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CHEMICAL CONTAMINANTS IN MARINE MAMMALS FROM WASHINGTON STATE

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PREFACE

This research report was initiated and funded by the Marine Ecosystems (MESA) Puget Sound Project of NOAA in Seattle. The Project was incorporated into the Ocean Assessments Division in 1982. The overall goals of the Project were to determine the existing levels, fates and effects of toxic chemicals in Puget Sound. In earlier studies the Project had focused primarily upon determining the concentrations of toxic chemicals in sediments, water, invertebrates and fish from Puget Sound. This study was conducted as an initial step to determine the existence and concentrations of toxic chemicals in upper trophic level animals, namely the marine mammals. Previously-acquired data are summarized and reported along with new measurements. The report was prepared by scientists in Cascadia Research Collective, the National Marine Mammal Laboratory, and incorporated data contributed by the Bodega Marine Laboratory and the Moss Landing Marine Laboratory. The Contracting Officer's Technical Representative for this study was Edward Long.

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Many persons contributed to the success of our effort. Steve Jeffries and Murray Johnson of the University of Puget Sound, John Rozdilsky of the Burke Memorial Washington Museum, and Jim Boran, Rich Osborne, and Chuck Flaherty of the Whale Museum all provided marine mammal tissues for analysis. Terry Newby provided information on some of his earlier research. Susanne Carter, Kathryn Bowman, Pierre Dawson, Thomas Fleischner, Joanne Schuett-Hames, John Skidmore, and Barbara Taylor all aided in the chemical analyses at The Evergreen State College. Chlorinated hydrocarbon analyses at The Evergreen State College were funded in part by a National Science Foundation Student Originated Study Grant. Dr. Steve Herman provided crucial advice and help.

Robert W. Risebrough, Walter M. Jarman, Brock W. de Lappe and Wayman Walker II contributed data obtained in the analyses of a series of samples at the Bodega Marine Laboratory. John H. Martin and Mark Stevenson, Moss Landing Marine Laboratory, analyzed a series of harbor seal kidney and liver samples for heavy metals and trace elements. Robert Giauque, Lawrence Berkeley Laboratory, analyzed replicates of a subsample of harbor seal kidney and liver tissues for selenium, and for other trace elements and metals.

Edward Long, Robert Risebrough, and Steven Speich critically reviewed the manuscript. Mary-Pat Larsen advised on statistical matters and conducted a major portion of the statistical tests. Nancy Herman provided some of the graphics for the manuscript. Shirley Beelik and Debbie Robinson helped in conducting the literature search. We thank all these individuals.

EXECUTIVE SUMMARY

The objectives of this study were to report the results of recent analyses of environmental toxicants in Washington marine mammals and evaluate the evidence for pollutant-related effects in marine mammals. In the last eight years, samples of close to 100 marine mammals from Washington State have been analyzed for concentrations of the chlorinated hydrocarbons: polychlorinated biphenyls (PCBs) and 2,2-bis-(p-chlorophenyl)-1,1-dichloroethylene (DDE). These samples have consisted primarily of harbor seal tissues, but also include minke whale, killer whale, pygmy sperm whale, harbor porpoise, Dall's porpoise, an unknown species of sea lion, and river otter. Data from these analyses are summarized in this report. Tissues from an additional 17 harbor seals from Southern Puget Sound were analyzed for a broader range of synthetic chlorinated organics, metals and other trace elements, and polyaromatic hydrocarbons. These results are also reported.

PCB and DDE concentrations in harbor seals varied widely; the highest concentration of PCBs was 750 ppm (wet weight) found in the blubber of one harbor seal from Southern Puget Sound. PCB concentrations were substantially higher than DDE concentrations in all samples except in a couple of the cetacean samples. Concentrations of PCBs and DDE varied significantly by location. Seals from Southern Puget Sound contained the highest levels. Concentrations of PCBs and DDE also varied significantly by age, with adults showing higher concentrations than pups and subadults.

The concentration of PCBs and DDE are substantially higher in harbor seals than in the fish they eat. We found PCBs in the scat of seals and found evidence that some PCB components are metabolized by seals. However, an examination of the body burden of PCBs and DDE in seals indicates seals absorb most of the PCBs and DDE present in their diet and retain it in their blubber.

A number of other synthetic chlorinated organics were detected in harbor seals but in substantially lower concentrations than PCBs and DDE. Analyses for metals and trace elements in harbor seal liver and kidney revealed high concentrations of mercury (Hg) in some samples. High mercury concentrations occur frequently in marine mammals. We analyzed for polyaromatic hydrocarbons, but none were detected.

PCBs appear to be the primary pollutants of concern in Puget Sound marine mammals. PCBs have been implicated as the cause of reproductive problems in pinnipeds from the Baltic and Wadden Seas in European waters and the Channel Islands in Southern California. PCB concentrations in Southern Puget Sound harbor seals are among the highest found anywhere in the world and are in the same range as those implicated as causing biological disorders in other areas.

Reproductive disorders in harbor seals from Southern Puget Sound were reported in the early 1970s and pollutants may have been a contributing factor. A thorough study to determine the presence of possible contaminant-related disorders is needed.

1. INTRODUCTION

In recent years, many toxic chemicals have been identified from the sediments and marine biota of Puget Sound (Malins et al. 1982, Long 1982). High concentrations of some of these chemicals were found near major population centers and industrial areas of the Sound (Mowrer et al. 1977, Malins et al. 1982). Fish from highly contaminated areas in Puget Sound were found to have a variety of biological abnormalities including liver tumors and liver lesions that were statistically correlated with high levels of certain contaminants (Malins et al. 1982).

A number of marine mammals inhabit the inland waters of Washington State. Of the pinnipeds, only the harbor seal, *Phoca vitulina* (scientific and common names appear in Appendix C) lives year round and breeds in Puget Sound. Harbor seals, like many marine mammals, tend to concentrate certain environmental toxicants as a result of the following characteristics: 1) they are long-lived, 2) they have large blubber layers that serve as a repository for fat soluble chemicals, 3) they feed at the top levels of long food chains, and 4) they feed in the marine environment which serves as a sink for many toxic chemicals discharged from coastal industries and population centers.

High concentrations of chlorinated hydrocarbons in certain populations of marine mammals have been the suspected cause of reproductive abnormalities. These abnormalities include premature births among California sea lions (DeLong et al. 1973, Gilmartin et al. 1976), pathological changes of the uterus in ringed seals (Helle et al. 1976a, Helle et al. 1976b), population decreases of harbor seals (Reijnders 1980), and birth defects in harbor seals (Newby 1971, Arndt 1973).

This report presents data on chemical contaminants found in marine mammals from Washington State over the period 1972-1982. This report also summarizes observations on the biological effects of chemical contaminants noted in other studies, and presents biological and chemical data relevant to the question of pollutant effects on the reproductive status of marine mammals in Washington State. Recommendations for future research are also presented.

2. METHODS

2.1 Sample Collection

Samples were collected under a variety of conditions by different investigators. Dr. Murray Johnson and Steve Jeffries of the Museum of Natural History, University of Puget Sound provided tissues from seals they had found dead in Washington waters or that they had collected in Grays Harbor as part of another study. All other marine mammal tissues were from stranded animals and included specimens provided by the Burke Memorial Washington State Museum, University of Washington, Seattle and the Whale Museum, Friday Harbor, San Juan Island, Washington. The animals collected from Grays Harbor were aged by tooth cross-sectioning (Steve Jeffries, pers. comm.).

Fish were collected by beach seine, hook and line, and otter trawl. Harbor seal scat samples were collected from seal haul out areas after the seals had left the area. Harbor seal scat samples were weighed, then freeze dried prior to chemical analysis. All tissue samples were frozen until analysis.

2.2 Analytical Methods

Two sets of samples were analyzed for environmental toxicants. Blubber tissues of 73 harbor seals and 9 blubber tissue samples from 7 other marine mammal species from Washington State were analyzed from 1977 to 1981 for PCB and DDE residues at The Evergreen State College (TESC), Environmental Analysis Laboratory. Table 1 summarizes the location, sex, age class, collection method, and year of collection of the harbor seals that were analyzed. Figure 1 shows our study areas. The blubber, liver, and kidney of 17 harbor seals from Southern Puget Sound (including some of the same animals analyzed at TESC) were analyzed in 1983 for a broader spectrum of synthetic chlorinated organic compounds, metals, trace elements, and polynuclear aromatics by the Bodega Marine Laboratory, in conjunction with California State University's Moss Landing Marine Laboratory and the Lawrence Berkeley Laboratory.

2.2.1 PCB and DDE analysis--The Evergreen State College

Samples weighing between 0.5 and 100 g (blubber, fish, or scat) were digested in BFM solution (glacial acetic and perchloric acid) and extracted with hexane (Stanley and LeFavoure 1965). Lipid weights were determined by evaporating a portion of the hexane-lipid extract to dryness. A portion of the hexane extract was cleaned up with concentrated sulfuric acid (Murphy 1972) and injected on a Hewlett-Packard electron capture gas chromatograph equipped with a 1/4" x 6' glass column packed with 10% DC-200 on gas chrom Q, 80/100 mesh, and 63Ni electron capture detector. Most samples were injected at least twice, once on a column with a 1" alkaline (KOH and NaOH) precolumn (to convert p,p'-DDT to p,p'-DDE) (Miller and Wells 1969) and once on a column without the alkaline precolumn to check for the presence of DDT and its metabolites other than p,p'-DDE. Peak areas were determined by integrating computers connected to the gas chromatograph.

PCB peaks were quantified by individual homolog analysis using mean weight percent figures reported by Webb and McCall (1973) for 21 peaks (see Mowrer et al. (1977) and Calambokidis et al. (1979b) for descriptions and application of this technique). In the event that less than five peaks could be discerned (for several of our fish samples only), quantification was made by extrapolation of the remaining peaks based on an Aroclor 1254 (trade name for a Monsanto Co. PCB mixture) standard. DDT standards and PCB standards (mixture of Aroclor 1242, 1254, and 1260) were injected between every series of three samples.

The principal DDT compound we found in our samples was p,p'-DDE. To aid in the analysis of DDT and minimize its interference with quantification of PCB peaks, we analyzed results from the gas chromatograph with an alkaline precolumn that converted all p,p'-DDT to p,p'-DDE. Our quantification of p,p'-DDE therefore may include a small amount of p,p'-DDT. The p,p'-DDE peak was quantified after subtraction of the estimated area of the PCB peak occurring with it (extrapolated from the previous, adjacent PCB peak). Throughout the text this quantity is referred to as "DDE".

2.2.2 Organic analysis--Bodega Marine Laboratory

Whenever possible, a subsample from the interior of the blubber was taken for analysis. The sample was ground with anhydrous sodium sulfate and soxhlet-extracted for approximately 8 hours with methylene chloride. A separate aliquot was weighed, placed in a drying oven at 110°C for 24-48 hours and reweighed to obtain the percentage of water. The lipid extract was rotary evaporated to remove the methylene chloride, and taken up in hexane. Lipid content was determined by removing a small aliquot, in the order of 5 microliters, which was weighed with a Cahn microbalance.

A mixture of deuterated hydrocarbons in acetone was diluted approximately 100-fold in hexane to provide concentrations of approximately 1 ng/microliter (Table 2). One ml was added to selected samples to serve as an internal standard for determinations of recovery and for estimating concentrations of compounds present at trace levels with gas chromatographic/mass spectrometric (GC/MS) techniques, either before soxhlet-extraction or to the lipids prior to column chromatography. Lipids were separated by florisil column chromatography (Supelco 60/100 mesh florisil; activated 250°C for 13 h, deactivated with 0.5% water, equilibrated for at least 15 h, used within 3 days; 16.5 cm florisil under 1.2 cm sodium sulphate; column 2.2 cm i.d.). Columns were packed dry and then rinsed with 200 ml hexane to remove potential contaminants present in the florisil; samples were applied in hexane. Three fractions were collected, eluting with hexane (F1); 30% methylene chloride in hexane (F2); and 50% methylene chloride in hexane (F3). Volumes were adjusted for each preparation of florisil such that the separation scheme presented in Table 3 would be achieved. Up to 0.5 g of lipid were placed on each column.

Extracts were analyzed by both FID (flame ionization detector) and ECD (electron-capture detector) gas chromatography. Hewlett-Packard 5840A gas chromatographs were equipped with capillary inlet systems. Column chromatography fractions were reduced by rotary evaporation to a volume of 30-100 microliters; injection volumes were 1 or 2 microliters; the splitless injection mode was used. The inlet was programmed to purge 1 minute after injection. Fraction 1 extracts were analyzed on a 30 m x 0.25 mm I.D. SE-30 fused silica capillary column; fractions 2 and 3 were run on a 30 m x 0.25 mm I.D. fused silica SE-54 capillary column (J&W Scientific). The initial temperature was 50°C. After an initial hold of 1 minute, the temperature was programmed at 10°C/min to 110°C and at 3.5°C/min to 275°C. The inlet was held at 250°C and the detector at 350°C. The carrier gas was helium.

An external standard consisting of *n*-alkanes, pristane and phytane, was run on the same day. Compounds other than alkanes, pristane, and phytane were quantified on the basis of the response factor of n-C23 which was used as a reference compound.

Synthetic organics were determined using two column types to obtain an initial confirmation of identity. A Carlo Erba 2350 gas chromatograph was equipped with a Brechbuhler 63Ni electron capture detector and a 30 m x 0.25 mm I.D. SE-30 fused silica column. The inlet and detector were maintained at 250°C and 265°C, respectively. Injections were performed in a split mode at an initial temperature of 275°C. A Carlo Erba 4160 gas chromatograph was equipped with a 30 m x 0.32 mm I.D. DB5 fused silica column (J&W Scientific). The detector was operated in the constant current mode and maintained at a temperature of 275°C. Samples were introduced by capillary on-column injection at an initial temperature of 70°C, programmed at a rate of 10°C/min to 120°C, and at 3.5°C/min to 290°C. GC signals from both chromatographs were processed using a dual channel Hewlett-Packard 3388 integrator.

A mixture of synthetic organics was injected into each chromatograph on each day (Figures 2 and 3). Preliminary quantifications were made on the basis of the response of decachlorobiphenyl, which was used as an internal standard. Application of a conversion factor permitted estimation of concentrations of individual compounds.

Identification was based on co-elution with authentic standards on both DB5 and SE-30 columns and was confirmed by mass spectrometry. Compounds that did not show a co-eluting peak of comparable magnitude from both columns are reported on a maximum concentration basis, based on the lesser peak. The majority of the chlorinated insecticides elute in Fraction 2 (Table 3).

Peaks on both FID and ECD chromatograms were assigned Kovats indices, using the retention times of the *n*-alkanes run on each column type. For peaks on FID chromatograms, Kovat indices were estimated using external standard *n*-alkanes. Kovats indices of synthetic organics were initially determined for each column type by co-injection with *n*-alkanes into a gas chromatograph equipped with an FID detector. The values thereby obtained were then used to obtain estimates of Kovats indices for unidentified peaks on the ECD chromatograms. Although changing the operating parameters frequently resulted in significant changes in the values of these estimates, the use of indices was found to provide a useful, first-order, reference for individual peaks.

Summaries of chromatographic information including a unique identifier, retention times, and integrated peak areas were either transmitted over a standard ASCII RS-232-C line to a Texas Instrument 733 ASR/KSR terminal with a built-in modem, and recorded on tape cassettes, or were recorded on data tape cartridges by the integrator. Selected data were processed with interactive software, and examples of the outputs are provided in Appendix B. Compounds assigned an identification were quantified with the application of the appropriate multiplier; other compounds not presently identified were quantified on the basis of the response of the decachlorobiphenyl. Kovats indices were assigned to each peak.

Gas chromatographic/mass spectrometric (GC/MS) analyses of selected extracts were undertaken using a Finnigan model 4023 quadrupole mass spectrometer and Incos data system installed at the Lawrence Berkeley Laboratory. This GC/MS is equipped with a model 9610 microprocessor-controlled gas chromatograph which has been modified for use with fused silica open tubular capillary columns.

