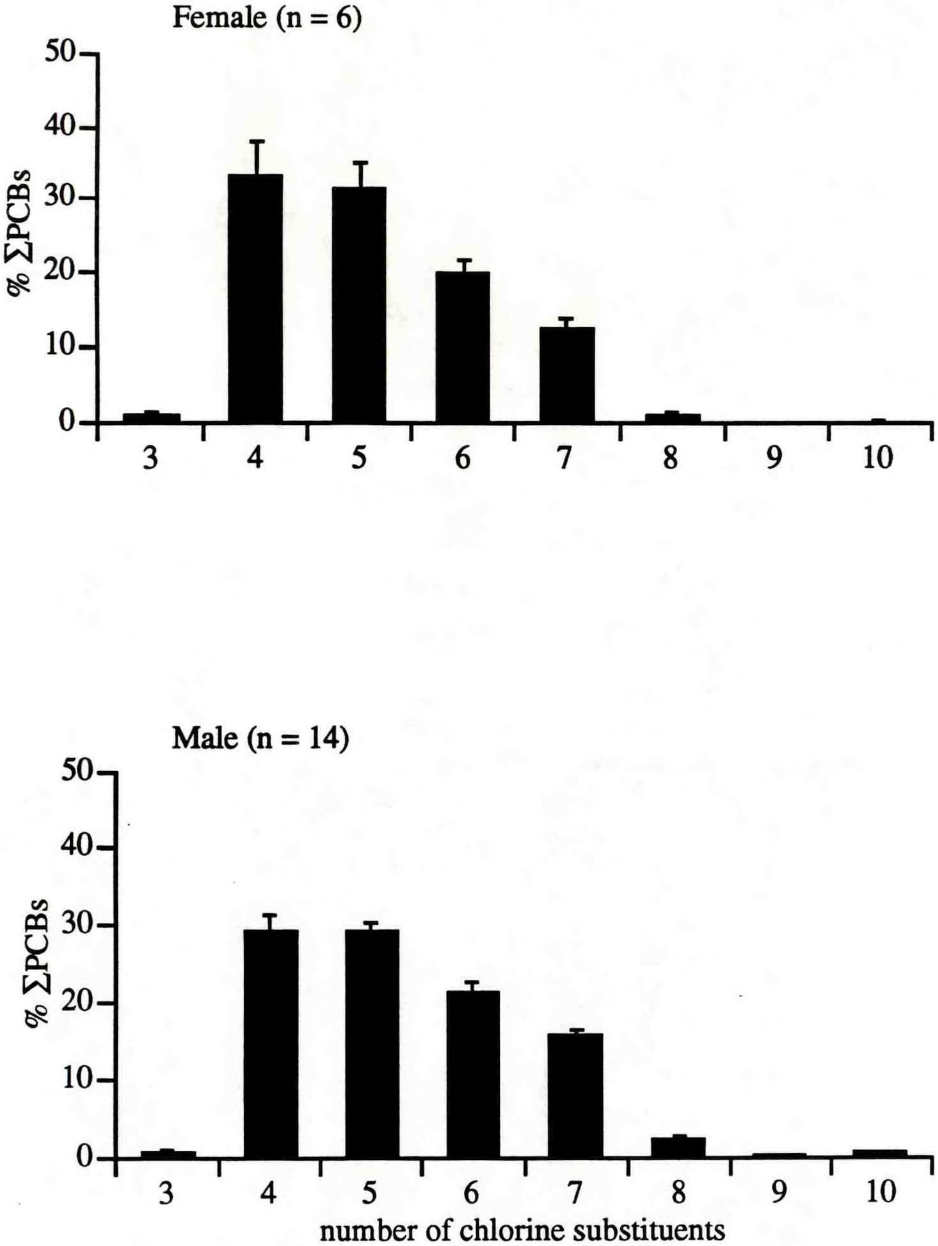

Figure 2. Polychlorinated biphenyl (PCB) isomer profiles in blubber of female and male gray whales.

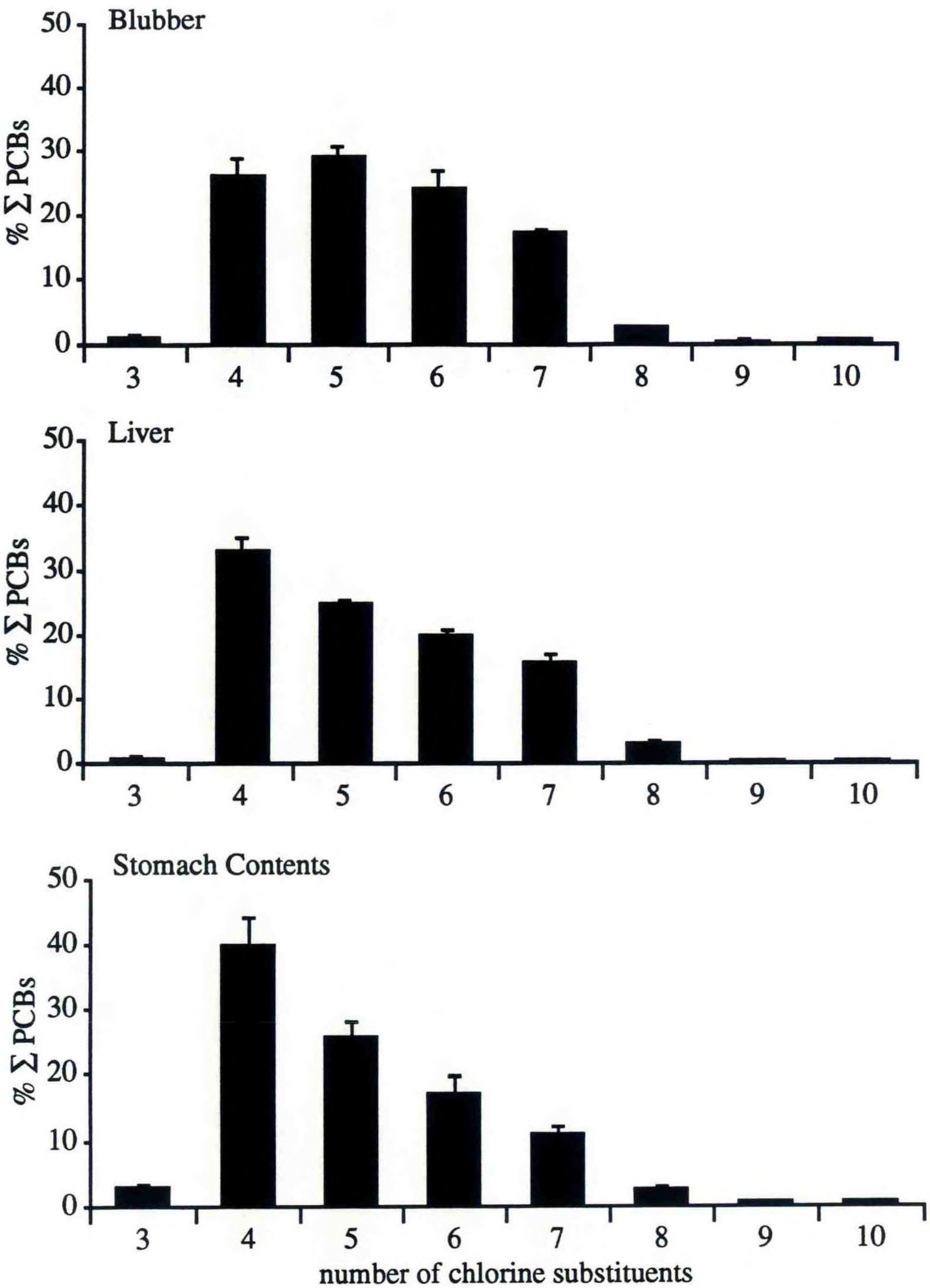

Figure 3. Polychlorinated biphenyl (PCB) isomer profiles in blubber, liver, and stomach contents of male gray whales (n = 6).

APPENDIX A

CONCENTRATIONS OF INDIVIDUAL CHLORINATED HYDROCARBONS IN GRAY WHALE SAMPLES, METHOD BLANKS, AND QUALITY CONTROL MATERIALS

Chlorinated Contaminants in Samples from Gray Whales
Explanatory Notes for Tables A1 through A26.