The quadrupole mass spectrometer was directly coupled to receive the total effluent from a DB-5 fused silica column used in these analyses (60 m, 0.315 mm I.D., J&W Scientific). Samples were introduced by splitless injection while the oven temperature was held for 3 min at 45°C; the temperature was then raised to 300°C at 4°C/min and held until the end of the analysis. The injector temperature was 290°C, and the injector was in the splitless mode from 0.1 to 2.1 minutes from the start of the run. Between 0.5 and 1.5 microliters of hexane containing the sample was injected using the hot needle technique at 0.3 minutes from the start of the run. The carrier gas was helium and the quadrupole mass filter was scanned over M/z 36-636 in two seconds.

The following fractions were examined by GC/MS (for each of the following coded samples):

Fraction 1: SJJ 93, PVES 18, SJJ 43, SJJ 114, DB 13
Fraction 2: SJJ, PVES 18, SJJ 43, SJJ 114, DB 13
Fraction 3: SJJ 132, PVES 24, GAB 115, SJJ, CRC-1, PVES 18, SJJ 43, SJJ 114, DB 13

Blanks and sample contamination--Organics. An analytical blank was analyzed in exactly the same way as the samples, using the same glassware and the same volume of solvents. A certain level of carryover from previous samples was therefore anticipated. Chromatograms and data summaries are presented in Appendix B.

Recovery. The mixture of perdeuterated standards (Table 2) had been diluted approximately 100-fold from acetone into hexane for gas chromatography and for florisil recovery experiments. Polynuclear aromatics are less soluble in hexane than in aromatic solvents; the necessity to work occasionally with hexane may therefore contribute selectively to loss of some compounds. A factor contributing to lower recoveries is the necessity to reduce many extracts to small volumes, less than 100 microliters, before gas chromatographic analysis. Reducing solvent volume of the standard mixture for gas chromatographic analysis resulted, in one instance, in a loss of approximately 50% of perylene, benzanthracene and chrysene. Among the compounds in the mixture, the deuterated n-C23 eluted in the F1 fraction, perylene in the F3, the remainder eluted principally in the F2 fraction.

When the standards were added to the lipid prior to florisil cleanup, recoveries were in the order of 50-80% in the F2 fraction (see Appendix B). The mixture was added to two samples prior to soxhlet extraction. In one, recoveries in the F2 fraction were in the order of 50-70%; in the other, recoveries were substantially lower, in the order of 10-20%. Carryover into the F3 fraction was determined for 4 samples analyzed by GC/MS. Recovery in this fraction averaged 4.4%, 18.5%, and 11.8% of the recovery in the F2 for phenanthrene, pyrene, and chrysene, respectively. Data presented in this report have not been corrected for recovery.

2.2.3 Metals and trace elements--Moss Landing Marine Laboratory

Atomic absorption analysis. The following procedures were used for the analyses of liver and kidney tissues. All glassware and plasticware, except the mercury (Hg) ampoules noted below, were cleaned by soaking in Micro cleaning solution, rinsing three times with tap water, rinsing three times with deionized 18 megaohm water produced by a millipore Mill-Q system, soaking in 1:1 nitric acid (HNO_3) for at least one week, rinsing three times with Milli-Q water, soaking in Milli-Q water for at least one week, and rinsing three times with Milli-Q water. The high quality of the Milli-Q water has been reported by Gordon et al. (1977). The procedure for cleaning glassware and plasticware is similar to that recommended by the National Bureau of Standards (NBS) (Moody and Lindstrom 1977). The ampoules used for Hg analysis were cleaned less stringently by rinsing with 1% HNO_3 and Milli-Q water because it was found that this procedure adequately removed Hg contamination.

Thawed tissues were placed in an acid-cleaned Pyrex homogenizing vessel and homogenized for three minutes in a Virtis-45 homogenizer equipped with a specially fabricated titanium shaft. The pure titanium shaft and blade eliminate possible sample contamination resulting from blade erosion. The titanium shaft and blade, cleaned in hot HNO_3 and rinsed with deionized water, contribute a non-significant amount of trace metal contaminants.

A 1 g wet weight subsample of the sample slurry was placed in an ampoule for Hg analysis, and a 5 g wet weight aliquot was placed in an acid-cleaned 30 ml beaker for analyses of the remainder of the trace elements.

Hg tissue samples. The flameless atomic absorption technique for analyzing Hg in tissue was adapted from Stainton (1971). The sample in a 20 ml ampoule was digested in 1 ml of concentrated sulfuric acid (H_2SO_4) and 0.5 ml of concentrated HNO_3. The sample was heated (less than 80°C) for three hours on the edge of a hot plate. After cooling, 6 ml of potassium permanganate ($KMnO_4$) were added and the sample was left overnight. The following morning, additional $KMnO_4$ was added to insure oxidation. The sample was cleared with a few drops of hydrogen peroxide (H_2O_2), followed by back titration with $KMnO_4$ until the sample turned pink. Two ml of sample, 2 ml of reductant (Stainton 1971) and 6 ml of air were aspirated into a 10 ml syringe, the syringe capped, and the contents were mixed on a vortex mixer for 10 seconds. The Hg vapor inside the syringe was then injected into an Hg cell fitted with quartz-end windows. The cell was locked in the light path of an atomic absorption spectrophotometer.

Other metal tissue samples. Silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), zinc (Zn), aluminum (Al), and manganese (Mn) analyses were performed as follows: The 5 g homogenized aliquot was placed in 30 ml beakers, and the beakers were placed in polyethylene trays, covered with three layers of Assembly Wipes and dried at 70°C for 72 hours in an oven. The sample was weighed and 5 ml of 70% ultra-pure HNO3 were added. The ultra-pure HNO3 was prepared by distilling G. Frederick Smith redistilled HNO3 with an all-quartz, sub-boiling distillation still. The high quality of acid produced using these techniques is reported elsewhere (Kuehner et al. 1972, Gordon et al. 1977). The sample was refluxed for 3 hours, taken to dryness slowly, charred at 350°C to remove lipids, dissolved in 5 ml ultra-pure HNO3 and further oxidized by adding drops of H2O2. The sample was then slowly evaporated until the residue was slightly moist, 25 ml of 1% HNO3 was added, and the solution transferred to an acid-cleaned 30 ml conventional polyethylene vial.

Hg analyses were performed on a Perkin-Elmer 305B atomic absorption spectrophotometer equipped with a flow-through cuvette described by Stainton (1971). Pb, Ag, and Cr analyses were conducted on a Perkin-Elmer 603 atomic absorption spectrophotometer equipped with an HGA 2100 graphite furnace. Air-acetylene flame atomic absorption was used for Cd, Cu, Mn, and Zn, and a nitrous oxide-acetylene flame was used for Al.

Several steps were taken to insure quality control for the metal analyses. Standards of Ag, Cd, Cr, Cu, Pb, Zn, Al, and Mn were prepared in 1% HNO3. Pb was analyzed by standard addition methodology. Trace metal levels in National Bureau of Standards (NBS) orchard leaves (NBS #1571) and bovine liver (NBS #1577) were measured to ensure the accuracy of analysis. The ultra-pure acid was pretested before use to ensure against possible contamination during digestion and analyses.

Selenium could not be determined by these procedures; selected samples were therefore analyzed by x-ray fluorescence.

<u>X-ray fluorescence analysis</u>. Methods used for the analysis of liver and kidney tissues were conducted at Lawrence Berkeley Laboratory of the University of California by x-ray fluorescence and have been described by Giauque et al. (1973).

2.3 Data Analysis

Collection sites for harbor seals were treated as four distinct regions: Northern Puget Sound, Southern Puget Sound, Hood Canal, and the Outer Coast (Figure 1). All samples were classified as either adult, subadult, or pup based on weight and length (where age from tooth sectioning had not been completed). The pup category includes two near-term fetuses from Grays Harbor (Outer Coast) as well as animals up to one year old.

To determine if our data met the assumptions of parametric statistics, we tested for how closely PCB and DDE concentration matched a normal distribution. As stratification of our data by location and age category created categories too small to test, we tested for normality by pooling all data and where sample size was adequate, by stratifying by site only. Ranked concentrations in a sample were tested for their correlation with the expected concentration for that rank if the data were normally distributed. In almost all cases, log transformation of data created greater normality in data distribution. All parametric statistical tests on contaminant concentrations and contaminant ratios were therefore conducted with log transformed values. Thus, central tendency is reported as geometric mean (antilog of the mean of the log transformed values). We defined the standard deviation interval around the geometric mean as the range from the antilog of the mean of the log values minus one standard deviation to the antilog of the mean of the log values plus one standard deviation. Hypotheses were also tested with non-parametric statistics (Kruskal-Wallis test and Spearman's rank correlation).

Parametric statistics on harbor seal pollutant concentrations were conducted with the BMDP statistical package at the University of Washington. Non-parametric tests and some additional parametric tests were conducted as described in Sokal and Rohlf (1981). Samples with incomplete information were excluded from some tests as necessary. For one of our multi-way ANOVA, we excluded samples from Hood Canal on the basis of the large number of empty sex/age class cells.

2.4 Literature Review

All published literature for 1969 to 1982 relavent to the affects of pollutants on marine mammals was searched with the computer-based Biosis (Bio Abstracts) system. A variety of subjects were cross-referenced to select for relevant topics. These included: 1) all articles on environmental pollutants in marine mammals 2) articles on the biology of the principal marine mammal species in Puget Sound 3) articles on bioaccumulation of pollutants in large mammals and 4) articles on the impact of pollutants on the reproductive system of large mammals. Over 1,000 abstracts of relevant articles were reviewed and, if appropriate, the entire article was obtained. The computer-based literature search was supplemented by the authors' existing library on pollutants and marine mammals, and by checking the "References Cited" section of all relevant articles obtained.

3. RESULTS

3.1 PCBs and DDE in Harbor Seals--The Evergreen State College

Concentrations of PCBs and DDE (p,p'-DDE plus any p,p'-DDT converted on the alkaline precolumn, see Section 2.2.1) in the blubber of 73 harbor seals from different parts of Washington State analyzed at The Evergreen State College are shown in Tables 4-7 with a summary of results in Table 8. Detectable concentrations of PCBs and DDE were found in all samples. PCB concentrations were higher than the DDE levels in all harbor seal samples analyzed. PCB and DDE levels varied greatly, ranging from 1.9 to 620 ppm in blubber (wet weight) for PCBs and <1 to 42 ppm for DDE. We tested for a number of factors that contributed to the high variations in our results.

The results of the analyses of tissues from 17 harbor seals conducted at the Bodega Marine Laboratory for a broad spectrum of synthetic chlorinated organics including PCBs and DDE are covered in

Section 3.2 and are not included in the analyses reported in this section.

3.1.1 Site differences

Site accounted for a highly significant amount of the variation ($p<.001$) in the concentrations of PCBs and DDE and their ratio as tested by multi-way Analysis of Variance (ANOVA)(Tables 9-10). The significant effect of site remained after the effects of other factors (age class and sex) were accounted for in the ANOVAs. PCBs, DDE, and their ratio were also significantly different by location when tested by the non-parametric Kruskal-Wallis test, the non-parametric equivalent of the ANOVA (PCBs:$p<.001$, DDE:$p<.025$, PCB/DDE ratio:$p<.001$). The Kruskal-Wallis test, best used to test sample populations that deviate substantially from a normal distribution, cannot test multiple and interactive effects as can the multi-way ANOVA.

Geometric mean concentrations of PCBs and DDE in the blubber of Southern Puget Sound seals were 110 and 10 ppm, respectively, the highest geometric mean concentrations of both contaminants found in any of the four study regions. Concentrations of PCBs were second highest in Hood Canal, whereas DDE levels were second highest on the Washington Outer Coast (see Table 8).

Concentrations of PCBs and DDE were highly correlated to each other, for all samples taken together and within each site (Table 11). The mean ratio of PCBs to DDE at different sites ranged from 2.1 on the Outer Coast to 11 in Southern Puget Sound (see Table 8). The ratio showed much less variation than the individual levels.

3.1.2 Age and age category

We found significant relationships between age and concentrations of PCBs and DDE in harbor seals. Of the 28 seals collected in Grays Harbor for which we had ages, we tested for significant regressions for PCB and DDE concentrations on age. For the rest of our samples only rough age class status (pup, subadult, or adult) was known.

Age category was a significant source of variation in the concentrations of PCBs and DDE in the multiway ANOVA tests (Tables 9, 10). The non-parametric Kruskal-Wallis test also revealed significant differences by age category for PCBs ($p<.005$) and DDE ($p<.001$). With a single exception, mean concentrations of PCBs and DDE separated by site and sex showed highest levels in adults, second highest in subadults, and lowest in pups (Table 8). The one exception was in Southern Puget Sound where an adult female had considerably lower concentrations of PCBs and DDE than the sub-adult females from Southern Puget Sound. This adult female was pregnant and near-term. Both these factors may have been partly responsible for the anomolous residue levels. The subadult females from Southern Puget Sound had the highest concentrations of any of our age/sex categories (Table 8).

Linear regressions and rank correlations on the age-determined sample from Grays Harbor are shown in Tables 12 and 13. PCBs and PCB/DDE ratios showed significant regression ($p<.01$) on age but DDE did not. When sexes were separated, males showed a regression on age that was highly significant for PCBs (p<.01) but not for DDE (p>.05), while no significant regressions were found in females. Males also showed a significant regression of the PCB/DDE ratio on age, though this relationship was not significant by the non-parametric rank correlation test (p>.05).

3.1.3 Sex

The main differences in PCB and DDE concentrations we noted between males and females were in regressions on age (see previous section). A three-way ANOVA, using data from all sites except Hood Canal (only one female from that site), testing for the effects of site, age category and sex, did not reveal significant differences (p>.05) between males and females (Table 10). This ANOVA did reveal a significant interactive effect between age category and sex, which would be expected if males and females accumulated these chemicals differentially (see previous section).

In Southern Puget Sound and the Outer Coast, sample sizes were large enough to compare males with females in different age classes. In samples from the Outer Coast, PCBs and DDE were generally higher in males than females of the same age class, but those differences were not significant (p>.05) In Southern Puget Sound there were several significant differences in concentrations by sex in equivalent age classes. Both PCBs and DDE were significantly higher in adult males than in the adult female (p<.01). PCBs and DDE were significantly higher in subadult females than subadult males from Southern Puget Sound (p<.01).

3.1.4 Blubber thickness

We found no significant correlation between blubber thickness and PCB or DDE concentrations or their ratio. However, the highest PCB and DDE levels we found in any sample were in an emaciated seal from Southern Puget Sound that had the smallest blubber thickness of any animal (PVES 19, Table 4). These results suggest that the normal variations in blubber thickness do not have a significant relationship to PCB or DDE levels, but extreme emaciation may result in elevated levels in the remaining fat tissues. There was a positive correlation between blubber thickness and weight (n=67, r=0.59, p<.001). Females had greater fluctuations in blubber thickness than males. In Grays Harbor females, the blubber layer from five females collected in May, four of which were pregnant or lactating, was significantly greater than in females collected in later months (p<.01).

3.1.5 Collection method

Of 34 harbor seal samples from the Outer Coast, 28 were animals that were collected as part of another study (Table 7a), and 6 were found dead (Table 7b). The Outer Coast was the only region from which collected animals were analyzed. To test the differences in PCB and DDE concentrations linked to collection method (killed vs. found dead), we ran a two-way ANOVA on the 23 Outer Coast males with age category and collections method as factors (Table 14). Only males were tested because five of the six animals found dead in this area were males. Collection method did not contribute significantly to the variation of PCB or DDE concentration or their ratio ($p>.05$), however, there was a significant interactive effect between age and collection method for PCBs.

3.1.6 Reproductive condition and transfer of pollutants to pups

PCB and DDE concentrations (ppm wet wt.) were generally lower in the four pregnant or lactating females collected in Grays Harbor compared to the four non-pregnant and non-lactating females from this area (geometric means for PCBs: 8.8 and 26 ppm respectively and for DDE: 3.3 and 8.5 ppm respectively). These differences fell short of statistical significance.

We compared the concentrations of PCBs and DDE we found in the blubber of four near-term or lactating females with the concentrations in their young (Table 15). Concentrations were lower in the young or fetuses than their mothers, with the ratios of levels in pups or fetuses to mothers ranging from 0.14 to 0.83. We did not find a significant correlation between the concentrations of PCBs or DDE in the mother and the corresponding concentration in her young ($p>.05$, for both PCBs and DDE). Ratios of PCBs to DDE in mothers correlated to ratios in their offspring ($r=.95$ $p=.05$).

3.1.7 Analysis of prey of harbor seals

Tables 16 and 17 show the residues found in fish from Southern Puget Sound and Hood Canal. In Southern Puget Sound we analyzed 14 samples from 9 species; 7 of the species were known prey of harbor seals in Southern Puget Sound (Calambokidis et al. 1978; Everitt et al. 1981). PCB levels were highly variable and ranged from 0.014 to 0.86 ppm (wet wt.). Four Pacific staghorn sculpin (Leptocottus armatus), the principal food item recovered from scat of harbor seals in Southern Puget Sound (Calambokidis et al. 1978), had levels of 0.058 ppm PCBs (geometric mean, std. dev. interval 0.022-0.15, wet wt.) and 0.0039 ppm DDE (geometric mean, std. dev. interval 0.0014-.011, wet wt.). Mowrer et al. (1977) found similar concentrations; eight L. armatus samples taken in Southern Puget Sound (south of Tacoma) had 0.049 ppm PCBs (geometric mean, std. dev. interval 0.026-0.091, wet wt.). We found 0.86 ppm PCBs and 0.14 ppm DDE (by wet wt.) in a single herring sample taken near Nisqually Reach, which is twice as high as any other fish sample. This high residue concentration probably reflects the high lipid content of this fish.

Samples of three species of fish known to be eaten by seals in Hood Canal were analyzed. Four individual samples of Pacific hake (Merluccius productus), the principal food item of the harbor seals in this area, contained 0.017 ppm PCBs (geometric mean, std. dev. interval 0.0096-0.029) and 0.0013 ppm DDE (geometric mean, std. dev. interval 0.0008-0.0023) on a wet weight basis. The average PCB concentration in these hake by lipid weight was 2.9 ppm (geometric mean, std. dev. interval 1.6-5.2).

The concentrations of PCBs and DDE in seals are substantially higher than in their prey when compared by wet weight or lipid weight. We compared the geometric mean concentrations of PCBs in the primary prey items of seals in Southern Puget Sound and Hood Canal with those in adult male harbor seals from the same area. Southern Puget Sound adult males contained levels of PCBs in blubber 110 times higher than the concentration in whole bodies of staghorn sculpin (by lipid wt.) from this area. In the Hood Canal, the concentration of PCBs in the blubber of two adult males was 56 times higher than the concentration (by lipid wt.) in muscle cross-sections of Pacific hake from the same area.

3.1.8 Excretion and metabolism

Concentrations of PCBs and DDE in harbor seal scat from three regions are shown in Table 18. Levels in scat, even from the same site, were highly variable, though these variations were much lower when the concentrations were based on lipid weight instead of wet or dry weight. The mean concentration of PCBs was higher in scat from Skokomish Delta, Hood Canal when calculated by wet or dry weight and highest from Eld Inlet, Southern Puget Sound, when calculated by lipid weight. These differences were not statistically significant ($p > .05$). DDE concentrations were highest in the Skokomish Delta scat by wet, dry or lipid weight basis, but again the difference was not significant ($p > .05$). Contaminant concentrations in scat (by lipid or wet wt.) were generally higher than those we found in prey of seals from the same area.

Examinations of the PCB homolog components we found in seals, fish, and scat indicate seals selectively metabolize some PCB components. Chromatograms of samples of the blubber of harbor seals from different areas and a comparison of the chromatograms of seals, fish, and scat are shown in Figures 4 and 5. The evidence for selective metabolism of certain PCB components is best seen with the homologs represented by peak #13 and peak #15. Peak #13 represents chlorinated biphenyls with 5 and 6 chlorines (primarily 6 chlorines) and peak #15 represents chlorinated biphenyl homologs with 6 and 7 chlorines (Webb and McCall 1973). Both of these peaks are present in the prey of seals from Southern Puget Sound and Hood Canal; peak #13 as a fairly large peak and peak #15 is in small but identifiable quantities (Figure 5). In harbor seal samples, however, peak #13 is always small in comparison to the other peaks and peak #15 is always absent (Figure 4). The relative proportion of these peaks (#13 and #15) in our chromatograms of scat are greater than in seals, but are still less than in fish prey. Urine would be an unlikely route for excretion due to PCBs' low solubility in water. We conclude that harbor seals selectively metabolize some of the PCB components to which they are exposed.

The total amount of PCBs excreted in the scat is small compared to the seal's intake. Scat weight can be roughly estimated as 5% of the food ration weight, based on experimental studies of the Baikal seal, *Pusa sibirica* (Pastukhov 1975). Therefore, since the concentration of PCBs in scat is equivalent to or greater than the concentration in fish (by wet wt.), we estimate a minimum of approximately 5% of the PCBs in prey is excreted in an unmetabolized form by the seal.

3.1.9 Body burden

Male harbor seals appear to absorb and retain most of the PCBs and DDE that they consume in their diet. Table 19 shows a derivation of the body burden of PCBs in adult male harbor seals in Southern Puget Sound and compares these figures to the estimated intake of PCBs from the seal's diet. We extrapolated the body burden of these highly lipophilic contaminants by assuming the body fat is the primary repository of PCBs and DDE in harbor seals. These calculations indicate that, based on our assumptions and data used in Table 19, the mean body burden of PCBs in the fat of an adult male harbor seal from Southern Puget Sound would be 4.6 g. This amount represents the amount of PCBs an adult seal would ingest and absorb in 11 years, an unrealistically high estimate. The most likely errors in our assumptions that might account for this high figure include: (1) Southern Puget Sound seals may feed on fish with higher concentrations than those we sampled, and (2) daily food intake in the wild may exceed the reported 6 percent of body weight a day.

This calculation, though it likely contains some error, does indicate that the body burden in adult male seals represents a substantial portion of the PCBs the seals have consumed in their lifetime. This conclusion is consistent with our observation of increased PCB concentrations with age in male harbor seals.

3.2 Synthetic Chlorinated Organics - Bodega Marine Laboratory

Tables 20-22 report the results of the analyses for a broad spectrum of synthetic organic compounds that were conducted at Bodega Marine Laboratory. Residues are reported on a dry weight basis. Blubber samples from 17 harbor seals found dead in Puget Sound were analyzed. These included 9 samples for which the PCB and DDE levels were reported in section 3.1 (on a wet wt. basis).

Of the synthetic organic compounds analyzed, only the identification of the beta and gamma isomers of HCH and of o,p'-DDD could not be confirmed by GC/MS, because levels in the extracts examined were not sufficiently high. Of the several F2 fractions examined by GC/MS, BML #83-67 provided the most information (Figures 6-10), and is discussed here in detail. Differences in elution patterns from the two columns are evident from a comparison of the chromatograms (Figures 6 and 7). On the DB5 column, the beta and gamma isomers of HCH, heptachlor epoxide and oxychlordane, and p,p'-DDD and o,p'-DDT were not resolved; these compounds were resolved by the SE-30 column. Like all other F2 and F3 extracts examined in the study, the BML #83-67 F2 extract contained many compounds that have not yet been identified; the concentrated extract (Figure 8) showed many compounds not visible in the more dilute extract (Figure 6). The FID chromatogram (Figure 9) shows relatively few peaks; with the exception of squalene and a minor compound with a similar structure, the resolved peaks represent organochlorine compounds. Generally, the gas chromatographic profiles were very similar among all of the samples, the principal differences deriving from the absolute concentrations of the components.

Among the DDT compounds, p,p'-DDE (DDE) was present at highest levels. DDE concentrations were several-fold lower than those of total PCBs (Tables 20 and 21). The ortho-para compounds were not detected, with the possible exception of ortho-para DDD in two samples. The meta-para isomer of DDD was looked for by GC/MS but was not found, with maximum concentrations being several-fold lower than those of p,p'-DDD.

The PCB composition was virtually identical among all the samples and was similar to that of Aroclor 1260 (Figure 11). Since the electron capture response of individual PCB compounds varies widely depending on the number of chlorine atoms, the FID response was used to estimate the percent composition of the PCBs by chlorine number, as determined by mass spectrometry. The majority of the PCBs were hexachlorobiphenyls (57.2%). Tetrachlorobiphenyls constituted 1.5% of the total, pentachlorobiphenyls 10.0%, heptachlorobiphenyls 23.9%, octachlorobiphenyls 6.9%, and nonachlorobiphenyl 0.6%.

Gamma-chlordane could not be measured, except as maximum values, by gas chromatography (Table 22). Its presence was, however, confirmed by GC/MS, along with two other chlordane compounds that have not yet been characterized.

Chlorinated butadienes in samples were examined by GC/MS by scanning for characteristic ions. These compounds were not identified in the samples at a detection limit of .01 ppm (dry wt.).

3.3 Interlaboratory Comparisons of PCB and DDT Levels

Blubber samples of 19 harbor seals from Southern Puget Sound were subsampled and analyzed for residues of PCBs and DDT by the two laboratories from which data are reported here: The Evergreen State College (this report) and Bodega Marine Laboratory (this report and Risebrough 1978). Tables 23 and 24 compare the analysis results for subsamples of the same animal that were analyzed by both laboratories. Residue levels analyzed by the Bodega Marine Laboratory and previously reported in Risebrough (1978) are designated BML #1; residue values from this report analyzed at the Bodega Marine Laboratory (Tables 20 and 21) are designated BML #2; and residue values from this report analyzed at The Evergreen State College (Table 4) are designated TESC. Since the Bodega Marine Laboratory reported concentrations based on dry weight of the samples, we converted these to wet weight concentrations to allow comparison to the wet weight concentrations reported from The Evergreen State College analyses.

The differences between geometric mean levels of PCBs, total DDT, and PCB/DDT ratios for TESC compared to BML #1 were 0, 67, and 33 percent, respectively; the TESC to BML #2 comparison showed differences in geometric mean levels of PCBs, total DDT, and PCB/DDT ratio of 22, 34, and 5 percent (Tables 23 and 24). These results are in good agreement despite different analysis procedures and quantification techniques that were utilized by the two laboratories. In addition to the different analysis techniques employed, moisture loss from long-term frozen storage and variation between subsamples could contribute to the differences in residue levels noted in these laboratory comparisons.

One sample from the TESC to BML #1 comparison and one sample from the TESC to BML #2 comparison (Table 23) were not included in the mean determinations (Table 24) because of major discrepancies. A large difference in the PCB level we found in SJJ 43 compared to the level found by Bodega Marine Laboratory as reported in Risebrough (1978) was due to a typographical error. The corrected value for the Bodega Marine Laboratory analysis is reported in Table 23a. Large differences were also found in the PCB level of sample SJJ 71 between TESC and BML #2. The PCB/DDT ratio in the BML #2 results for this sample was unusually high. The differences in the PCB level reported by the two laboratories in SJJ 71 could be related to variations in residues in the subsamples analyzed by the two laboratories; the subsamples were not homogenized and this animal was extremely emaciated so the blubber layer was difficult to sample.

3.4 Metals and Trace Elements

The results of the analyses for metals and trace elements in 14 liver samples and 12 kidney samples of Southern Puget Sound harbor seals analyzed by atomic absorption spectrophotometry are presented in Tables 25 and 26. Results of additional analyses of liver and kidney from five of these animals undertaken by x-ray fluorescence are listed in Tables 27 and 28. The x-ray fluorescence analyses were conducted to test for selenium concentrations. Other trace elements detected through x-ray fluorescence are also reported in Tables 26 and 27 though we consider the atomic absorption analysis results more reliable.

Sample sizes for liver and kidney tissues analyzed by atomic absorption allowed tests for differences by age category. Only Hg and Pb concentrations in liver varied significantly by age category ($p<.05$ for both cases, Kruskal-Wallis test). For both Hg and Pb the highest concentrations were found in adults and lowest concentrations were found in pups. Concentrations of Cd in liver also tended to be higher in adults and lowest in pups, but fell short of statistical significance ($p>.05$) The atomic ratios of mercury/selenium and mercury/bromine levels in livers of five harbor seals from Southern Puget Sound were calculated. Results are given in Table 29.

3.5 Polynuclear Aromatics

The aromatic fractions of samples analyzed by GC/MS were scanned for ions characteristic of the polynuclear aromatics. In only one sample, BML #83-67, an adult male, there was a minute amount of phenanthrene found, on the order of a few parts per billion. Methyl phenanthrenes, if present, had maximum concentrations that were several times lower than phenanthrene, which indicates a combustion rather than a petroleum source. These compounds are abundant constituents of local sediments; it would appear that they have a relatively low persistence in the food web.

3.6 PCBs and DDE in Other Washington Marine Mammals

Table 30 shows the concentrations of PCBs and DDE we found in the blubber tissue of seven cetaceans (five species), a sea lion of undetermined species, and a river otter. These tissues were collected from animals found dead between 1976 and 1981.

4.0 DISCUSSION

4.1 Chlorinated Hydrocarbons

4.1.1 Comparison to levels reported in the literature

Concentrations of chemical contaminants found in this study were compared to residues reported in pinnipeds from other parts of the world. Variations in analysis techniques, quantification methods, and report formats confound precise comparisons of results. However, comparisons can be useful by providing an understanding of the similarities and differences in concentrations between species and geographic regions.

Polychlorinated biphenyls. We found PCB concentrations in Washington State harbor seal blubber that ranged up to 750 ppm wet weight (1100 ppm dry wt.) with highest concentrations found in animals from Southern Puget Sound. Anas (1974a) analyzed two seals collected from Puget Sound in 1971, and reported high levels of DDT plus PCB compounds (Table 31). Unfortunately, his analysis combined DDT and PCB residue levels making comparison to other research difficult. The combined PCB and DDT concentrations reported by Anas (1974a) are higher than the combined concentrations we found in the blubber of Southern Puget Sound seals. Arndt (1973) determined residues of DDT and PCBs in tissues of harbor seals from three areas of Washington State (Table 32). In comparison, PCB residues reported by Arndt in harbor seal blubber from Southern Puget Sound are very similar to those we found (Table 8), but the residues reported for Northern Puget Sound and Grays Harbor are three to four times higher than ours.

The PCB concentrations we found in the blubber of Southern Puget Sound harbor seals are among the highest reported in pinnipeds throughout the world. We examined data sets in 31 references that reported PCB concentrations in the blubber of 10 species of pinnipeds (see Table 33 for a summary). The majority of the PCB concentrations reported in the literature were less than 100 ppm and were well below the concentrations we found in Southern Puget Sound. The lowest concentrations were in Arctic and Antarctic species.

The highest concentrations of PCBs that are reported in the literature occur in seals from protected waters near industrial and population centers. These areas include the Wadden Sea, portions of the Baltic, San Francisco Bay, and some sites in southwest and east England. Harbor seals in the Dutch portion of the Wadden Sea have concentrations of up to 2,500 ppm PCBs (lipid wt.) in their blubber, the highest reported anywhere.

DDT. Arndt (1973) reported DDT concentrations in the blubber of harbor seals from locations similar to those we sampled (Table 32). Concentrations of DDT he reported for Southern Puget Sound and Grays Harbor are similar to those we found for those areas, but the concentration of DDT he reported for seals from Northern Puget Sound was about twice a high as we found in that area. The concentrations of DDT (primarily as p,p'-DDE) we found in harbor seals from Washington State were within the range or much lower than the majority of the DDT levels reported in pinnipeds from other parts of the world. We identified data sets on 11 species from 39 references that reported DDT residues in the blubber of pinnipeds (Table 34). Levels of total DDT that were consistently lower than those we found have only been reported from Arctic and Antarctic regions. DDT concentrations greater than 500 ppm, an order of magnitude higher than those we found, have been reported in harbor seals and grey seals from the Baltic and in California sea lions from the California coast.

Hexachlorobenzene. HCB concentrations were below detection limits (0.05 to 0.55 ppm dry wt.) for the 17 samples we examined. Table 35 summarizes the results of three references that reported HCB residues in the blubber of pinnipeds. The residue values reported in the literature are in the same range as the detection limits of our analyses, so we cannot compare our findings with those reported for other areas.