Abbreviations used:

nd - indicates that the analyte was not detected above the limit of detection which ranged from 0.2 to 2 ng/g (ppb) wet weight.

RSD - relative standard deviation is the standard deviation divided by the mean and expressed as a percent.

GC/MS - gas chromatography/mass spectrophometry

Results were determined by gas chromatography (GC)/electron capture detection (ECD).

4,4'-dibromooctofluorobiphenyl was the internal standard (surrogate standard) for all the analytes.

Percent recoveries for the internal standard averaged 87%, RSD = 20%, n = 55.

Table A1. Liver. Concentrations, ng/g wet weight, of chlorinated analytes in Washington gray whales.

Chlorinated analytes	Site:	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City	Ocean City
	Animal ID:	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402	RCF 246
	Sample no.:	59-282	59-280	59-397	59-400	59-403	59-431	59-277
hexachlorobenzene		220	110	150	180	220	320	77
lindane (gamma-BHC)		nd	nd	2	3	4	2	nd
heptachlor		nd	nd	nd	nd	nd	2	nd
aldrin		nd	nd	nd	nd	nd	nd	nd
heptachlor epoxide		13	8	10	17	28	28	8
alpha-chlordane		11	8	8	17	3	28	4
trans-nonachlor		65	45	37	72	66	110	23
dieldrin		78	40	30	51	92	95	34
mirex		8	9	5	10	12	22	2
o,p'-DDE		5	3	3	6	5	16	3
p,p'-DDE		180	77	60	170	120	260	31
o,p'-DDD		27	8	12	19	22	3	4
p,p'-DDD		25	9	7	17	14	32	4
o,p'-DDT		nd	0.8	0.4	2	nd	3	0.9
p,p'-DDT		nd	nd	nd	nd	nd	nd	nd
trichlorobiphenyls		5	3	8	5	10	8	3
tetrachlorobiphenyls		220	120	140	200	230	670	130
pentachlorobiphenyls		160	91	110	200	180	380	66
hexachlorobiphenyls		120	78	93	170	150	260	36
heptachlorobiphenyls		89	60	69	130	130	200	26
octachlorobiphenyls		20	17	11	25	19	47	4
nonachlorobiphenyls		2	2	1	5	3	3	0.5
decachlorobiphenyl		2	1	2	5	5	6	0.6
sample weight, grams		2.98	2.96	1.00	1.03	1.03	1.01	3.06
% lipid		3.9	4.0	4.1	4.5	4.2	4.4	2.2

Table A2. Liver. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Washington gray whales.

Individual PCB isomers								
	Site:	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City	Ocean City
	Animal ID:	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402	RCF 246
	Sample no.:	59-282	59-280	59-397	59-400	59-403	59-431	59-277
2,2',5-trichlorobiphenyl (no. 18) *		nd	nd	4	1	5	nd	nd
2,4,4'-trichlorobiphenyl (no. 28)		2	2	5	3	6	3	2
2,2',3,5'-tetrachlorobiphenyl (no. 44)		2	3	2	6	4	12	3
2,2',5,5'-tetrachlorobiphenyl (no. 52)		61	21	22	27	20	47	26
2,3',4,4'-tetrachlorobiphenyl (no. 66)		8	4	7	14	8	23	4
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		17	13	12	26	19	44	7
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		8	5	6	11	8	14	2
2,3',4,4',5-pentachlorobiphenyl (no. 118)		16	8	9	19	16	28	4
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		2	1	2	4	3	9	0.8
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		29	19	24	41	32	53	6
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		42	26	26	53	41	73	12
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		5	4	7	5	4	9	2
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		10	6	7	16	12	24	2
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		14	11	9	20	16	33	4
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.6	0.5	0.6	1	0.7	0.3	nd
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		1	1	0.8	3	2	0.5	nd
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		2	1	2	5	5	6	0.6

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A3. Liver. Concentrations, ng/g wet weight, of chlorinated analytes in Alaska gray whales.

Chlorinated analytes			
	Site:	Kodiak Island, Karluk	Tugidak Island
	Animal ID:	AKI 101	AKI 102
	Sample no.:	59-438	59-440
hexachlorobenzene		75	11
lindane (gamma-BHC)		2	0.4
heptachlor		3	nd
aldrin		nd	1
heptachlor epoxide		11	1
alpha-chlordane		2	0.7
trans-nonachlor		37	2
dieldrin		34	3
mirex		9	0.6
o,p'-DDE		5	3
p,p'-DDE		66	4
o,p'-DDD		14	nd
p,p'-DDD		8	0.6
o,p'-DDT		nd	nd
p,p'-DDT		0.6	nd
trichlorobiphenyls		9	2
tetrachlorobiphenyls		430	23
pentachlorobiphenyls		220	24
hexachlorobiphenyls		99	12
heptachlorobiphenyls		95	11
octachlorobiphenyls		22	3
nonachlorobiphenyls		2	3
decachlorobiphenyl		4	1
sample weight, grams		1.02	0.99
% lipid		2.9	1.5

Table A4. Liver. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Alaska gray whales.

Individual PCB isomers			
	Site:	Kodiak Island, Karluk	Tugidak Island
	Animal ID:	AKI 101	AKI 102
	Sample no.:	59-438	59-440
2,2',5-trichlorobiphenyl (no. 18) *		nd	7
2,4,4'-trichlorobiphenyl (no. 28)		6	2
2,2',3,5'-tetrachlorobiphenyl (no. 44)		19	4
2,2',5,5'-tetrachlorobiphenyl (no. 52)		34	4
2,3',4,4'-tetrachlorobiphenyl (no. 66)		13	1
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		35	3
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		5	0.7
2,3',4,4',5-pentachlorobiphenyl (no. 118)		9	1
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		3	0.2
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		23	5
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		85	4
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		17	2
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		7	0.5
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		12	0.9
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.9	0.8
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.8	2
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		4	1

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A5. Liver. Concentrations, ng/g wet weight, of chlorinated analytes in a California gray whale.

Chlorinated analytes		
	Site:	Point Richmond
	Animal ID:	SFB 102
	Sample no.:	59-589
hexachlorobenzene		23
lindane (gamma-BHC)		nd
heptachlor		nd
aldrin		nd
heptachlor epoxide		2
alpha-chlordane		2
trans-nonachlor		7
dieldrin		5
mirex		0.3
o,p'-DDE		1
p,p'-DDE		11
o,p'-DDD		1
p,p'-DDD		2
o,p'-DDT		nd
p,p'-DDT		nd
trichlorobiphenyls		2
tetrachlorobiphenyls		25
pentachlorobiphenyls		66
hexachlorobiphenyls		24
heptachlorobiphenyls		14
octachlorobiphenyls		3
nonachlorobiphenyls		2
decachlorobiphenyl		0.7
sample weight, grams		1.07
% lipid		1.4

Table A6. Liver. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in a California gray whale.

Individual PCB isomers		
	Site:	Point Richmond
	Animal ID:	SFB 102
	Sample no.:	59-589
2,2',5-trichlorobiphenyl (no. 18) *		1
2,4,4'-trichlorobiphenyl (no. 28)		1
2,2',3,5'-tetrachlorobiphenyl (no. 44)		5
2,2',5,5'-tetrachlorobiphenyl (no. 52)		7
2,3',4,4'-tetrachlorobiphenyl (no. 66)		0.8
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		3
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		2
2,3',4,4',5-pentachlorobiphenyl (no. 118)		3
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		0.4
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		6
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		7
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		2
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		1
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		2
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.2
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		2
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		0.7

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A7. Blubber. Concentrations, ng/g wet weight, of chlorinated analytes in Washington gray whales.