Dieldrin. Residues of dieldrin reported in this study are lower than the majority of the values reported in the literature on pinnipeds. Table 36 summarizes the data sets on 6 species of pinnipeds from 18 references that reported dieldrin residues in the blubber of pinnipeds. Dieldrin concentrations reported in grey seals from England and Scotland and harbor seals from the Wadden Sea are over an order of magnitude higher than the highest values we found.

Heptachlor epoxide. We identified three references that report heptachlor epoxide in the blubber of pinnipeds (Table 37). The residues we found were higher than those reported in a fur seal from the Pribilof Islands and in three species of seals from the west coast of Greenland, but were lower than the residues found in harbor seals from the North Sea.

Hexachlorocyclohexanes. Table 38 summarizes five references that reported HCH residues (lindane, alpha-HCH, or total HCH) in the blubber of pinnipeds. The concentrations of HCH we found are generally within the range of these reports from the literature.

Chlordane compounds. We found total chlordane compound levels ranging from 0.16-3.9 ppm (dry weight) in the blubber of 17 harbor seals from Southern Puget Sound. Chlordane compounds detected included trans-nonachlor, cis-nonachlor, oxychlordane, gamma-chlordane, and alpha-chlordane. Oxychlordane was present in the highest concentrations (geometric mean of 0.44 ppm, dry wt.) followed by trans-nonachlor and cis-nonachlor. Only three references were located in the literature for comparison; these are listed in Table 39. Levels of chlordane compounds detected in harbor seals from Southern Puget Sound were higher than levels in northern fur seals from Alaska, in the same range as levels in harbor seals from the coast of the Netherlands, but lower than the levels in grey seals from the Baltic Sea.

4.1.2 PCB and DDT dynamics in seals

Age and sex. Positive correlations between age and concentrations of PCBs and DDT have been reported for male ringed seals (Addison and Smith 1974), harp seals (Addison et al. 1973), grey seals (Donkin et al. 1981) and harbor seals (this study). Some studies could not find significant regressions of chlorinated hydrocarbons on age in harbor seals (Drescher et al. 1977) and grey seals (Olsson et al. 1975). In these two studies the sex of study animals was not treated separately.

Several authors have noted great variance in chlorinated hydrocarbon levels among mature female seals or have not found significant regressions of PCB and DDT concentrations on age of females (Donkin et al. 1981; Addison and Smith 1974; this study). Transport of chlorinated hydrocarbons to pups through gestation and lactation is often cited as the probable cause of this difference (see section 4.1.2). This high variance of chlorinated hydrocarbon levels among mature females must be accounted for in comparisons between study areas.

Our observations of higher PCB and DDE concentrations in Southern Puget Sound sub-adult female harbor seals compared to other sex/age classes is puzzling. Gilmartin et al. (1976) found higher PCB and total DDT concentrations in young female California sea lions giving birth to premature pups than in older full-term females. They speculated that the higher concentrations in the younger females was the result of their feeding in more polluted areas than the older females.

Blubber thickness. Changes in thickness of blubber, the repository for pollutants, might mask meaningful comparison of residue levels. Blubber thickness was not correlated with chlorinated hydrocarbon levels in either harbor seals (this study) or in harp seals (Addison et al. 1973). We noted, however, elevated levels in the blubber of a seal that was extremely emaciated; a pattern also reported by Drescher et al. (1977). Blubber thickness was inversely correlated with chlorinated hydrocarbon levels in ringed seals (Addison and Smith 1974) and grey seals (Donkin et al. 1981). Donkin et al. (1981) also noted changes in blubber thickness in lactating females, and suggested energetic demands of the breeding season may be partially responsible.

Collection method. The condition of specimens, whether collected, or found sick or dead, was not a significant factor in concentrations of chlorinated hydrocarbons in California sea lions (Le Boeuf and Bonnell 1971) or harbor seals (Drescher et al. 1977, this study). Olsson (1978) notes that ringed seals and grey seals found dead had significantly higher concentrations of chlorinated hydrocarbons than those killed for study in a previous year. Such comparisons between years should be regarded with caution since other factors that differ between years may account for the differences noted. Collection method would become more of a factor if a significant number of the stranded animals were emaciated; the tendency of emaciated animals to show elevated levels of chlorinated hydrocarbons is discussed in the previous section on blubber thickness.

Transfer of chlorinated hydrocarbons to pups. Chlorinated hydrocarbons are transported to pups through the placenta and during lactation; both seal fetuses and milk have been reported to contain chlorinated hydrocarbons. Comparisons between levels in mothers and pups show significantly lower concentrations in ringed seal fetuses (Helle et al. 1976b), harp seal pups (Jones et al. 1976), grey seal pups (Addison and Brodie 1977) and harbor seal pups and fetuses (this study) relative to those of their mothers. Addison and Brodie (1977) also noted a significant increase in the PCB/DDT ratio between levels in milk and in pup blubber. This observation suggests a barrier or selective metabolism to some chlorinated hydrocarbons.

Addison and Brodie (1977) note that the entire theoretical annual intake of DDE for grey seals could be excreted through lactation and would thus account for variable levels in female seals. This excretion could confound studies that attempt to compare chlorinated hydrocarbon levels with reproductive condition (Helle et al. 1976a, 1976b) in that lack of pregnancy and the subsequent lack of lactation might actually cause an increase in observed chlorinated hydrocarbon levels in females not giving birth as compared with females giving birth.

Bioaccumulation. The difference in PCB concentrations between seal blubber and their fish prey that we found is higher than most other reports in the literature. Levels in the blubber of seals were 110 times higher and 56 times higher than the levels in fish prey (by lipid wt.) in Southern Puget Sound and the Hood Canal, respectively. Frank et al. (1973) found captive harbor seals concentrate PCBs and DDT in their blubber up to 10 times the concentration in their diet on a lipid weight basis. Jensen et al. (1969) report a similar ten-fold increase in grey seals and harbor seals from the Baltic. Holden (1972) reported a maximum ten-fold increase from fish prey (by lipid wt.) to the blubber of harbor seals and grey seals from Britain.

Body burden calculations in this study show that a large percentage of the chlorinated hydrocarbons in fish prey is absorbed and retained by adult male seals. The number of years (11) we calculated it would take adult male seals in Southern Puget Sound to reach their body burden of PCBs is unrealistically high. The high variability of PCB concentrations in seal prey and the relatively higher concentration factors from prey to seals that we found suggests that we are underestimating the concentration of PCBs in the prey of seals. This could be the result of seals feeding in more contaminated areas than those we sampled or of seals feeding on fish with a greater proportion of lipids than those we sampled.

Metabolism and excretion. Jensen and Jansson (1976) found methyl sulfone metabolite products of PCBs and DDE in blubber of ringed seals, grey seals and harbor seals. Jansson et al. (1979) identified phenolic metabolites of PCBs and DDE in grey seal scat from the Baltic. We found evidence of selective metabolism of different PCB homologs and estimate that a minimum of 5 percent of the PCBs and DDE present in seal prey is excreted in scat in an unmetabolized form.

4.1.3 PCB and DDT in other marine mammals

Minke whale. Minke whales are found in the waters off the Washington coast as well as the protected waters of Puget Sound. They are sighted much less frequently in Southern Puget Sound than in more northerly parts of Puget Sound (Everitt et al. 1980).

Low levels of PCBs and DDE were found in blubber tissue of a male minke whale found stranded at the Nisqually Delta (Southern Puget Sound) in March 1976. The DDE level (0.55 ppm wet wt.) was 3.7 times greater than the PCB residue (0.15 ppm wet wt.). Elsewhere, Henry and Best (1982) reported a mean of 0.17 ppm (wet weight) DDT and <0.5 ppm PCB in the blubber tissue of 29 minke whales landed at Durban, South Africa in 1974.

Killer whale. Very high concentrations of PCBs and DDE were found in the blubber tissue of an adult male killer whale found dead in Boundary Bay, British Columbia in January 1979. Levels of PCBs in this animal (250 ppm wet wt.) were similar to those found in adult harbor seals from Southern Puget Sound, and the DDE level (640 ppm wet wt.) was much higher than has been reported in any marine mammal from Washington State. This killer whale was identified as a member of "O" pod, a small group of killer whales thought to be transients in the Northern Puget Sound area (Balcomb et al. 1980).

High levels of PCBs and DDE (38 and 59 ppm wet wt., respectively) were also found in blubber of an adult male killer whale found dead in the San Juan Islands (Northern Puget Sound) in September 1977. As in the killer whale found dead in British Columbia, the DDE level was higher than that for PCBs. This particular animal was identified as a member of "L" pod, one of three resident groups of killer whales that frequent the waters of Puget Sound (Balcomb et al. 1980). We know of no other reports of PCB or DDE residues in the killer whale. Because high concentrations of PCBs and DDE were found in these two animals, it would be valuable to get additional information on chemical contaminants in killer whales.

Pygmy sperm whale. Analysis of the blubber of a male pygmy sperm whale found dead on Whidbey Island (Northern Puget Sound) in October 1977, revealed a low level of PCB (0.15 ppm wet wt.) but a higher level of DDE (1.3 ppm wet wt.). This species is considered rare throughout its range of primarily tropical and subtropical waters. The whale found stranded on Whidbey Island is the first record of this species for inland Washington waters, and, based on stomach contents, was not believed to have fed in Puget Sound (Everitt et al. 1980).

Jenness and Odell (1978) reported a level of 1.7 ppm total DDT (wet wt.) and 1.2 ppm PCB (wet wt.) in the milk from a lactating female pygmy sperm whale stranded on a south Florida beach in 1974.

Dall's porpoise. Residues of PCBs and DDE in the blubber of a male Dall's porpoise found dead on Lopez Island (Northern Puget Sound) in August 1981, were 9.0 and 5.0 ppm wet wt., respectively. The ratio of PCB to DDE in this porpoise is similar to that found in harbor seals from the Northern Puget Sound and Outer Coast regions. Northern Puget

Sound has a resident population of Dall's porpoise. Dall's porpoise are known to feed on small schooling and demersal fish (Everitt et al. 1980).

PCB and total DDT levels of 3.4 and 8.6 ppm wet wt., respectively, were reported in the blubber of a female Dall's collected off the Japanese coast in the mid-1970's (O'Shea et al. 1980). High residues of PCBs and total DDT (94 and 246 ppm wet wt., respectively) were reported in the blubber of an adult female Dall's porpoise collected in the mid-1970's from southern California waters (O'Shea et al. 1980).

Harbor porpoise. The blubber tissue of two harbor porpoise, one caught in a gillnet in Carr Inlet (Southern Puget Sound) in 1979 and the other a fetus found in the San Juan Islands (Northern Puget Sound) in 1977, were analyzed for residues of PCBs and DDE. Although the harbor porpoise is sighted regularly in Northern Puget Sound, the animal caught in Carr Inlet is the only recent record for this species in Southern Puget Sound (Everitt et al. 1980) and is definitely not a resident of this area. Before the 1950's, harbor porpoise were considered common in Southern Puget Sound (Scheffer and Slipp 1948).

Residues of both PCBs and DDE in the blubber tissue of the porpoise caught in Carr Inlet were high (55 and 14 ppm wet wt., respectively). The ratio of PCBs to DDE was lower than those we found in harbor seals from Southern Puget Sound but was similar to that of harbor seals from Northern Puget Sound. The levels of PCBs and DDE in the harbor porpoise fetus found on the San Juan Islands were 1.7 and 1.4 ppm wet wt., respectively.

High levels of PCB and DDT compounds have been documented in harbor porpoise from other areas. See Tables 40 and 41 for a summary of PCB and total DDT levels in blubber tissue of harbor porpoise from areas other than Washington State.

Population declines of the harbor porpoise in a number of areas have been suspected to be related to high concentrations of PCBs. Otterlind (1976) noted a drastic decline in the abundance of harbor porpoise along the Swedish west coast and in the Baltic Sea between 1940 and the mid-1970s and found high levels of both PCBs and DDT in the blubber of harbor porpoise from these areas in the 1970s (see Tables 40 and 41). Otterlind (1976) concluded that the declines were most likely linked to high levels of PCB. He also cited evidence that PCB concentrations were related to reproductive disorders found in seals from the Swedish west coast and the Baltic (Helle et al. 1976b, see section 4.3.6), and suggested the possibility of a similar effect in harbor porpoise.

Harbor porpoise have virtually disappeared from Southern Puget Sound and Hood Canal in Washington State (Calambokidis et al. 1978; Everitt et al. 1979) and from most areas in the Wadden Sea (Wolff 1982). In both these areas, high levels of PCBs are suspected to be linked to the disappearance of the harbor porpoise (Calambokidis et al. 1978; Wolff 1982).

River otter. Blubber tissue from a female river otter found dead at the Nisqually Delta (Southern Puget Sound) in September 1981, had ten times greater levels of PCBs (6.7 ppm wet wt.) than of DDE (0.6 ppm wet wt.). This PCB/DDE ratio is similar to that of harbor seals from Southern Puget Sound. The river otter frequents both freshwater and marine areas of Puget Sound and in Northern Puget Sound and feeds on sculpins, flounders, crayfish, and during the fall, spawning salmon (Hirischi 1978).

PCB contamination has been associated with declines in otter populations from two areas. River otters collected in the lower Columbia River area of Oregon contained high levels of PCBs in liver and muscle tissue (a mean of 9.3 and 3.7 ppm, wet weight, respectively, in five males) (Henny et al. 1981). River otters collected in other areas of Oregon contained low residues of PCBs. Based on the analysis of trapper harvest statistics, Henny et al. (1981) found that the lower Columbia River area showed a decreasing harvest during the period 1949-1976, while the river otter harvest has increased over this time in other areas of the state. They noted that PCB residues in livers of some of river otters from the lower Columbia River were higher than the residues detected in livers of mink that died of PCB dosage during experimental studies, and concluded that population declines of river otters in the lower Columbia River may have resulted from high concentrations of PCBs.

Almkvist (1982) reported that otter populations have decreased severely along the Baltic coasts of Sweden and Finland, and notes high levels of PCBs in otters from the Swedish coast. Otters from a stable population in northern Norway had PCB residues an order of magnitude lower than those found in the otters from the Baltic coast of Sweden. Seals living along the Baltic coasts of Sweden and Finland have been reported to suffer reproductive abnormalities that have been linked to high levels of PCBs (see section 4.3.6).

Otters inhabiting marine areas in Southern Puget Sound would be exposed to PCB concentrations in the environment that are within the range of those suggested to be responsible for the otter declines in the Columbia River and the Baltic. It appears important, therefore, to monitor levels of chemical contaminants in otters that are regularly feeding in marine waters of Puget Sound.

4.2 Metals and Trace Elements

All discussion of metal concentrations with the exeption of selenium refer to our results based on atomic absorption analysis.

4.2.1 Metal concentrations in harbor seals-comparison to world literature

Mercury. The Hg concentrations we found in the liver of harbor seals ranged from 1.7 to 1100 ppm (dry wt.). All but two samples, however, had concentrations <30 ppm. A pregnant adult female contained 1100 ppm Hg (dry wt.), a concentration over ten times higher than found in our other samples. This animal was the only adult female from Southern Puget Sound that we analyzed. This seal also had unusually low concentrations of PCBs and DDE.

Anas (1974b) reported total mercury residues in the liver tissue of two harbor seals from Puget Sound and one seal from the Outer Coast (Table 42). The range of total mercury and methylmercury residues in liver, kidney, and muscle tissues of over 35 harbor seals collected in Grays Harbor (Outer Coast) from 1976 through 1978 were reported by Northrup (1981) (Table 43). The concentrations reported by Northrup (1981) and Anas (1974a) for mercury concentrations in the liver of seals from Washington State are in the same range as those we found.

We identified 66 data sets on eight species of pinnipeds from 21 references reporting Hg concentrations in the liver (Table 44). The concentrations of Hg we found were generally in the same range as those reported in the literature. **The highest concentrations reported in the literature are in California sea lions and harbor seals from southern California, harbor seals from the Wadden Sea, ringed seals from Finland, and bearded seals from the Canadian Northwest Territories.**

The concentrations of Hg we found in kidney tissue of harbor seals (3.5–120 ppm, dry wt.) were generally higher than those reported in the literature. We found 12 references containing data sets on five species for Hg concentrations in the kidney of pinnipeds (Table 45). The highest reported concentrations were in California sea lions from southern California, and in adult harbor seals from San Francisco Bay, the Dutch Coast, and the Wadden Sea. The concentration of 120 ppm by dry wt. or 37 ppm by wet wt. Hg in the kidney of a subadult female from Gertrude Island (Southern Puget Sound) was higher than any Hg concentration reported in the literature for levels in the kidneys of pinnipeds. This was not the same animal that had the high Hg concentration in liver.

<u>Silver</u>. Only three references were found that reported Ag concentrations in the liver or kidney of pinnipeds (Table 46). Harbor seals from San Francisco Bay and the California coast and California sea lions from southern California had concentrations of Ag in the same range or slightly higher than those we found. The highest concentration reported, however, was in the liver of a Weddell seal from the Antarctic that had a concentration of Ag that was twice as high as the highest value we found.

<u>Aluminum</u>. Some of the tissues analyzed in this study were stored in aluminum foil, resulting in high values (up to 5100 ppm dry wt.) for Al in those samples. We found no references in the literature of Al levels in liver or kidney tissues of pinnipeds.

<u>Cadmium</u>. Cadmium concentrations ranged from 0 to 2.0 ppm (dry wt.) in the liver of 14 seals from Southern Puget Sound. These levels are lower than almost all the Cd liver levels from 19 data sets concerning eight pinniped species from 11 references (Table 47).

With few exceptions, Cd levels are higher in kidney tissue than in the liver tissue from the same animal. We found levels ranging from 0 to 46 ppm (dry wt.) in the kidney tissue of Southern Puget Sound seals. Nine of the 13 samples contained Cd levels of less than 5 ppm (dry wt.). The majority of the kidney data found in the literature reported higher levels of Cd than determined in this study (Table 48).

Age is an important factor in comparisons of Cd concentrations, as age-related increases of Cd in kidney tissues have been reported (Heppleston and French 1973; Roberts et al. 1976).

Copper. Copper levels ranged from 4.6 to 87 ppm (dry wt.) in the livers of our samples. Comparison to the literature shows these levels are in the same range of those found for harbor seals from the Wadden Sea, but lower than the levels in harbor seals and California sea lions from California (Table 49).

Levels of Cu in kidneys were lower on the average than the Cu levels in the liver of the same animals. A range of 6.8 to 120 ppm (dry wt.) was found in kidney. Only two of these samples contained residues greater than 25 ppm. Cu levels in kidney of Southern Puget Sound seals are in the same range as harbor seals from the Wadden Sea and San Francisco Bay, and in California sea lions from southern California (Table 50).

Chromium. Liver samples of seals from Southern Puget Sound had Cr levels ranging from 0 to 0.81 ppm (dry wt.). Only one comparative reference in the literature could be found; concentrations of Cr in the liver of two adult harbor seals from San Francisco Bay were approximately 20 times higher than levels reported in this study (Table 51).

Levels of Cr in kidney tissue were similar to levels in the livers of the same animals. Levels ranged from 0.13 to 0.97 ppm (dry wt.) in kidney tissue. Two references in the literature reported Cr levels in harbor seal kidney tissue (Table 51). Levels reported from the Wadden Sea were in the same range as the Southern Puget Sound seals. The other reference cited had detection limits well above the range of levels found in our samples.

Manganese. Four references were found that reported manganese levels in liver of pinnipeds (Table 52). Average Mn levels in livers of adult California sea lions were higher than those reported in our samples. We found a range of 4.8 to 31 ppm (dry wt.) in livers of Southern Puget Sound seals. One animal (a subadult male) had 31 ppm Mn in the liver, which was almost twice as high as any other sample we analyzed and higher than any reported in the literature.

Mn levels were lower in kidney tissues than in the liver tissues of the same animals. We found levels in kidneys ranging from 1.7 to 8.3 ppm (dry wt.). These levels were generally higher than those found in harbor seals from central California and the Wadden Sea, but in the same range as adult California sea lions from southern California (Table 52).

Zinc. The Zn levels in liver of harbor seals from Southern Puget Sound ranged from 54 to 410 ppm (dry wt.). All but three samples were under 200 ppm. We located data sets on seven species of pinnipeds from eight references concerning Zn concentrations in liver (Table 53). The levels we found were in the same range as the majority of reports in the literature. Higher levels of Zn were reported in California sea lions from southern California, harbor seals from San Francisco Bay, and a Weddell seal from the Antarctic.

Concentrations of Zn in kidney tissues of harbor seals from Southern Puget Sound were lower than the Zn levels in liver tissues of the same animals. Zn levels in kidneys of three species of pinnipeds reported in the literature (Table 54) were in the same general range as we found in this study.

Lead. Pb levels in the livers of Southern Puget Sound seals ranged from 0.15 to 1.5 ppm (dry wt.). We found data for comparison on six species of pinnipeds (Table 55). Residues of Pb higher than those determined in the Southern Puget Sound seals have been reported for harbor seals from the Wadden Sea and Britain, California sea lions from the California coast, and in northern fur seals from the Washington coast. Levels similar to ours were reported in ringed seals and grey seals from the North Sea.

Concentrations of Pb were lower in kidney tissue than in the liver of our samples. We found Pb levels in kidneys that ranged from 0.086 to 0.57 ppm (dry wt.). Pb levels reported in the kidney of harbor seals from Britain, northern fur seals from the Washington coast, and California sea lions from southern California, were higher than the levels in Southern Puget Sound seals. Residue levels similar to ours were reported in the kidneys of harbor seals from the Wadden Sea (Table 56).

Selenium. Levels of Se ranging from 4.7 to 210 ppm (dry wt.) were determined in the liver tissue of five Southern Puget Sound harbor seals. Four of the animals were subadults that together had a geometric mean of 13 ppm (dry wt.). The one adult animal contained 210 ppm Se in the liver. These results reflect age-related increases in liver Se concentrations that have been reported in the literature (Martin et al. 1976). We found data on Se in the liver of four species of pinnipeds contained in 8 references from the literature (Table 57). For subadult animals, levels of Se in livers appear to be highest in harbor seals from the Dutch coast. Se levels reported in subadult harbor seals from the Wadden Sea were lower than those we reported from Southern Puget Sound.

A range of 7.2 to 12 ppm (dry wt.) Se was found in the kidneys of five harbor seals from Southern Puget Sound. The highest concentration (12 ppm) was again found in the one adult seal. This level, however, was only slightly higher than the level in the four subadults, in contrast to the Se levels in liver tissue where the adult contained over 10 times the levels in the subadults. We compared residues of Se in kidneys reported in five references of three species of pinnipeds (Table 58). Se levels we found from Southern Puget Sound are in the same range as those reported in harbor seals from other areas.

Bromine. Bromine levels in the livers of five harbor seals from Southern Puget Sound ranged from 29 to 35 ppm (dry wt.). Only three references reporting Br levels in livers of pinnipeds were located (Table 59). The Br levels we found were lower than in harbor seals from San Francisco Bay, the California coast, and the Wadden Sea, and also lower than levels reported in California sea lions from southern California.

Levels of Br were consistently higher in the kidneys than in the livers of the five harbor seals we analyzed. Br levels in kidneys ranged from 41 to 77 ppm (dry wt.). Compared to the three references in the literature that reported Br concentrations in kidneys of pinnipeds, the levels we found were lower than in harbor seals and California sea lions from California, but in the same range as harbor seals from the Wadden Sea (Table 60).

Iron. Iron levels of 1200-4400 ppm (dry wt.) were found in the livers of five harbor seal samples from Southern Puget Sound. These levels are in the same range as the Fe levels reported in Weddell seals, harbor seals, and California sea lions from other areas (Table 61).

Kidney tissues of five harbor seals from Southern Puget Sound contained a range of 640 to 1000 ppm (dry wt.) Fe. Residue concentrations in kidney tissue were consistently less than the residues found in liver tissue of the same animal. The levels we found were in the same range as harbor seals from California, but are higher than the levels reported in harbor seals from the Wadden Sea and in California sea lions from southern California (Table 62).

Arsenic and rubidium. Tables 63 and 64 list the levels of As and Rb found in the liver and kidney tissues of harbor seals from California. Levels of As reported in harbor seals from California were below the detection limit (2.0 ppm dry wt.) of the As analysis of the Southern Puget Sound harbor seals.

Rubidium levels in the livers and kidneys of four subadult seals from Southern Puget Sound were in the same range as levels in harbor seals from California. In the one adult seal analyzed from Southern Puget Sound, the Rb level in the kidney (20 ppm dry wt.) was over four times higher than levels reported in the harbor seals from California.

Nickel, gallium, and strontium. No reports of Ni, Ga, or Sr residues in liver or kidney tissue of pinnipeds were found in the literature for comparison to the levels reported in five Southern Puget Sound harbor seals.

4.2.2 Mercury, selenium, and bromine relationships

Reports of mercury residues in liver tissues of marine mammals have demonstrated that the majority (approximately 80%) of the mercury detected is not in the methylated form, although the methylated form predominates in fish prey (Koeman et al. 1975; Roberts et al. 1976; Smith and Armstrong 1978). Age-related increases of both mercury and selenium in the liver of marine mammals have been reported, and mercury/selenium atomic relationships were found to be close to 1:1 (Koeman et al. 1973; Koeman et al. 1975; Kari and Kauranen 1978; Smith and Armstrong 1978; Ven et al. 1979). The 1:1 mercury/selenium ratio is generally considered evidence that selenium plays a key role in the detoxification of mercury in the liver of marine mammals (Smith and Armstrong 1978; Ven et al. 1979). Laboratory studies with rodents have demonstrated the detoxifying effects of selenium when administered in conjunction with mercury compounds (Parizek et al. 1971).

Martin et al. (1976) found atomic ratios of mercury, selenium, and bromine close to 1:1:1 in livers of adult female California sea lions that had given birth to healthy pups, while in females that had given birth to premature pups the mercury/selenium atomic ratios were close to 1:1 but the bromine concentrations were low. They suggested that bromine is also involved in the detoxification process, interacting with mercury and selenium.

The atomic ratio of mercury/selenium found in the liver of four of five harbor seals from Southern Puget Sound approximated the 1:1 ratio that has been reported in other marine mammal species (see Table 29). The one sample that did not approximate the 1:1 mercury/selenium atomic ratio was a subadult animal that contained the lowest levels of total mercury (<10 ppm dry wt.). The mercury/bromine atomic ratios varied much more than did the mercury/selenium ratios. Only two of the five samples approximated a 1:1 mercury/bromine ratio (Table 29). Further discussion of the significance of mercury/selenium/bromine atomic ratios in livers of the harbor seals we analyzed is precluded by the small sample size and limited age-class of the seals, four of the five animals analyzed were subadults.

4.2.3 Metal dynamics in harbor seals

Clearly, levels of Hg in liver are positively correlated with age in pinnipeds including grey seals (Freeman and Horne 1973), harbor seals (Roberts et al. 1976; Harms et al. 1978; Heppleston and French 1973), ringed seals (Smith and Armstrong 1978), harp seals (Freeman and Horne 1973), and bearded seals (Smith and Armstrong 1978).

Of other heavy metals investigated in soft tissues (Zn, Pb, Cd) only Cd is consistently reported to increase with age (Heppleston and French 1973; Roberts et al. 1976). Kidney was the primary site of concentration for Cd (Heppleston and French 1973). Lead was found most prevalently in bones, and no clear correlations to age could be drawn (Roberts et al. 1976). Our finding of significant differences related to age category of Cd concentrations in the liver and not in the kidney is unusual and has not been reported in the literature.

4.3 Biological Effects of Environmental Toxicants

It is extremely difficult to determine how chemical contaminants in the environment affect marine mammals. Most laboratory toxicity studies only provide information on the toxicity of individual contaminants, over a short period, in the absence of other environmental stresses. Toxicity studies are rarely done on large mammals. Due to the plethora of uncontrolled variables outside of the laboratory, cause and effect relationships are difficult to isolate in wild populations. The presence of large numbers of chemical contaminants, human disturbance pressures, natural pathogens, and other environmental stresses all confound attempts to establish links of biological disorders with environmental toxicants.

To evaluate effects of environmental contaminants on Washington marine mammals we reviewed information on 1) disorders observed in Puget Sound seals, 2) population trends of Washington harbor seals, 3) correlations that have been made by others between chemical contaminants and disorders in marine mammals and their close relatives, and 4) the general toxic effects of environmental toxicants.

4.3.1 Disorders in Puget Sound harbor seals

Several studies on the biology of harbor seals in Southern Puget Sound have reported disorders that may be related to pollutants. Reported disorders include premature births, birth defects, and high pup mortality. Most of this information has not been published.

Terry Newby, in research on harbor seals at Gertrude Island in Southern Puget Sound, found high rates of pup mortality , premature births, and birth defects (Newby 1971, 1973b, unpublished data; Arndt 1973). Four pups with birth defects were observed at Gertrude Island in 1970, three of which were found dead (Newby 1973b). An estimated 38 pups were born that year. In 1972, eight birth defects were seen at Gertrude Island, in six pups found dead and in two collected pups. An estimated 26 pups were born that year. Birth defects included omphaloceles, skeletal deformities, and lack of limbs. Premature births, characterized by the presence of the lanugo coat, was also seen up to 3 months prior to the pupping season. Two premature births were found in 1965, two in 1970, and two in 1972. The total incidence of prenatal and neonatal deaths at Gertrude was 8 out of an estimated 38 pups in 1970 and 9 out of an estimated 26 pups born in 1972.

Research in Southern Puget Sound from 1975 to 1977 (Johnson and Jeffries 1977, 1983, Calambokidis et al. 1978) revealed cases of premature births and birth defects. Johnson and Jeffries (1983) found a pup from Budd Inlet in 1977 that had a teratoma of the brain and recovered two dead pups with lanugo coats on Gertrude Island in 1975. Calambokidis et al. (1978) found a pup with a deformed flipper at Quilcene Bay, Hood Canal in 1977. In 1977, 50 percent of the pups born at two sites in Southern Puget Sound were reported to have died or were found dead within a few months of the pupping season (Calambokidis et al. 1978). This mortality rate exceeded that found in other parts of the state in 1977.

It is difficult to determine changes in pup mortality and in the number of premature births and birth defects that have occurred since 1972. Recent research has relied on different techniques and different levels of effort. However, the high incidence of birth defects reported in 1970-1972 at Gertrude Island, and the much more infrequent recovery of pups with birth defects in later years suggest that this phenomenon was of short duration.

4.3.2 Population trends in Washington harbor seals

The number of harbor seals in Washington state decreased between 1940 and the early 1970s. Scheffer and Slipp (1944) estimated the Washington State population at 5,000 seals in the early 1940s. Newby

(1973a) reported much lower numbers in the 1970s, estimating the population at under 2,000 seals. This decrease was attributed to extensive bounty hunting through 1960, loss of habitat due to increasing human disturbance, and the increase in pollutant levels in Puget Sound (Newby 1971). From the 1920s through 1960, in response to perceived depredation on fisheries, Washington State paid a bounty for harbor seals and sea lions (Johnson and Jeffries 1977). Newby (1971) estimated that 10,000 to 17,000 harbor seals were killed between 1943 and 1960.

Between 1970 and 1977, seal numbers apparently increased in Northern Puget Sound, Hood Canal (Calambokidis et al. 1978, 1979a) and on the Outer Coast (Johnson and Jeffries 1983). The Southern Puget Sound populations did not appear to increase in the 1970s. At Gertrude Island, the largest breeding site, a high count of 194 seals was recorded between 1965-1968 in a study by Arnold (1968). In research at Gertrude Island between 1968 and 1977, counts of just over 200 were recorded on 25 July 1970 (Newby 1971) and April 1976 (Johnson and Jeffries 1983).