Chlorinated analytes	Site:	Eagle Point	Hartstene Island	Sequim Bay	Lyre River	Norwegian Memorial	Totten Inlet	Owens Beach
	Animal ID:	CRC 332	CRC 334	CRC 337	GLR 101	CRC 395	CRC 397	CRC 398
	Sample no.:	59-278	59-281	59-801	59-279	59-406	59-398	59-401
hexachlorobenzene		430	250	64	2,900	190	100	37
lindane (gamma-BHC)		nd	nd	nd	nd	9	1	0.9
heptachlor		nd	nd	nd	nd	nd	nd	0.3
aldrin		nd	nd	nd	nd	2	nd	1
heptachlor epoxide		36	16	5	440	27	7	5
alpha-chlordane		47	34	nd	260	15	8	4
trans-nonachlor		300	220	19	1,500	75	41	26
dieldrin		200	84	12	1,600	54	23	11
mirex		18	25	nd	100	4	6	4
o,p'-DDE		23	13	nd	140	8	4	3
p,p'-DDE		590	590	15	2,000	76	79	51
o,p'-DDD		16	nd	5	86	9	5	5
p,p'-DDD		71	41	7	380	14	8	5
o,p'-DDT		180	100	nd	370	17	22	11
p,p'-DDT		nd	nd	nd	nd	5	nd	nd
trichlorobiphenyls		nd	nd	nd	57	11	6	8
tetrachlorobiphenyls		800	410	47	3,700	370	93	74
pentachlorobiphenyls		730	520	52	3,400	200	120	84
hexachlorobiphenyls		420	790	44	1,700	110	99	68
heptachlorobiphenyls		360	370	31	1,400	88	74	48
octachlorobiphenyls		48	80	nd	130	8	12	7
nonachlorobiphenyls		4	9	nd	nd	0.7	1	3
decachlorobiphenyl		8	9	nd	14	2	1	4
sample weight, grams		3.02	2.96	1.01	3.00	1.00	1.03	1.03
% lipid		16	1.9	1.0	0.9	73	2.0	0.8

Table A8. Blubber. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Washington gray whales.

Individual PCB isomers	Site: / Animal ID: / Sample no.:	Eagle Point CRC 332 59-278	Hartstene Island CRC 334 59-281	Sequim Bay CRC 337 59-801	Lyre River GLR 101 59-279	Norwegian Memorial CRC 395 59-406	Totten Inlet CRC 397 59-398	Owens Beach CRC 398 59-401
2,2',5-trichlorobiphenyl (no. 18) *		nd	nd	nd	nd	4	5	6
2,4,4'-trichlorobiphenyl (no. 28)		nd	nd	nd	nd	8	3	2
2,2',3,5'-tetrachlorobiphenyl (no. 44)		nd	nd	11	43	7	5	7
2,2',5,5'-tetrachlorobiphenyl (no. 52)		280	160	16	740	230	26	28
2,3',4,4'-tetrachlorobiphenyl (no. 66)		29	21	4	120	10	6	4
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		75	55	12	410	23	12	8
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		23	29	nd	79	5	6	4
2,3',4,4',5-pentachlorobiphenyl (no. 118)		50	44	4	200	12	11	9
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		4	nd	11	25	2	1	2
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		90	100	9	350	23	21	16
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		130	160	nd	430	25	30	22
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		8	17	3	24	2	2	3
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		19	35	2	45	4	6	5
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		35	56	4	100	6	10	8
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		nd	nd	nd	nd	0.5	0.4	0.8
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		nd	nd	nd	nd	0.7	0.7	2
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		8	9	nd	14	2	1	4

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A9. Blubber. Concentrations, ng/g wet weight, of chlorinated analytes in Washington gray whales.

Chlorinated analytes	Site:	Port Susan	Ocean City	Ocean City	Manchester	Manchester	Ocean City
	Animal ID:	CRC 401	CRC 402	CRC 402	RCF 243A [a]	RCF 243B [a]	RCF 246
			Duplicates [b]				
	Sample no.:	59-404	59-430	59-432	59-721	59-725	59-276
hexachlorobenzene		500	68	63	700	800	220
lindane (gamma-BHC)		22	nd	nd	64	74	nd
heptachlor		nd	nd	nd	nd	nd	nd
aldrin		nd	nd	nd	nd	nd	nd
heptachlor epoxide		170	6	6	99	120	39
alpha-chlordane		74	8	8	27	32	33
trans-nonachlor		380	39	38	190	230	190
dieldrin		440	21	19	230	270	110
mirex		40	6	5	4	4	10
o,p'-DDE		66	6	6	42	51	23
p,p'-DDE		660 [c]	84	78	230	280	230
o,p'-DDD		70 [c]	3	2	35	40	12
p,p'-DDD		140 [c]	8	7	94	110	31
o,p'-DDT		220 [c]	18	17	64	75	47
p,p'-DDT		40 [c]	3	3	17	21	nd
trichlorobiphenyls		23	2	1	32	41	nd
tetrachlorobiphenyls		1,200	91	83	870	910	730
pentachlorobiphenyls		1,200	120	110	570	650	510
hexachlorobiphenyls		770	90	76	390	390	280
heptachlorobiphenyls		750	62	54	190	220	250
octachlorobiphenyls		62	11	10	18	22	19
nonachlorobiphenyls		1	0.3	0.5	nd	1	nd
decachlorobiphenyl		5	4	3	1	2	7
sample weight, grams		1.01	1.03	1.00	1.00	1.02	3.19
% lipid		9.1	0.7	0.6	27	32	0.6

[a] Subsamples were analyzed from two different locations of the sample of blubber.
[b] Duplicates refers to analyses of replicate subsamples of a unique sample.
[c] The identification of the analyte was confirmed by gas chromatography/mass spectrophotometry (GC/MS); the identification would apply to all other samples that had similar GC patterns.

Table A10. Blubber. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Washington gray whales.

Individual PCB isomers							
	Site:	Port Susan	Ocean City	Ocean City	Manchester	Manchester	Ocean City
	Animal ID:	CRC 401	CRC 402	CRC 402	RCF 243A [a]	RCF 243B [a]	RCF 246
			Duplicates [b]				
	Sample no.:	59-404	59-430	59-432	59-721	59-725	59-276
2,2',5-trichlorobiphenyl (no. 18) [c]		12	2	1	13	18	nd
2,4,4'-trichlorobiphenyl (no. 28)		10	nd	nd	16	20	nd
2,2',3,5'-tetrachlorobiphenyl (no. 44)		13	4	4	19	21	nd
2,2',5,5'-tetrachlorobiphenyl (no. 52)		250	35	33	220	280	180
2,3',4,4'-tetrachlorobiphenyl (no. 66)		35	6	5	22	26	20
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		110	13	12	160	190	53
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		120	6	5	13	16	16
2,3',4,4',5-pentachlorobiphenyl (no. 118)		80	10	9	30	35	31
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		10	2	1	6	7	7
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		160	21	18	73	87	64
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		170	29	24	69	83	92
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		12	2	2	3	4	8
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		37	5	5	16	18	11
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		49	9	8	15	18	24
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.8	0.3	0.3	nd	nd	nd
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.3	nd	0.2	nd	nd	nd
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		5	4	3	1	2	7

[a] Subsamples were analyzed from two different locations of the sample of blubber.
[b] Duplicates refers to analyses of replicate subsamples of a unique sample.
[c] The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A11. Blubber. Concentrations, ng/g wet weight, of chlorinated analytes in Washington gray whales.

Chlorinated analytes	Site:	Point Roberts	La Push	Tahola	Ruby Beach	Queets
	Animal ID:	RCF 252	RCF 268	RCF 269	RCF 271	RCF 272
	Sample no.:	59-722	59-724	59-435	59-275	59-274
hexachlorobenzene		17	560	400	170	450
lindane (gamma-BHC)		0.8	7	11	nd	nd
heptachlor		nd	nd	nd	nd	nd
aldrin		nd	nd	nd	nd	nd
heptachlor epoxide		3	60	62	13	24
alpha-chlordane		nd	6	57	19	17
trans-nonachlor		12	180	240	130	120
dieldrin		7	120	190	57	70
mirex		1	3	16	15	8
o,p'-DDE		nd	26	45	nd	14
p,p'-DDE		11	130	490	240	99
o,p'-DDD		1	16	120	nd	22
p,p'-DDD		3	61	140	21	42
o,p'-DDT		1	5	nd	62	nd
p,p'-DDT		nd	nd	4	nd	nd
trichlorobiphenyls		3	11	15	nd	nd
tetrachlorobiphenyls		44	450	700	280	410
pentachlorobiphenyls		32	320	780	290	270
hexachlorobiphenyls		25	260	530	220	130
heptachlorobiphenyls		17	150	260	170	89
octachlorobiphenyls		1	14	38	39	16
nonachlorobiphenyls		nd	nd	3	5	nd
decachlorobiphenyl		nd	2	5	7	5
sample weight, grams		1.05	1.02	1.00	2.97	2.99
% lipid		1.8	6.3	16	1.4	19

Table A12. Blubber. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Washington gray whales.