Since 1977, populations on the Outer Coast have continued to increase (Everitt and Beach 1982). Southern Puget Sound populations also appear to be increasing. During isolated visits at Gertrude Island, we observed 280 seals hauled out in September 1980 and 368 seals hauled out in July 1983 (authors, unpublished data). We also noted a substantial increase in the number of harbor seals sighted at Henderson Inlet (in Southern Puget Sound) between 1977 and 1983. We observed up to 134 animals at Henderson Inlet in 1983 (authors, unpublished data), where the high count was 40 seals in 1977 (Calambokidis et al. 1978).

In summary, population increases between 1960 and the late 1970s suggest that harbor seal populations in most areas of Washington State were responding to the end of the bounty in 1960 and marine mammal protection in the 1970s. The Southern Puget Sound seal population apparently did not increase during this time. In recent years, however, evidence of increased populations at major sites in Southern Puget Sound has been observed.

4.3.3 Premature births in California sea lions off southern California

A complex phenomenon has been documented in California sea lions giving birth to premature pups in the Channel Islands off southern California. Premature parturition in California sea lions was first observed in the Channel Islands in the late 1960s (Odell 1971; Gilmartin et al. 1976). Pups were generally born alive 1-4 months premature, and lacked motor coordination and had difficulty breathing (DeLong et al. 1973; Gilmartin et al. 1976). The early premature pups are not furred and appear to die shortly after birth; those born later were furred and appeared to live up to several days (DeLong et al. 1973). An estimated 20 percent of the pups on San Miguel Island were born premature in the early 1970s (Gilmartin et al. 1976).

Five factors have been isolated in the females giving birth to premature pups, that singly or in combination, may be responsible for the premature births. These factors are: 1) high concentrations of PCBs and DDT, 2) an imbalance of certain heavy metals, 3) age differences between the full-term and premature partus females, 4) presence of the bacterium Leptospira pomona, and 5) presence of San Miguel sea lion virus (SMSV). These factors are discussed in turn in the following paragraphs.

The premature births were associated with high levels of PCBs and DDT. Le Boeuf and Bonnel (1971) found extremely high concentrations of DDT (41 to 2678 ppm by wet wt.) in the blubber of California sea lions collected and stranded along the coast of California from the Channel Islands to San Francisco. DeLong et al. (1973) found PCB and DDE residues 2 to 8 times higher in 6 premature pups and their mothers than in 4 full-term pups and their mothers collected from San Miguel Island in 1970. Gilmartin et al. (1976) found DDE residues 7.6 and 4.8 times greater in blubber and liver of premature parturient California sea lions compared to the same tissues of full-term animals. PCB residues were 4.4 and 3.8 times greater in blubber and liver of the premature animals compared to the full-term animals. Ten females that gave birth to full-term pups were between 10 and 14 years old while, with one exception, the premature partus females were between 6 to 8 years old (Gilmartin et al. 1976). The differences in PCB and DDT residues between the premature partus females and full-term females may be caused by segregation of age classes into differentially contaminated feeding areas (Gilmartin et al. 1976). Risebrough (1978) suggested that other factors that covary with age (besides pollutant concentrations) may be the cause of these premature births. Bowes et al. (1973) examined liver and blubber tissue of California sea lions that had given birth to premature pups for the presence of chlorinated dibenzofurans, highly toxic compounds that are associated with or derived from PCB compounds, although none were detected.

Martin et al. (1976) examined heavy metal concentrations in the tissues of the premature partus and full-term California sea lions reported by Gilmartin et al. (1976). Concentrations of Hg, Se, Cd, and Br were significantly higher in the older full-term females than in the younger aborting females. The concentrations of these four chemicals were highly correlated, with atomic ratios of Hg:Se:Br of 1:1:1 in the full term females but not in the aborting females. Martin et al. (1976) suggest that the balance between these chemicals may be more important than the absolute concentration.

Two disease agents, isolated from California sea lions, appear to be involved with the reproductive difficulties. Leptospira pomona, a bacterium known to cause abortions in several animal species (Roberts 1971), was shown to be the cause of death of male California sea lions along the California coast in 1970 (Vedros et al. 1971). L. pomona was recovered from the placenta and fetus of one of the aborting California sea lion females (Smith et al. 1974a, 1974b; Vedros et al. 1971) and four aborting females had L. pomona antibody titers (Gilmartin et al. 1976). A second disease agent, San Miguel sea lion virus (SMSV) was also isolated from three aborting females and the fetus of one aborting female (Smith et al. 1973; Gilmartin et al. 1976). This virus appears to be identical to vesicular exanthema of swine virus (VESV) which can cause near term abortions in domestic animals (Sawyer 1976). Gilmartin et al. (1976) suggest that an interrelationship of disease agents and environmental contaminants is the cause of the premature pupping in California sea lions.

4.3.4 Population declines of harbor seals in the Wadden Sea

Reijnders (1981) and Reijnders et al. (1982a, 1982b) document the decline of the harbor seal population of the Wadden Sea and cite PCBs as the cause of these declines. While harbor seal populations in the German and Danish parts of the Wadden Sea have increased in the 1970s, the populations in the Dutch Wadden Sea (the western-most portion) have not shown much improvement. Extensive hunting appears to have been the cause of the decline through the 1960s. Low reproductive rates in seals of the Dutch Wadden Sea were reported to be responsible for a population decline in this area during the 1970s. In the last few years the harbor seal population in the Dutch Wadden Sea has stabilized, though this appears to be, in part, the result of immigration from other areas. The southern Dutch harbor seal population (south of the Wadden Sea) is virtually extinct in the areas where it was previously common (Reijnders 1982c).

Harbor seals in the Wadden Sea show an increase in reproductive rate in a west to east gradient, with harbor seals in the Dutch Wadden Sea having the lowest reproductive rate (Reijnders et al. 1982a, Drescher 1979). Harbor seals in the Dutch Wadden Sea also have a higher mortality in the first weeks of life compared to other parts of the Wadden Sea, though overall mortality appears to be of the same order after three months (Reijnders et al. 1982a, Reijnders 1982b). Drescher (1978) documented a high incidence of skin lesions in harbor seals from the Wadden Sea, involving 40 percent of the juvenile seals in one area. This high incidence of skin lesions may be partly responsible for the population decline (Drescher 1978).

PCB concentrations in harbor seals from the Dutch Wadden Sea (an average of 700 ppm wet wt. in the blubber of eight adults) are among the highest found anywhere, and are higher than the concentrations in other parts of the Wadden Sea (Reijnders 1980, 1982b). Outflow from the Rhine River appears to be the source of the PCB residues in the Dutch Wadden Sea.

Reijnders (1980,1982a) concludes that PCBs are responsible for the low reproductive rate of Dutch harbor seals, and cites the following evidence: 1) the pattern of lower reproductive success in areas of higher PCB concentrations in the Wadden Sea, and 2) the demonstrated effect of PCBs on mammalian reproduction. They suggest that PCBs alter steroid hormone levels and may affect seal reproduction during delayed implantation. The immuno-suppressive properties of PCBs are also cited as possibly contributing to disease and infection. Both PCBs and abrasions caused by human disturbance are suspected as the cause of the high incidence of skin lesions found in harbor seals from the Wadden Sea (Drescher 1978, Reijnders 1981, Reijnders et al. 1982b).

4.3.5 Premature births in San Francisco Bay harbor seals

In 1971 five premature stillborn harbor seal pups were found on Strawberry Spit in San Francisco Bay, California (Paulbitsky 1975); two more premature pups were found in January-February 1972 (Risebrough et al. 1979). These findings prompted concern that pollutants in San Francisco Bay were the cause of the reproductive problems. A study to examine the problem was funded by the Marine Mammal Commission (Risebrough et al. 1979).

In 1975 and 1976 only one premature harbor seal pup was found each year. Risebrough et al. (1979) concluded that incidence of premature pupping was lower than in 1971. PCB concentrations in San Francisco Bay harbor seals were higher and DDE concentrations lower (an average of 195 and 56 ppm, respectively, lipid weight in blubber of two adults) than in California sea lions giving birth to premature pups in the Channel Islands (Risebrough et al. 1979). They concluded that pollutants are not a current threat to San Francisco Bay harbor seals because of: 1) the low rate of premature pupping in 1975 and 1976, 2) the low concentration of DDE relative to that suspected to be the cause of premature births in California sea lions, and 3) the probable continued decline of DDE in the environment. The role of PCBs or DDT in the premature pupping that occurred in the early 1970s could not be determined, although Risebrough et al. (1979) suspected that DDT levels were higher during that time. The number of harbor seals using Mowry Slough, the primary haul out site in San Francisco Bay, appears stable with little change between 1972 and 1980 (Fancher and Alcorn 1982).

4.3.6 Reproductive dysfunctions in Baltic seal populations

Three species of seals in the Baltic Sea area have experienced pathological changes of the uterus that appear to be related to pollutants (Helle et al. 1976a, 1976b).

Reports of lowered reproduction in Baltic ringed seals began around 1967 (Helle 1979b, 1980a). Pathological changes in the uterus of Baltic seals were first noted in 1973 and appear to be the primary cause of the lowered reproduction of ringed seals (Helle 1980a). The pathogical changes consist of occlusions or stenoses of one or both horns of the uterus of collected ringed seals (Helle 1979b, 1980a). These changes may be the result of infection or early termination of pregnancy, during the period of delayed implantation or the early stages of fetal development (Helle 1980a). The pathological changes have been studied primarily in ringed seals from the Bothnian Bay, but have also been documented, to a more limited degree, in grey seals from the Baltic proper and in harbor seals from the Swedish west coast (Helle et al. 1976b, Olsson 1978). In addition to the ringed seals with uterine occlusions, 25 percent of the adult females collected in these studies were not pregnant even though they showed no pathological disorders in the uterus (Helle 1980b). This is an unusually high percentage of non-pregnant females (Helle 1980a).

The reproductive problems of Baltic ringed seals have reached critical proportions (Helle 1980b). Between 1974 and 1979 the frequency of adult female ringed seals with uterine occlusions increased steadily from 35% to 59% and the proportion of pregnant females decreased steadily from over 30% to under 20% (Helle 1980a). If this low rate of reproduction were to continue, the number of ringed seals in the Baltic would drop to half its current level in less than 20 years (Helle 1980b).

Helle et al. (1976a, 1976b) found a significantly higher concentration of PCBs and DDT in female ringed seals with the uterine occlusions than in pregnant females. They concluded PCBs and not DDT were directly or indirectly responsible for the ringed seal reproductive problems because: 1) the DDT levels in the blubber of Baltic ringed seals were equivalent to healthy non-aborting female California sea lions studied by DeLong et al. (1973) and Gilmartin et al. (1976), and 2) the PCB concentrations in Baltic ringed seals were equivalent to those shown to cause reproductive problems in mink (Jensen et al. 1977). Helle et al. (1976b) suggest that the occlusions and stenoses are either the direct effect of PCB intoxication or the result of an infection of the uterus in females weakened by PCBs. Olsson et al. (1975) monitored Baltic ringed seal populations for premature births, but found only small numbers.

Reijnders (1980), in reviewing the Baltic ringed seal studies, concludes that the hypothesis that PCBs are the cause of the pathological disorders should be viewed with reserve. The difference between the mean concentrations of PCBs in the ringed seals with occlusions and those that were pregnant is small (110 vs 73 ppm lipid weight in blubber) and could easily have been the result of the difference in reproductive status. Though not reported by Helle et al. (1976b), his figures indicate there was not a significant difference in the PCB levels between the non-pregnant females with normal uterii and the females with the uterine occlusions.

4.3.7 PCB and DDT effects on mink

Mink are the most closely related mammal to pinnipeds for which both 1) a direct cause and effect relationship between reproductive problems and environmental concentrations of PCBs or DDT has been demonstrated and 2) laboratory studies have demonstrated PCB or DDT toxicity at levels present in the environment. Jensen et al. (1977) considered mink the best species for testing the effects of pollutants on pinnipeds because, like seals, they feed on fish and delayed implantation is a part of their reproductive cycle.

Ranch mink fed fish from the Great Lakes in the late 1960s began to experience reproductive problems and high kit mortality (Aulerich et al. 1971). Subsequent studies indicated PCBs in the fish were responsible for the reproductive failures (Aulerich et al. 1973). Experimental studies have shown that mink are highly sensitive to PCBs. Mink that were fed 2 ppm PCBs in their diet for 9 months prior to whelping (total dose estimated at 61 g) did not reproduce (Aulerich and Ringer 1977). Mink fed cow meat (*ad libitum*) containing 0.64 ppm PCBs by wet wt. for 7 months, produced no surviving young (Platonow and Karstad 1973). Jensen et al. (1977) found that PCBs had a more powerful effect on mink reproduction than did DDT, with PCB fed mink exhibiting a reduced number of whelps, smaller whelps, and increased number of stillbirths, undersize young, and reduced survival of young.

Ranch mink fed fish caught in New Brunswick concentrated higher levels of DDT, had higher embryonic loss, and gave birth to a disproportionate ratio of females over males compared to mink fed commercial mink food (Gilbert 1969). Gilbert (1969) concluded the DDT residues in the fish (1.52 to 13.23 ppm wet weight) were the cause of the problems; concentrations of PCBs were apparently not determined and therefore may have also been present.

4.3.8 Toxic effects of PCBs and DDT

An overview of the toxic effects of all the environmental toxicants present in Puget Sound marine mammals is beyond the scope of this report. Because reproductive problems in pinnipeds have been associated with concentrations of PCBs and DDT, a brief review of relevant aspects of the toxicology of these two chlorinated hydrocarbons is discussed below. The presence of polychlorinated dibenzofurans (PCDFs) as a chemical contaminant in PCBs is an important consideration in evaluating the reported toxic effects of PCBs. Many studies of the toxic effects of PCBs use commercial PCB mixtures that are likely to also contain PCDFs, making it difficult to separate toxic effects attributed to PCBs from those that may be the result of PCDFs. We discuss PCDFs in section 4.3.9.

Two toxic effects of PCBs and DDT have been suggested as the mechanism for the effect of these chemicals on pinniped reproduction: 1) alteration of hormone levels, and 2) immunosuppression.

PCBs and DDT induce hepatic microsomal enzyme activity which may affect the levels of steroid hormones involved in reproduction (Peakall 1967; Conney et al. 1967; Kupfer 1969). PCBs altered steroid hormone biosynthesis <u>in vitro</u> in the grey seal (Freeman and Sangalang 1977). PCBs and DDT increased the length of the estrous cycle in mice, probably as a result of the increased steroid hormone metabolism (Orberg et al. 1972). The DDT compound o,p'-DDT was shown to have estrogenic activity in the reproductive tissues of birds and mammals (Bitman et al. 1968).

Reijnders (1980, 1982a) noted that the period of delayed implantation in seals may be a time that would be extremely sensitive to disruption by hormonal imbalance. He suspects that pollutant-caused hormonal imbalance during delayed implantation to be the likely mechanism for PCB interference with reproduction of harbor seals in the Wadden Sea. The end of the period of delayed implantation is the suspected time of the disruption of reproduction in Baltic ringed seals (Helle 1980a).

The immunosuppressive properties of PCBs and DDT could also influence the reproductive success of seals. Friend and Trainer (1970) reported that mallards fed PCBs at doses that caused no apparent clinical intoxication had significantly higher mortality when exposed to duck hepatitis virus. Hansen et al. (1971) reported that pinfish and spot exposed to PCBs were more susceptible to disease. The body defense systems of rats were moderated by ingestion of DDT (Wassermann et al.

1969). Vos and deRoij (1972) demonstrated the immunosuppressive activity of PCBs on the humoral immune response in guinea pigs.

PCBs (or contaminants present in PCBs) and DDT have been shown to cause reproductive difficulties, relevant to observed reproductive problems in pinnipeds, in a variety of other animals. Stendell (1976) summarizes some of the findings on the effect of PCBs on birds and mammals. White-footed mice fed PCBs gave birth to a reduced number of litters with no young surviving past 21 days (Merson and Kirkpatrick 1976). Feeding DDT to rabbits caused prematurity and intra-uterine growth retardation (Hart et al. 1971). The reproductive effects of DDT and PCBs on several species of birds have been documented (Peakall 1970, Peakall et al. 1972, Cook 1973, Cecil et al. 1974). PCBs affect the reproduction of fathead minnows (Nebeker et al. 1974) and were implicated as the cause of stillbirths in big brown bats (Clark and Lamont 1976). Allen and Norback (1976) and Allen and Barsotti (1976) reported that female rhesus monkeys fed dietary levels of PCBs as low as 2.5 and 5 ppm for up to 1.5 years developed reproductive dysfunctions (among other symptoms) which included irregular menstrual cycles, early abortion, and stillbirths. Of the rhesus monkey infants born of dosed mothers, 50 percent died within 4 months. Women who ingested rice oil contaminated with PCBs in Japan suffered symptoms which included menstrual disturbances, undersized offspring, and unusual pigmentation of young (Kuratsune et al. 1976), as well as a high incidence of stillbirths (Kuratsune et al. 1972).