Individual PCB isomers	Site:	Point Roberts	La Push	Tahola	Ruby Beach	Queets
	Animal ID:	RCF 252	RCF 268	RCF 269	RCF 271	RCF 272
	Sample no.:	59-722	59-724	59-435	59-275	59-274
2,2',5-trichlorobiphenyl (no. 18) *		nd	7	15	nd	nd
2,4,4'-trichlorobiphenyl (no. 28)		2	5	1	nd	nd
2,2',3,5'-tetrachlorobiphenyl (no. 44)		4	6	10	nd	nd
2,2',5,5'-tetrachlorobiphenyl (no. 52)		9	100	180	120	100
2,3',4,4'-tetrachlorobiphenyl (no. 66)		2	12	43	13	12
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		8	120	89	30	27
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		2	11	25	14	nd
2,3',4,4',5-pentachlorobiphenyl (no. 118)		4	25	52	24	12
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		nd	3	8	5	5
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		6	43	83	50	26
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		9	58	130	76	50
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		0.9	2	11	6	5
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		1	9	24	14	9
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		2	6	23	25	8
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		nd	nd	2	nd	nd
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		nd	nd	2	5	nd
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		nd	2	5	7	5

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A13. Blubber. Concentrations, ng/g wet weight, of chlorinated analytes in Alaska gray whales.

Chlorinated analytes			
	Site:	Kodiak Island, Karluk	Tugidak Island
	Animal ID:	AKI 101	AKI 102
	Sample no.:	59-437	59-439
hexachlorobenzene		78	16
lindane (gamma-BHC)		5	0.5
heptachlor		nd	nd
aldrin		1	0.4
heptachlor epoxide		18	3
alpha-chlordane		21	1
trans-nonachlor		92	9
dieldrin		59	4
mirex		24	2
o,p'-DDE		14	0.3
p,p'-DDE		190	9
o,p'-DDD		17	0.2
p,p'-DDD		25	1
o,p'-DDT		72	1
p,p'-DDT		16	0.5
trichlorobiphenyls		4	0.6
tetrachlorobiphenyls		310	59
pentachlorobiphenyls		320	34
hexachlorobiphenyls		270	26
heptachlorobiphenyls		210	23
octachlorobiphenyls		47	3
nonachlorobiphenyls		2	0.6
decachlorobiphenyl		5	1
sample weight, grams		1.04	1.05
% lipid		3.2	0.9

Table A14. Blubber. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Alaska gray whales.

Individual PCB isomers		Kodiak Island, Karluk	Tugidak Island
	Site:	Kodiak Island, Karluk	Tugidak Island
	Animal ID:	AKI 101	AKI 102
	Sample no.:	59-437	59-439
2,2',5-trichlorobiphenyl (no. 18) *		4	nd
2,4,4'-trichlorobiphenyl (no. 28)		nd	nd
2,2',3,5'-tetrachlorobiphenyl (no. 44)		6	4
2,2',5,5'-tetrachlorobiphenyl (no. 52)		160	34
2,3',4,4'-tetrachlorobiphenyl (no. 66)		13	2
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		32	2
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		14	2
2,3',4,4',5-pentachlorobiphenyl (no. 118)		25	2
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		7	1
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		53	6
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		71	9
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		7	0.5
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		16	2
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		31	3
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.7	0.2
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.8	0.3
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		5	1

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A15. Blubber. Concentrations, ng/g wet weight, of chlorinated analytes in California gray whales.

Chlorinated analytes						
	Site:	Point Richmond	Carquinez Strait	Alcatraz Island	Oakland	Oakland
	Animal ID:	SFB 102	SFB 103	SFB 105	SFB 107	SFB 107
					Duplicates *	
	Sample no.:	59-585	59-586	59-588	59-587	59-594
hexachlorobenzene		56	110	200	150	150
lindane (gamma-BHC)		0.4	0.5	1	0.9	1
heptachlor		nd	nd	nd	nd	nd
aldrin		nd	nd	nd	nd	nd
heptachlor epoxide		4	7	19	16	16
alpha-chlordane		8	11	22	18	18
trans-nonachlor		49	68	120	110	100
dieldrin		17	37	85	71	69
mirex		3	4	6	6	5
o,p'-DDE		3	7	13	12	11
p,p'-DDE		60	130	220	200	180
o,p'-DDD		3	22	10	9	nd
p,p'-DDD		10	25	40	35	34
o,p'-DDT		5	2	40	33	27
p,p'-DDT		nd	nd	0.7	0.5	0.5
trichlorobiphenyls		5	6	5	5	5
tetrachlorobiphenyls		73	140	270	230	220
pentachlorobiphenyls		260	170	320	280	260
hexachlorobiphenyls		110	140	230	200	190
heptachlorobiphenyls		67	96	210	190	170
octachlorobiphenyls		11	15	30	22	19
nonachlorobiphenyls		0.6	0.9	2	2	1
decachlorobiphenyl		2	2	3	4	3
sample weight, grams		1.01	0.99	1.11	1.11	1.00
% lipid		1.1	1.6	2.7	1.5	1.3

* Duplicates refers to analyses of replicate subsamples of a unique sample.

Table A16. Blubber. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in California gray whales.

Individual PCB isomers		Point Richmond	Carquinez Strait	Alcatraz Island	Oakland	Oakland
	Site:	Point Richmond	Carquinez Strait	Alcatraz Island	Oakland	Oakland
	Animal ID:	SFB 102	SFB 103	SFB 105	SFB 107	SFB 107
					Duplicates[a]	
	Sample no.:	59-585	59-586	59-588	59-587	59-594
2,2',5-trichlorobiphenyl (no. 18)[b]		2	3	3	1	1
2,4,4'-trichlorobiphenyl (no. 28)		3	3	2	2	6
2,2',3,5'-tetrachlorobiphenyl (no. 44)		4	6	6	5	6
2,2',5,5'-tetrachlorobiphenyl (no. 52)		25	48	82	71	47
2,3',4,4'-tetrachlorobiphenyl (no. 66)		4	7	13	11	18
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		13	18	36	30	25
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		6	8	13	11	19
2,3',4,4',5-pentachlorobiphenyl (no. 118)		10	16	24	21	16
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		2	2	3	3	4
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		20	30	48	43	32
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		28	40	61	55	40
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		9	5	5	5	8
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		5	7	14	12	10
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		8	13	16	18	11
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.2	0.4	0.7	0.7	0.6
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.4	0.5	1	1	0.8
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		2	2	3	4	3

[a] Duplicates refers to analyses of replicate subsamples of a unique sample.
[b] The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A17. Brain. Concentrations, ng/g wet weight, of chlorinated analytes in a Washington gray whale.

Chlorinated analytes		
	Site:	Hartstene Island
	Animal ID:	CRC 334
	Sample no.:	59-283
hexachlorobenzene		110
lindane (gamma-BHC)		nd
heptachlor		nd
aldrin		nd
heptachlor epoxide		8
alpha-chlordane		11
trans-nonachlor		32
dieldrin		47
mirex		3
o,p'-DDE		4
p,p'-DDE		100
o,p'-DDD		11
p,p'-DDD		10
o,p'-DDT		4
p,p'-DDT		nd
trichlorobiphenyls		3
tetrachlorobiphenyls		120
pentachlorobiphenyls		140
hexachlorobiphenyls		81
heptachlorobiphenyls		59
octachlorobiphenyls		10
nonachlorobiphenyls		1
decachlorobiphenyl		1
sample weight, grams		5.13
% lipid		11

Table A18. Brain. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in a Washington gray whale.