4.3.9 Polychlorinated dibenzofurans

Polychlorinated dibenzofurans (PCDFs) are highly toxic contaminants of PCBs and polychlorinated phenols. Since PCDFs are present in commercial mixtures of PCBs, toxic effects of PCBs determined in experiments using commercial mixtures may in part be the result of PCDFs. Toxic effects attributed to the ingestion of PCB contaminated rice oil in Japan may instead be caused by PCDFs occurring with the PCBs (Kuroki and Masuda 1978).

PCDFs were chosen as one of the contaminants of greatest concern in Puget Sound by Konasewich et al. (1982) because of their high toxicity and potential wide-spread distribution throughout Puget Sound. PCDFs have been detected in Puget Sound sediments (Malins et al. 1982). PCDFs have not been detected in biota from Puget Sound though the low concentrations at which they occur makes detection difficult. As mentioned earlier, Bowes et al. (1973) searched for, but did not detect PCDFs in tissues of California sea lions that had given birth to premature young on the Channel Islands off southern California. Rappe et al. (1981) found 12 PCDF isomers totaling 40 parts per trillion (.00004 ppm) in the fat of a grey seal from the Baltic. The isomers present in the seal fat suggested that contamination in PCBs was the source of the PCDFs (Rappe et al. 1981).

Association between PCB concentrations and reproductive problems discussed in previous sections could reflect the effects of PCDFs and/or PCBs. Though a concerted search for PCDFs in Puget Sound seals has not been made, the high PCB concentrations in this area, make seal exposure to PCDFs in Puget Sound likely.

5. CONCLUSIONS

There is evidence that PCBs or PCB-related compounds may have had a deleterious effect on harbor seals in Southern Puget Sound. Harbor seals in Southern Puget Sound contain higher concentrations of PCBs than those from other parts of the state and from most other parts of the world. Reproductive problems and high juvenile mortality have been reported in seals from Southern Puget Sound. Harbor seal populations in Southern Puget Sound did not rebound as quickly as did those from other parts of the state after legal protection of marine mammals was implemented. In two other areas, the Baltic and the Wadden Sea, PCB concentrations similar to those found in Puget Sound seals have been implicated as the cause of reproductive problems or high juvenile mortality. Mink, similar to pinnipeds in their delayed implantation, have been shown to be highly sensitive to PCB-induced reproductive difficulties.

There are several considerations, however, that argue against the existence of any link between pollutants and disorders in harbor seals in Southern Puget Sound. There is not a consistent pattern in the types of dysfunctions that have been linked to pollutants in pinnipeds. Near-term premature births seen in California sea lions are not seen in high numbers in seals from the Baltic or Wadden Sea. Uterine occlusions similar to those reported in Baltic seals, thought to be caused by PCBs, have not been seen in the Wadden Sea, despite higher PCB levels there. Birth defects, reported in high numbers in Southern Puget Sound harbor seals in the early 1970s, have not been reported as possible pollutant-related dysfunctions in other pinniped populations.

There is no evidence that other pollutants, besides PCB or PCB-related compounds, may be affecting seals in Puget Sound. We did not find any evidence of unusually elevated levels of other pollutants. DDT, another environmental toxicant linked to reproductive problems in pinnipeds, is present in lower concentrations in Puget Sound seals than is reported for many other areas. There are other possible sources of stress or mortality, exclusive of pollutants, that affect seals in Southern Puget Sound. These include human-induced disturbance and habitat modification or loss.

There is no evidence of high rates of premature births and birth defects in the Southern Puget Sound population in the last 10 years, and numbers at certain sites have increased in recent years. There has not been a recent focussed attempt, however, to search for a variety of potential disorders in harbor seals that may be related to pollutants in Puget Sound.

It is difficult to link pollutants directly to dysfunctions in pinnipeds. Though correlations between several disorders in pinnipeds and pollutants have been made, no study has firmly established a cause and effect relationship. Variations in the reported pollutant-related effects indicates a phenomenon more complicated than direct acute toxicity. Interactions between pathogens and pollutant-induced immunosuppression, as well as dysfunctions in steroid hormone regulation caused by pollutants, appear to be the most likely mechanisms that would explain patterns of disorders seen in different seal populations.

6. RESEARCH RECOMMENDATIONS

1. Determine the population trends of harbor seals in polluted and non-polluted areas of Puget Sound.

   Comparative population trends serve as an indicator of the presence of high rates of mortality or low reproductive rates. If pollutants are having a significant deleterious effect on seal populations, it should be discernible through comparative population trends.

2. Examine harbor seals in polluted and non-polluted areas for signs of disorders that may be pollutant-related.

   Low reproductive rates, reproductive pathology, premature births, neonatal mortality, and certain pathology in pinnipeds have been linked to pollutants. Examination of stranded animals in polluted and non-polluted areas in Puget Sound would help to determine if significant incidences of biological disorders are present. This includes examination of Puget Sound animals for pathology that has been identified as related to pollutants in European waters.

3. Determine if concentrations of PCBs have changed over time.

   Populations of harbor seals in Southern Puget Sound appear to be higher now than in the early 1970s. PCBs are the principal pollutant implicated in reproductive problems in several marine mammal species. Information on trends in the concentration of PCBs in Puget Sound is essential for evaluating the reproductive problems that have been reported in Puget Sound seals in the early 1970s. Some of the authors (J.C. and J.P.) measured PCB concentrations in fish, sediment, and mussels at 21 sites in Southern Puget Sound in the early 1970s (Mowrer et al. 1977). If such a study were repeated using the same species, sites, collection methods, analytical methods, and quantitative techniques, changes in PCB concentrations in Southern Puget Sound could be determined.

4. Evaluate possible threats (besides pollution) that may adversely affect harbor seals in Southern Puget Sound.

   A number of factors including decreased prey abundance, habitat availability, fishery interactions, and increased human disturbance, could adversely affect the status of harbor seals in Southern Puget Sound. Combinations of these potential problems (with or without the contribution of toxic chemicals) may occur and a better understanding of the role of these factors is required in order to isolate effects of pollutants.

5. Collect additional biological and chemical data on river otter, killer whale, and harbor porpoise.

   We found high concentrations of PCBs and DDT in killer whales from Northern Puget Sound. Population declines of river otters and harbor porpoise in other areas have been linked to PCBs. Information on toxicant concentrations and their possible effects on these species in Puget Sound is extremely limited.

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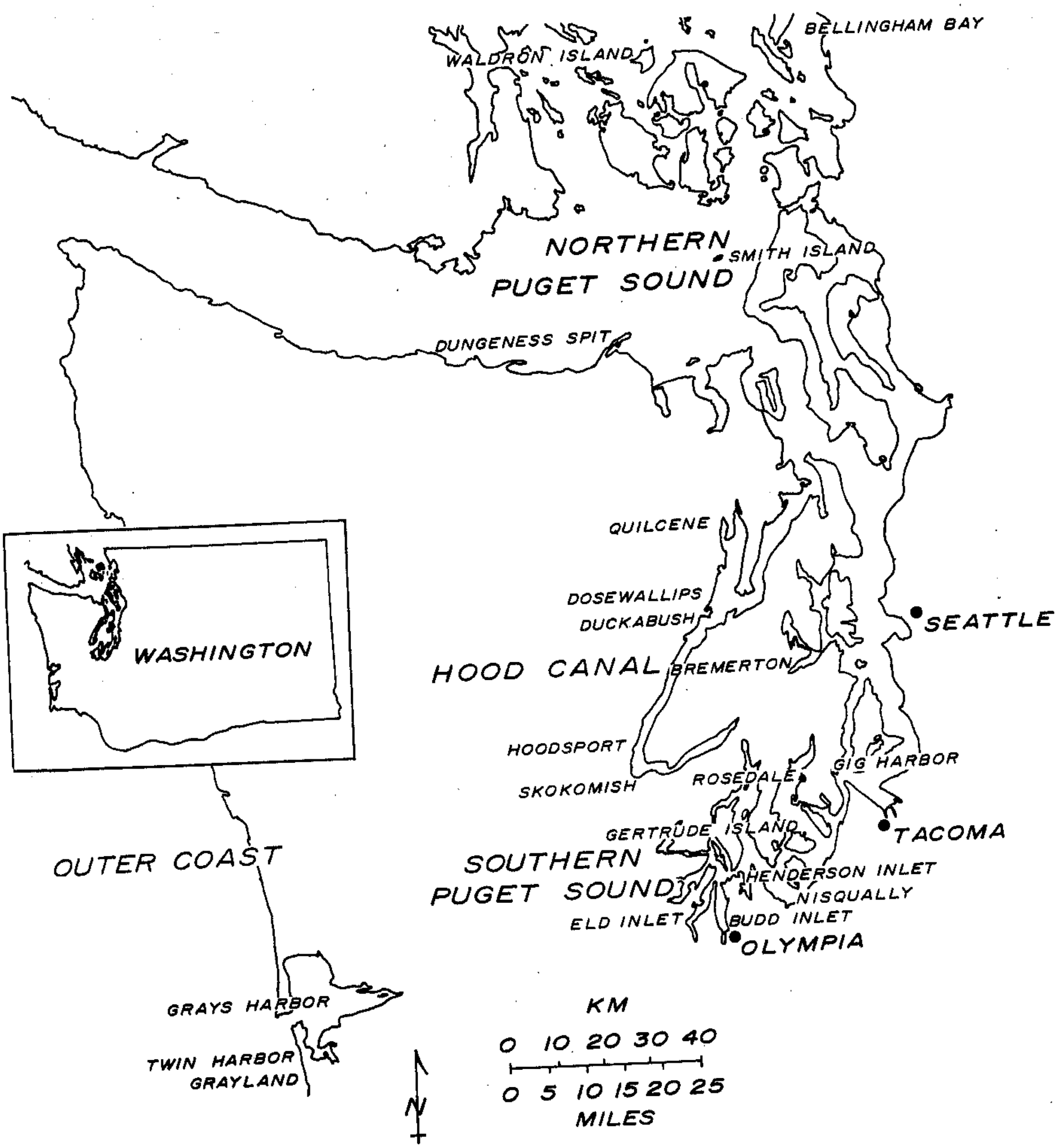

Figure 1. Map of western Washington showing the four study regions and the major locations referred to in this report. The Northern Puget Sound region includes the Strait of Juan de Fuca and the San Juan Islands.

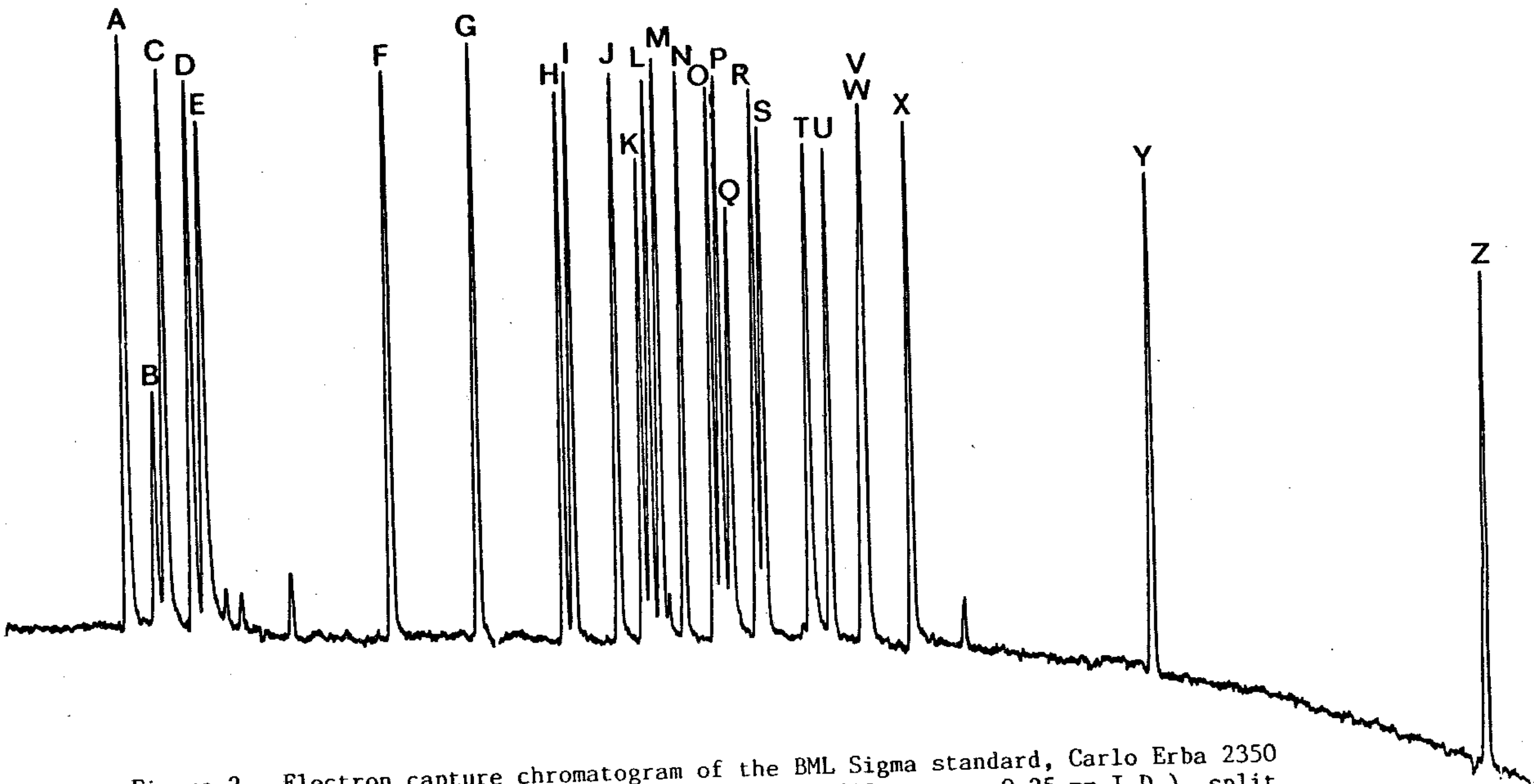

Figure 2. Electron capture chromatogram of the BML Sigma standard, Carlo Erba 2350 GC, SE-30 fused silica capillary column (30 meter x 0.25 mm I.D.), split injection. Components: A. alpha HCH; B. beta HCH; C. HCB; D. gamma HCH; E. delta HCH; F. heptachlor; G. aldrin; H. heptachlor epoxide; I. oxy-chlordane; J. gamma chlordane; K. o,p'-DDE; L. endosulfan I; M. alpha chlordane; N. trans-nonachlor; O. dieldrin; P. p,p'-DDE; Q. o,p'-DDD; R. endrin; S.endosulfan II; T. p,p'-DDD; U. o,p'-DDT; V. kepone; W. endosulfan cyclic sulfate; X. p,p'-DDT; Y. mirex; Z. decachlorobiphenyl (internal standard).