Individual PCB isomers	Site:	Hartstene Island
	Animal ID:	CRC 334
	Sample no.:	59-283
2,2',5-trichlorobiphenyl (no. 18) *		5
2,4,4'-trichlorobiphenyl (no. 28)		nd
2,2',3,5'-tetrachlorobiphenyl (no. 44)		2
2,2',5,5'-tetrachlorobiphenyl (no. 52)		39
2,3',4,4'-tetrachlorobiphenyl (no. 66)		5
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		17
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		5
2,3',4,4',5-pentachlorobiphenyl (no. 118)		10
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		1
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		18
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		26
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		2
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		5
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		7
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		nd
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		nd
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		1

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A19. Stomach Contents. Concentrations, ng/g wet weight, of chlorinated analytes in Washington gray whales.

Chlorinated analytes	Site:	Eagle Point	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City
	Animal ID:	CRC 332	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402
	Sample no.:	59-289	59-290	59-291	59-399	59-402	59-405	59-426
hexachlorobenzene		29	23	39	10	12	70	40
lindane (gamma-BHC)		nd	nd	nd	nd	nd	nd	4
heptachlor		nd	nd	nd	nd	nd	nd	nd
aldrin		nd	nd	nd	nd	nd	0.9	nd
heptachlor epoxide		1	1	1	nd	nd	nd	3
alpha-chlordane		0.3	1	0.2	0.4	1	1	0.3
trans-nonachlor		11	9	10	2	4	21	13
dieldrin		11	9	12	1	1	15	13
mirex		1	0.7	2	1	2	4	nd
o,p'-DDE		0.7	0.6	0.7	nd	nd	0.5	2
p,p'-DDE		32	21	24	4	7	62	42
o,p'-DDD		2	2	0.9	1	1	4	3
p,p'-DDD		3	3	1	1	0.6	4	3
o,p'-DDT		nd	0.3	nd	nd	nd	1	nd
p,p'-DDT		nd	nd	nd	0.6	nd	nd	nd
trichlorobiphenyls		2	1	9	2	4	4	3
tetrachlorobiphenyls		57	26	79	49	31	78	56
pentachlorobiphenyls		26	20	24	24	25	84	44
hexachlorobiphenyls		20	15	18	5	22	52	32
heptachlorobiphenyls		16	8	12	10	10	43	20
octachlorobiphenyls		4	2	3	nd	4	1	5
nonachlorobiphenyls		0.6	0.4	0.3	1	0.5	2	0.4
decachlorobiphenyl		0.4	0.4	0.3	0.6	0.7	2	0.3
sample weight, grams		5.02	5.27	5.01	1.01	1.04	1.02	3.13
% lipid		1.6	1.6	1.6	0.8	1.1	1.8	0.8

Table A20. Stomach Contents. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in Washington gray whales.

Individual PCB isomers		Eagle Point	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City
	Site:	Eagle Point	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City
	Animal ID:	CRC 332	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402
	Sample no.:	59-289	59-290	59-291	59-399	59-402	59-405	59-426
2,2',5-trichlorobiphenyl (no. 18) *		1	nd	nd	1	5	3	3
2,4,4'-trichlorobiphenyl (no. 28)		0.6	nd	2	2	1	2	0.1
2,2',3,5'-tetrachlorobiphenyl (no. 44)		2	0.8	5	5	4	5	2
2,2',5,5'-tetrachlorobiphenyl (no. 52)		14	9	11	8	8	27	18
2,3',4,4'-tetrachlorobiphenyl (no. 66)		2	1	1	6	6	15	3
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		3	2	3	3	4	6	5
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		1	0.9	1	0.8	1	4	2
2,3',4,4',5-pentachlorobiphenyl (no. 118)		3	2	2	3	3	6	5
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		0.4	0.2	0.3	0.6	3	2	0.8
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		5	3	5	4	7	15	8
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		7	5	7	4	7	19	10
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		1	0.8	0.9	1	2	0.6	2
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		1	1	1	1	2	5	2
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		2	1	2	0.7	2	4	3
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		nd	nd	nd	nd	0.2	0.4	0.2
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.3	0.2	0.2	1	0.5	2	0.1
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		0.4	0.4	0.3	0.6	0.7	2	0.3

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A21. Stomach Contents. Concentrations, ng/g wet weight, of chlorinated analytes in an Alaska gray whale.

Chlorinated analytes		
	Site:	Tugidak Island
	Animal ID:	AKI 102
	Sample no.:	59-427
hexachlorobenzene		14
lindane (gamma-BHC)		4
heptachlor		0.1
aldrin		nd
heptachlor epoxide		3
alpha-chlordane		0.4
trans-nonachlor		2
dieldrin		2
mirex		0.6
o,p'-DDE		nd
p,p'-DDE		7
o,p'-DDD		nd
p,p'-DDD		4
o,p'-DDT		nd
p,p'-DDT		nd
trichlorobiphenyls		6
tetrachlorobiphenyls		54
pentachlorobiphenyls		21
hexachlorobiphenyls		13
heptachlorobiphenyls		14
octachlorobiphenyls		3
nonachlorobiphenyls		0.8
decachlorobiphenyl		1
sample weight, grams		3.00
% lipid		1.7

Table A22. Stomach Contents. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in an Alaska gray whale.

Individual PCB isomers		
	Site:	Tugidak Island
	Animal ID:	AKI 102
	Sample no.:	59-427
2,2',5-trichlorobiphenyl (no. 18) *		8
2,4,4'-trichlorobiphenyl (no. 28)		0.4
2,2',3,5'-tetrachlorobiphenyl (no. 44)		3
2,2',5,5'-tetrachlorobiphenyl (no. 52)		4
2,3',4,4'-tetrachlorobiphenyl (no. 66)		1
2,2',4,5,5'-pentachlorobiphenyl (no. 101)		1
2,3,3'4,4'-pentachlorobiphenyl (no. 105)		0.6
2,3',4,4',5-pentachlorobiphenyl (no. 118)		1
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)		0.4
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)		2
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)		3
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)		10
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)		0.5
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)		0.4
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)		0.2
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)		0.4
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)		1

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A23. Method blanks. Concentrations, ng/g wet weight, of chlorinated analytes in method blanks.

Chlorinated analytes	Lab no.: 59-284	59-293	59-408	59-442	59-596	59-728
hexachlorobenzene	nd	nd	nd	nd	nd	nd
lindane (gamma-BHC)	nd	nd	nd	nd	nd	nd
heptachlor	nd	nd	nd	nd	nd	nd
aldrin	nd	nd	nd	nd	nd	nd
heptachlor epoxide	nd	nd	nd	nd	nd	nd
alpha-chlordane	nd	nd	nd	nd	nd	nd
trans-nonachlor	nd	nd	nd	nd	nd	nd
dieldrin	nd	nd	nd	nd	nd	nd
mirex	nd	nd	nd	nd	nd	nd
o,p'-DDE	nd	nd	nd	nd	nd	nd
p,p'-DDE	nd	nd	nd	nd	nd	nd
o,p'-DDD	nd	nd	nd	nd	nd	nd
p,p'-DDD	nd	nd	nd	nd	nd	nd
o,p'-DDT	nd	nd	nd	nd	nd	nd
p,p'-DDT	nd	nd	nd	nd	nd	nd
trichlorobiphenyls	nd	0.9	1	nd	2	6
tetrachlorobiphenyls	nd	2	5	5	7	nd
pentachlorobiphenyls	2	2	4	2	4	nd
hexachlorobiphenyls	nd	0.4	2	2	2	nd
heptachlorobiphenyls	nd	nd	nd	nd	0.3	nd
octachlorobiphenyls	nd	nd	nd	nd	nd	nd
nonachlorobiphenyls	nd	nd	nd	nd	nd	nd
decachlorobiphenyl	nd	nd	nd	nd	nd	nd

Table A24. Method blanks. Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in method blanks.

Individual PCB isomers	Sample no.: 59-284	59-293	59-408	59-442	59-596	59-728
2,2',5-trichlorobiphenyl (no. 18) *	nd	nd	nd	nd	1	nd
2,4,4'-trichlorobiphenyl (no. 28)	nd	nd	1	nd	0.9	nd
2,2',3,5'-tetrachlorobiphenyl (no. 44)	nd	nd	3	4	3	4
2,2',5,5'-tetrachlorobiphenyl (no. 52)	nd	nd	nd	nd	0.6	nd
2,3',4,4'-tetrachlorobiphenyl (no. 66)	nd	nd	0.7	nd	0.9	nd
2,2',4,5,5'-pentachlorobiphenyl (no. 101)	nd	nd	0.8	0.4	0.7	nd
2,3,3'4,4'-pentachlorobiphenyl (no. 105)	nd	nd	nd	nd	nd	nd
2,3',4,4',5-pentachlorobiphenyl (no. 118)	nd	nd	0.9	0.6	0.9	nd
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)	nd	nd	nd	nd	nd	nd
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)	nd	nd	1	1	1	nd
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)	nd	nd	nd	1	0.8	nd
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)	nd	nd	nd	nd	0.3	nd
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)	nd	nd	nd	nd	nd	nd
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)	nd	nd	nd	nd	nd	nd
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)	nd	nd	nd	nd	nd	nd
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)	nd	nd	nd	nd	nd	nd
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)	nd	nd	nd	nd	nd	nd

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

Table A25. National Institute of Standards and Technology (NIST) reference tissue *(Mytilus edulis)*.
Concentrations, ng/g wet weight, of chlorinated analytes in NIST Standard Reference Material Control Tissue SRM 1974.

							Analyzed SRM 1974 (n= 15)	
Chlorinated analytes	Sample no. : 59-285	59-294	59-407	59-441	59-595	59-727	Mean	RSD
hexachlorobenzene	nd	nd	0.5	0.3	nd	nd	1	120
lindane (gamma-BHC)	nd	nd	0.1	0.1	0.3	nd	0.9	0
heptachlor	nd	nd	nd	nd	0.2	nd	1	0
aldrin	nd	nd	3	3	3	nd	2	95
heptachlor epoxide	0.8	nd	nd	0.6	0.2	nd	0.8	18
alpha-chlordane	2	4	3	3	4	3	3	28
trans-nonachlor	2	3	2	2	3	3	2	31
dieldrin	3	4	0.5	2	2	1	3	70
mirex	nd	nd	nd	nd	0.2	nd	0.2	45
o,p'-DDE	2	2	1	2	2	2	2	33
p,p'-DDE	4	7	4	4	7	7	5	23
o,p'-DDD	2	2	1	1	3	2	2	34
p,p'-DDD	5	10	3	4	8	6	5	38
o,p'-DDT	0.9	1	0.2	0.9	1	1	0.9	53
p,p'-DDT	nd	0.5	0.2	0.3	0.4	nd	0.6	100
trichlorobiphenyls	20	28	21	19	28	19	21	31
tetrachlorobiphenyls	170	210	150	140	220	170	170	18
pentachlorobiphenyls	110	140	100	100	160	120	120	20
hexachlorobiphenyls	42	48	47	44	64	61	47	23
heptachlorobiphenyls	7	7	10	9	16	11	9	38
octachlorobiphenyls	nd	nd	0.7	0.3	0.3	nd	0.7	120
nonachlorobiphenyls	nd	0.2	0.4	0.8	0.2	nd	0.4	76
decachlorobiphenyl	nd	nd	nd	0.2	0.2	nd	0.9	110
sample weight, grams	5.01	5.10	3.01	2.99	3.03	3.04	-	-

Table A26. National Institute of Standards and Technology (NIST) reference tissue *(Mytilus edulis)*.
Concentrations, ng/g wet weight, of individual polychlorinated biphenyl (PCB) isomers in NIST Standard Reference Material Control Tissue SRM 1974.

							Analyzed SRM 1974 (n= 15)	
Individual PCB isomers	Sample no.: 59-285	59-294	59-407	59-441	59-595	59-727	Mean	RSD
2,2',5-trichlorobiphenyl (no. 18) *	3	4	5	4	5	5	4	30
2,4,4'-trichlorobiphenyl (no. 28)	19	25	18	17	55	16	19	35
2,2',3,5'-tetrachlorobiphenyl (no. 44)	10	13	10	9	14	12	10	20
2,2',5,5'-tetrachlorobiphenyl (no. 52)	15	18	15	14	15	17	16	15
2,3',4,4'-tetrachlorobiphenyl (no. 66)	23	29	22	21	54	18	24	18
2,2',4,5,5'-pentachlorobiphenyl (no. 101)	16	18	16	16	20	20	18	22
2,3,3'4,4'-pentachlorobiphenyl (no. 105)	5	7	4	4	10	6	7	110
2,3',4,4',5-pentachlorobiphenyl (no. 118)	15	18	15	14	16	19	16	19
2,2',3,3',4,4'-hexachlorobiphenyl (no. 128)	2	3	2	2	5	3	2	32
2,2',3,4,4',5'-hexachlorobiphenyl (no. 138)	14	17	15	15	18	19	16	21
2,2',4,4',5,5'-hexachlorobiphenyl (no. 153)	19	20	20	19	17	27	20	22
2,2',3,3',4,4',5-heptachlorobiphenyl (no. 170)	0.6	0.8	0.7	0.7	2	nd	0.7	36
2,2',3,4,4',5,5'-heptachlorobiphenyl (no. 180)	1	2	2	2	3	3	2	43
2,2',3,4',5,5',6-heptachlorobiphenyl (no. 187)	3	3	4	4	4	6	4	25
2,2',3,3',4,4',5,6-octachlorobiphenyl (no. 195)	nd	nd	0.4	0.3	0.5	nd	0.5	99
2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (no. 206)	nd	0.2	0.4	0.8	0.2	nd	0.4	76
2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (no. 209)	nd	nd	nd	0.2	0.1	nd	0.9	110

* The accepted numbering system for PCB isomers as developed by Ballschmiter and Zell (1980).

APPENDIX B

CONCENTRATIONS OF AROMATIC CONTAMINANTS IN GRAY WHALE SAMPLES, METHOD BLANKS, AND QUALITY CONTROL MATERIALS

Aromatic Contaminants in Samples from Gray Whales
Explanatory Notes for Tables B1 through B6.

Abbreviations used:

LACs - sum of 2,3-ring aromatic contaminants (lower molecular weight).

HACs - sum of 4-6-ring aromatic contaminants (higher molecular weight).

nd - indicates that the analyte was not detected above the limit of detection which ranged from 0.5 to 2 ng/g (ppb) wet weight.

RSD - relative standard deviation is the standard deviation divided by the mean and expressed as a percent.

Results were determined by gas chromatography (GC)/mass spectrophotometry (MS) - multiple ion detection.

Naphthalene-d8 was the internal standard (surrogate standard) for naphthalene through C4-naphthalenes. Acenaphthene-d10 was the internal standard for acenaphthylene through C1-fluoranthenes/pyrene. Benzo[a]pyrene-d12 was the internal standard for benz[a]anthracene through benzo[ghi]perylene.

Percent recoveries for the internal standards averaged 86%, RSD = 19%, n = 35. Percent recoveries of the surrogates include quality assurance samples.

Table B1. Stomach Contents. Concentrations, ng/g wet weight, of lower molecular weight aromatic contaminants (LACs) in Washington gray whales.

	Site:	Eagle Point	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City	Tugidak Island
	Animal ID:	CRC 332	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402	AKI 102
Aromatic contaminants	Sample no.:	59-289	59-290	59-291	59-399	59-402	59-405	59-426	59-427
naphthalene		*	*	*	*	*	*	*	*
C1-naphthalenes		78	nd	2	27	25	11	3	5
C2-naphthalenes		88	nd	nd	55	17	7	2	9
C3-naphthalenes		68	nd	nd	86	8	nd	2	10
C4-naphthalenes		25	nd	nd	73	nd	nd	nd	6
acenaphthylene		1	nd	nd	12	nd	3	nd	nd
acenaphthene		1	nd	nd	12	18	4	nd	nd
fluorene		9	nd	1	20	20	3	nd	2
C1-fluorenes		12	nd	nd	18	5	nd	nd	2
C2-fluorenes		17	nd	nd	31	nd	nd	nd	3
C3-fluorenes		29	nd	nd	18	nd	nd	nd	nd
phenanthrene		49	*	4	150	64	10	2	4
C1-phenanthrenes/anthracenes		48	nd	4	82	23	5	*	6
C2-phenanthrenes/anthracenes		62	nd	nd	96	17	nd	0.6	6
C3-phenanthrenes/anthracenes		42	nd	nd	120	2	nd	nd	2
C4-phenanthrenes/anthracenes		12	nd	nd	27	nd	nd	nd	nd
dibenzothiophene		5	nd	nd	16	7	nd	nd	0.7
C1-dibenzothiophenes		5	nd	nd	11	3	nd	nd	0.5
C2-dibenzothiophenes		6	nd	nd	10	nd	nd	nd	nd
C3-dibenzothiophenes		6	nd	nd	nd	nd	nd	nd	nd
sample weight, grams		5.02	5.27	5.01	1.01	1.04	1.02	3.13	3.00

* Low levels of the analyte were indistinguishable from those of the blank analyses.

Table B2. Stomach Contents. Concentrations, ng/g wet weight, of higher molecular weight aromatic contaminants (HACs) in Washington gray whales.

Aromatic contaminants	Site: Animal ID: Sample no.:	Eagle Point CRC 332 59-289	Hartstene Island CRC 334 59-290	Lyre River GLR 101 59-291	Totten Inlet CRC 397 59-399	Owens Beach CRC 398 59-402	Port Susan CRC 401 59-405	Ocean City CRC 402 59-426	Tugidak Island AKI 102 59-427
fluoranthene		23	2	0.5	230	71	17	*	1
pyrene		23	1	0.8	230	47	14	*	1
C1-fluoranthenes/pyrenes		23	nd	0.3	72	44	9	1	3
benz[a]anthracene		8	0.3	1	65	19	9	0.3	0.4
chrysene		14	0.9	nd	58	56	10	0.5	1
C1-chrysenes/benz[a]anthracenes		18	nd	nd	33	8	3	0.3	1
C2-chrysenes/benz[a]anthracenes		12	nd	nd	43	2	nd	0.8	1
C3-chrysenes/benz[a]anthracenes		7	nd	nd	50	nd	nd	0.6	nd
C4-chrysenes/benz[a]anthracenes		0.6	nd	nd	3	nd	nd	nd	nd
benzo[b]fluoranthene		8	0.7	1	130	10	6	0.3	0.7
benzo[k]fluoranthene		6	0.5	0.2	36	7	4	0.2	0.2
benzo[a]pyrene		7	0.4	0.2	45	5	3	nd	0.2
indeno[1,2,3-cd]pyrene		5	0.5	0.3	87	5	3	nd	0.3
dibenz[a,h]anthracene		5	0.5	0.4	17	1	0.9	nd	nd
benzo[ghi]perylene		6	0.5	1	94	4	2	nd	0.6
sample weight, grams		5.02	5.27	5.01	1.01	1.04	1.02	3.13	3.00

* Low levels of the analyte were indistinguishable from those of the blank analyses.

Table B3. Method blanks. Concentrations, ng/g wet weight, of lower molecular weight aromatic contaminants (LACs) in method blanks.

Aromatic contaminants	Sample no.:	59-293	59-408
naphthalene		3	5
C1-naphthalenes		nd	nd
C2-naphthalenes		nd	nd
C3-naphthalenes		nd	nd
C4-naphthalenes		nd	nd
acenaphthylene		nd	nd
acenaphthene		nd	nd
fluorene		nd	nd
C1-fluorenes		nd	nd
C2-fluorenes		nd	nd
C3-fluorenes		nd	nd
phenanthrene		0.6	nd
C1-phenanthrenes/anthracenes		nd	nd
C2-phenanthrenes/anthracenes		nd	nd
C3-phenanthrenes/anthracenes		nd	nd
C4-phenanthrenes/anthracenes		nd	nd
dibenzothiophene		nd	nd
C1-dibenzothiophenes		nd	nd
C2-dibenzothiophenes		nd	nd
C3-dibenzothiophenes		nd	nd

Table B4. Method blanks. Concentrations, ng/g wet weight, of higher molecular weight aromatic contaminants (HACs) in method blanks.

Aromatic contaminants	Sample no.:	59-293	59-408
fluoranthene		nd	nd
pyrene		nd	nd
C1-fluoranthenes/pyrenes		nd	nd
benz[a]anthracene		nd	nd
chrysene		nd	nd
C1-chrysenes/benz[a]anthracenes		nd	nd
C2-chrysenes/benz[a]anthracenes		nd	nd
C3-chrysenes/benz[a]anthracenes		nd	nd
C4-chrysenes/benz[a]anthracenes		nd	nd
benzo[b]fluoranthene		nd	nd
benzo[k]fluoranthene		nd	nd
benzo[a]pyrene		nd	nd
indeno[1,2,3-cd]pyrene		nd	nd
dibenz[a,h]anthracene		nd	nd
benzo[ghi]perylene		nd	nd

Table B5. National Institute of Standards and Technology (NIST) reference tissue *(Mytilus edulis)*. Concentrations, ng/g wet weight, of lower molecular weight aromatic contaminants (LACs) in NIST Standard Reference Material Control Tissue SRM 1974.

Aromatic contaminants	Sample no.: 59-294	59-407	Analyzed SRM 1974 (n=103 for parents) (n=88 for alkyls) Mean	RSD
naphthalene	4	3	4	39
C1-naphthalenes	2	3	4	45
C2-naphthalenes	2	4	4	51
C3-naphthalenes	4	8	9	40
C4-naphthalenes	24	19	24	42
acenaphthylene	0.8	1	0.6	52
acenaphthene	nd	1	0.8	40
fluorene	1	nd	1	43
C1-fluorenes	4	4	4	33
C2-fluorenes	25	22	21	39
C3-fluorenes	36	35	24	64
phenanthrene	7	4	6	24
C1-phenanthrenes/anthracenes	17	7	12	31
C2-phenanthrenes/anthracenes	66	30	47	31
C3-phenanthrenes/anthracenes	55	37	51	36
C4-phenanthrenes/anthracenes	22	14	12	75
dibenzothiophene	0.7	0.7	0.9	37
C1-dibenzothiophenes	4	4	6	33
C2-dibenzothiophenes	29	25	30	34
C3-dibenzothiophenes	21	30	35	38
sample weight, grams	5.10	3.01	-	-

Table B6. National Institute of Standards and Technology (NIST) reference tissue ***(Mytilus edulis)***. Concentrations, ng/g wet weight, of higher molecular weight aromatic contaminants (HACs) in NIST Standard Reference Material Control Tissue SRM 1974.

Aromatic contaminants	Sample no.: 59-294	59-407	Analyzed SRM 1974 (n=103 for parents) (n=88 for alkyls) Mean	RSD
fluoranthene	46	43	46	15
pyrene	46	38	44	15
C1-fluoranthenes/pyrenes	21	26	24	27
benz[a]anthracene	6	5	5	24
chrysene	23	14	18	15
C1-chrysenes/benz[a]anthracenes	10	5	7	36
C2-chrysenes/benz[a]anthracenes	16	3	3	76
C3-chrysenes/benz[a]anthracenes	nd	nd	1	86
C4-chrysenes/benz[a]anthracenes	nd	nd	1	86
benzo[b]fluoranthene	9	6	7	33
benzo[k]fluoranthene	6	4	4	29
benzo[a]pyrene	2	0.5	2	52
indeno[1,2,3-cd]pyrene	2	2	2	55
dibenz[a,h]anthracene	0.6	0.5	0.4	69
benzo[ghi]perylene	3	2	2	44
sample weight, grams:	5.10	3.01	-	-

APPENDIX C

CONCENTRATIONS OF ELEMENTS
IN GRAY WHALE SAMPLES AND METHOD BLANK

Elements in Samples from Gray Whales
Explanatory Notes for Tables C1 through C10.

nd - indicates that the analyte was not detected above the limit of detection which ranged from 2 to 30 ng/g (ppb) wet weight.

Results were determined by atomic absorption spectrophotometry and inductively coupled argon plasma emission spectroscopy.

Table 4 (page 36) contains quality control data on Certified Reference Materials.

Table C1. Liver. Concentrations, ng/g wet weight, of elements in Washington gray whales.

Elements	Site:	Hartstene Island	Lyre River	Totten Inlet	Owens Beach	Port Susan	Ocean City	Ocean City
	Animal ID:	CRC 334	GLR 101	CRC 397	CRC 398	CRC 401	CRC 402	RCF 246
aluminum		9,200	9,200	8,500	93,000	16,000	18,000	4,600
iron		4,200,000	3,600,000	*	*	*	*	1,400,000
chromium		110	150	nd	nd	nd	nd	130
manganese		3,000	3,000	*	*	*	*	3,000
nickel		350	100	*	*	*	*	nd
copper		6,500	8,300	5,700	25,000	9,500	16,000	9,400
zinc		150,000	120,000	120,000	160,000	140,000	89,000	75,000
arsenic		390	410	530	700	440	360	160
selenium		2,300	2,100	2,500	2,400	3,000	3,400	1,100
silver		20	20	*	*	*	*	10
cadmium		6,800	3,100	5,100	11,000	7,400	6,200	210
mercury		100	120	80	60	10	80	30
lead		110	110	150	80	190	110	140
strontium		*	*	200	550	210	930	*
tin		*	*	nd	nd	nd	nd	*
barium		*	*	20	80	10	70	*
sample weight, grams		1.5	1.4	1.3	1.4	1.4	1.2	1.2
% dry weight		23	24	20	22	19	23	23

* The sample was not anaylzed for this element.

Table C2. Liver. Concentrations, ng/g wet weight, of elements in Alaska gray whales.

	Site:	Kodiak Island, Karluk	Tugidak Island
Elements	Animal ID:	AKI 101	AKI 102
aluminum		10,000	150,000
iron		*	*
chromium		nd	250
manganese		*	*
nickel		*	*
copper		9,600	1,200
zinc		93,000	1,600
arsenic		270	140
selenium		2,200	1,000
silver		*	*
cadmium		2,700	200
mercury		40	9
lead		60	270
strontium		880	4,400
tin		nd	nd
barium		30	94
sample weight, grams		1.2	1.5
% dry weight		22	15

* The sample was not anaylzed for this element.

Table C3. Liver. Concentrations, ng/g wet weight, of elements in a California gray whale.

	Site:	Point Richmond
Elements	Animal ID:	SFB 102
aluminum		6,400
iron		120,000
chromium		nd
manganese		*
nickel		*
copper		630
zinc		46,000
arsenic		47
selenium		350
silver		nd
cadmium		60
mercury		30
lead		20
strontium		520
tin		40
barium		120
sample weight, grams		1.3
% dry weight		18

* The sample was not anaylzed for this element.

Table C4. Kidney. Concentrations, ng/g wet weight, of elements in Washington gray whales.

Elements	Site: / Animal ID:	Eagle Point CRC 332	Hartstene Island CRC 334	Lyre River GLR 101	Totten Inlet CRC 397	Owens Beach CRC 398	Port Susan CRC 401	Ocean City CRC 402
aluminum		9,300	17,000	1,600	1,800	4,100	1,800	1,700
iron		75,000	150,000	100,000	*	*	*	*
chromium		1,000	260	70	60	10	40	10
manganese		nd	nd	nd	*	*	*	*
nickel		210	200	nd	*	*	*	*
copper		2,900	1,500	3,200	2,400	2,000	2,400	2,600
zinc		59,000	32,000	78,000	47,000	47,000	36,000	32,000
arsenic		270	230	190	160	150	150	90
selenium		1,100	1,500	2,100	1,200	1,200	1,800	1,000
silver		30	10	10	*	*	*	*
cadmium		3,700	3,700	5,100	5,200	5,200	6,100	4,200
mercury		nd	nd	60	20	20	30	20
lead		80	80	100	30	50	40	10
strontium		*	*	*	1,600	1,000	1,200	1,600
tin		*	*	*	nd	nd	nd	nd
barium		*	*	*	140	80	60	140
sample weight, grams		1.0	1.0	1.0	1.0	1.0	1.0	1.0
% dry weight		27	30	25	27	27	26	25

* The sample was not anaylzed for this element.

Table C5. Kidney. Concentrations, ng/g wet weight, of elements in Alaska gray whales.

Elements	Site: / Animal ID:	Kodiak Island, Karluk AKI 101	Tugidak Island AKI 102
aluminum		2,800	4,800
iron		*	*
chromium		30	10
manganese		*	*
nickel		*	*
copper		450	1,600
zinc		45,000	35,000
arsenic		10	2,700
selenium		340	1,100
silver		*	*
cadmium		140	2,600
mercury		30	30
lead		nd	10
strontium		770	2,300
tin		nd	50
barium		20	10
sample weight, grams		1.0	1.0
% dry weight		23	30

* The sample was not anaylzed for this element.

Table C6. Kidney. Concentrations, ng/g wet weight, of elements in a California gray whale.

	Site:	Point Richmond
Elements	Animal ID:	SFB 102
aluminum		5,100
iron		84,000
chromium		nd
manganese		*
nickel		*
copper		4,900
zinc		110,000
arsenic		480
selenium		1,600
silver		nd
cadmium		5,400
mercury		60
lead		80
strontium		1,300
tin		30
barium		160
sample weight, grams		1.0
% dry weight		21

* The sample was not anaylzed for this element.

Table C7. Stomach Contents. Concentrations, ng/g wet weight, of elements in Washington gray whales.

Elements	Site: / Animal ID:	Eagle Point CRC 332	Hartstene Island CRC 334	Lyre River GLR 101	Totten Inlet CRC 397	Owens Beach CRC 398	Port Susan CRC 401	Ocean City CRC 402
aluminum		3,100,000	190,000	940,000	3,400,000	580,000	1,800,000	860,000
iron		5,800	140,000	810,000	*	*	*	*
chromium		11,000	360	5,400	2,700	500	4,800	510
manganese		54,000	11,000	5,100	*	*	*	*
nickel		1,500	240	380	*	*	*	*
copper		8,000	4,200	66,000	15,000	3,000	14,000	5,100
zinc		19,000	10,000	85,000	3,200	7,300	40,000	22,000
arsenic		11,000	640	1,300	2,300	1,800	14,000	980
selenium		430	470	2,300	420	700	1,400	470
silver		10	30	30	*	*	*	*
cadmium		50	40	530	230	380	840	690
mercury		100	20	70	160	30	500	30
lead		320	300	100	3,300	380	2,600	140
strontium		*	*	*	3,000	1,900	150,000	360,000
tin		*	*	*	nd	20	nd	nd
barium		*	*	*	2,100	310	3,600	16,000
sample weight, grams		0.7	3.5	1.3	0.7	2.8	1.6	0.9
% dry weight		50	8	25	50	12	18	31

* The sample was not anaylzed for this element.

Table C8. Stomach Contents. Concentrations, ng/g wet weight, of elements in an Alaska gray whale

	Site:	Tugidak Island
Elements	Animal ID:	AKI 102
aluminum		2,900,000
iron		*
chromium		2,100
manganese		*
nickel		*
copper		55,000
zinc		41,000
arsenic		16,000
selenium		1,400
silver		*
cadmium		1,700
mercury		80
lead		350
strontium		410,000
tin		nd
barium		24,000
sample weight, grams		1.2
% dry weight		25

* The sample was not anaylzed for this element.

Table C9. Brain. Concentrations, ng/g wet weight, of elememts in a Washington gray whale.

	Site:	Hartstene Island
Elements	Animal ID:	CRC 334
aluminum		2,300
iron		39,000
chromium		60
manganese		nd
nickel		nd
copper		2,400
zinc		10,000
arsenic		nd
selenium		100
silver		20
cadmium		20
mercury		nd
lead		60
strontium		*
tin		*
barium		*
sample weight, grams		1.0
% dry weight		37

* The sample was not anaylzed for this element.

Table C10. Method Blanks. Concentrations, ng/g wet weight, of elements in method blanks.

Elements	
aluminum	4.5
iron	*
chromium	0.3
manganese	*
nickel	*
copper	0.3
zinc	0.1
arsenic	6.3
selenium	4.2
silver	0.8
cadmium	0.1
mercury	*
lead	4.2
strontium	0.2
tin	*
barium	0.2

* Data not available for this element.

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