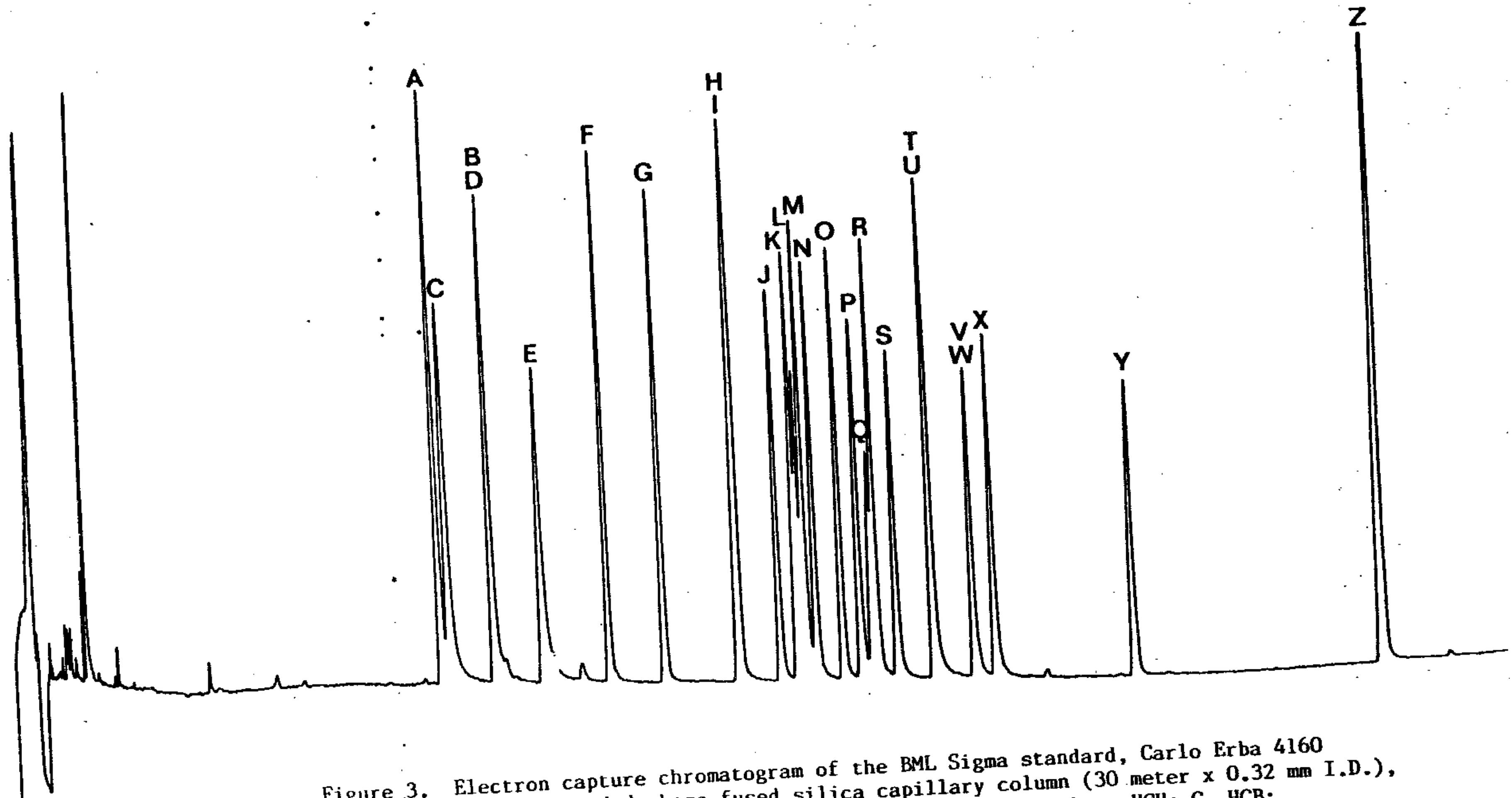

Figure 3. Electron capture chromatogram of the BML Sigma standard, Carlo Erba 4160 GC, DB-5 bonded phase fused silica capillary column (30 meter x 0.32 mm I.D.), on-column injection. Components: A. alpha HCH; B. beta HCH; C. HCB; D. gamma HCH; E. delta HCH; F. heptachlor; G. aldrin; H. heptachlor epoxide; I. oxychlordane; J. gamma chlordane; K. o,p'-DDE; L. endosulfan I; M. alpha chlordane; N. trans-nonachlor; O. dieldrin; P. p,p'-DDE; Q. o,p'-DDD; R. endrin; S. endosulfan II; T. p,p'-DDD; U. o,p'-DDT; V. kepone; W. endosulfan cyclic sulfate; X. p,p'-DDT; Y. mirex; Z. decachlorobiphenyl (internal standard).

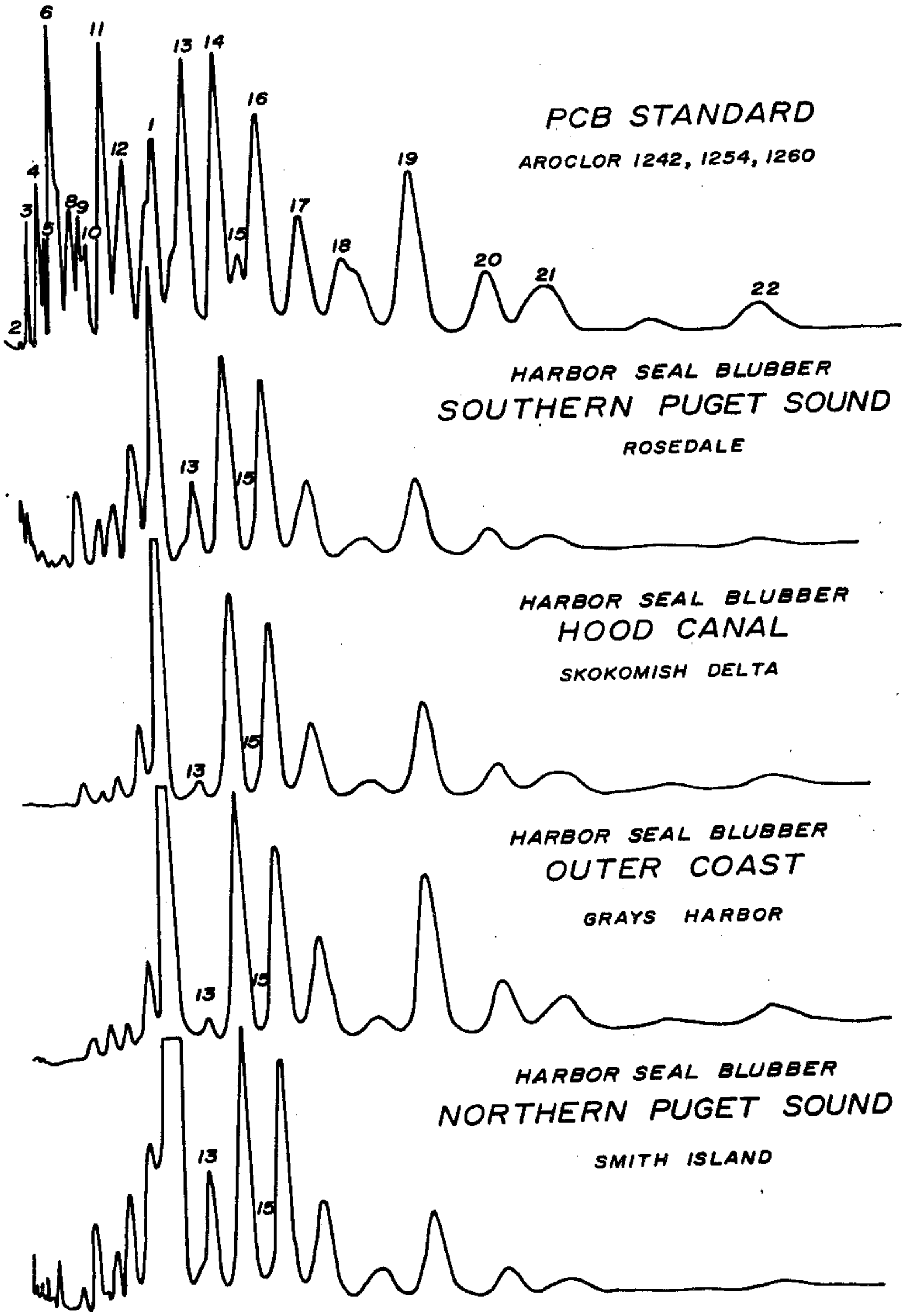

Figure 4. Chromatograms of PCB compounds in a standard and in harbor seal blubber from different regions. Note the consistent low area of peak #13 and #15 in the seals compared to the standard.

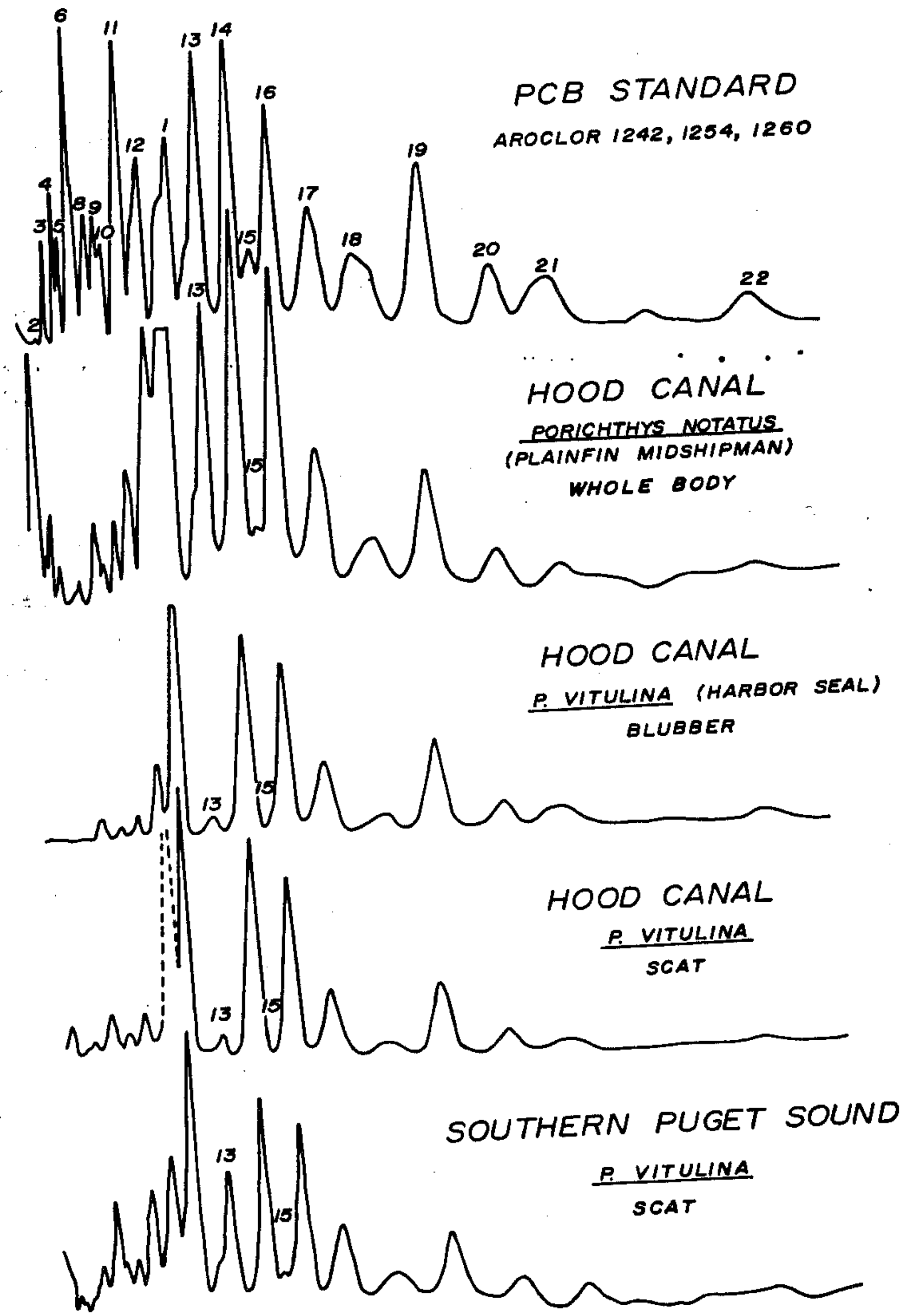

Figure 5. Chromatograms of PCB compounds in a standard and in harbor seal blubber, scat, and prey. Note the differences in peaks #13 and #15 between the different samples.

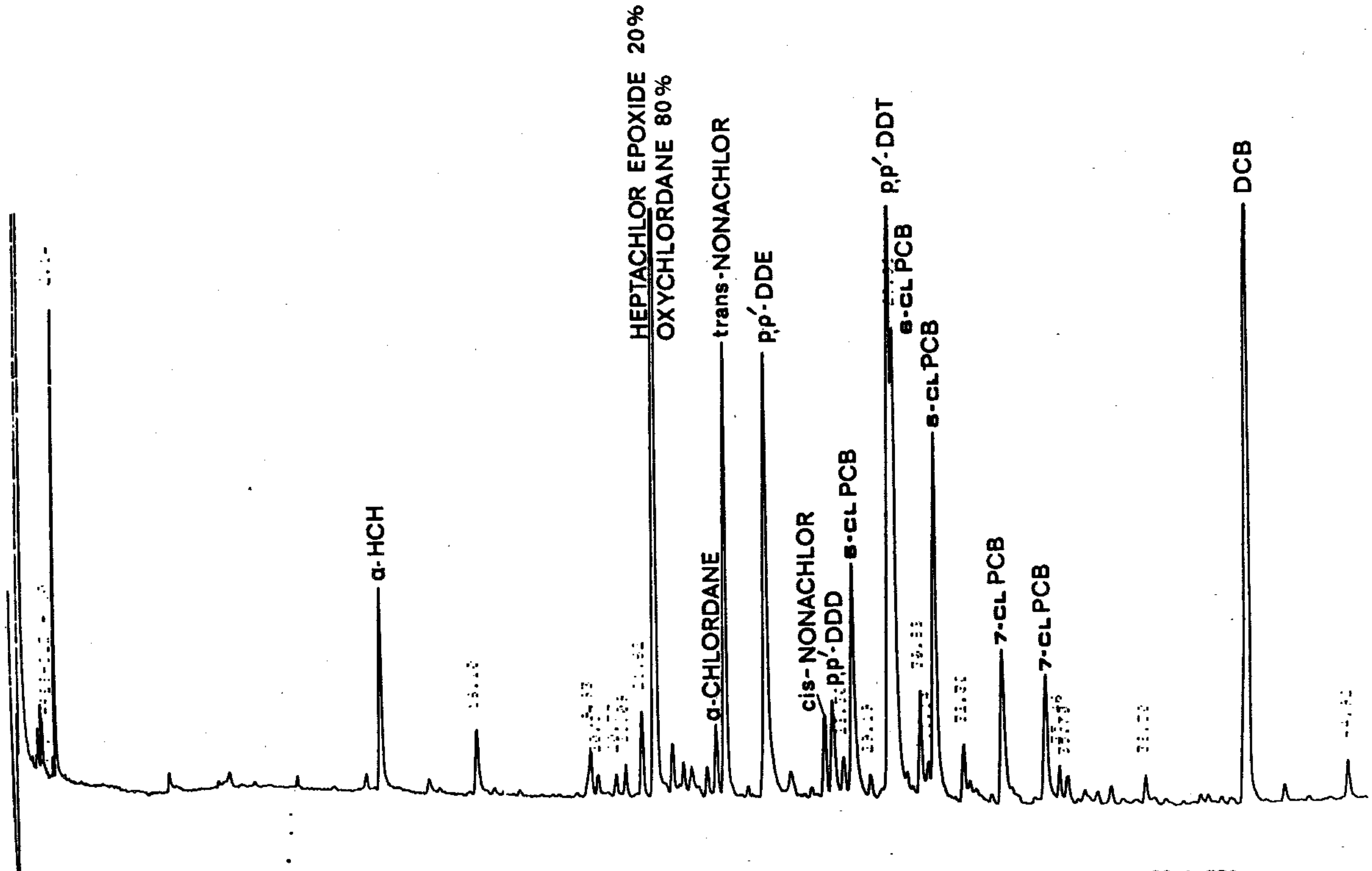

Figure 6. ECD chromatrogram of the F2 fraction, BML 83-67. DB5 column. Injection 82.1-773. Compare with SE-30 column (Figure 7), chromatogram of more concentrated extract (Figure 8), FID chromatogram (Figure 9), and the reconstructed ion chromatogram of the mass spectrometer (Figure 10).

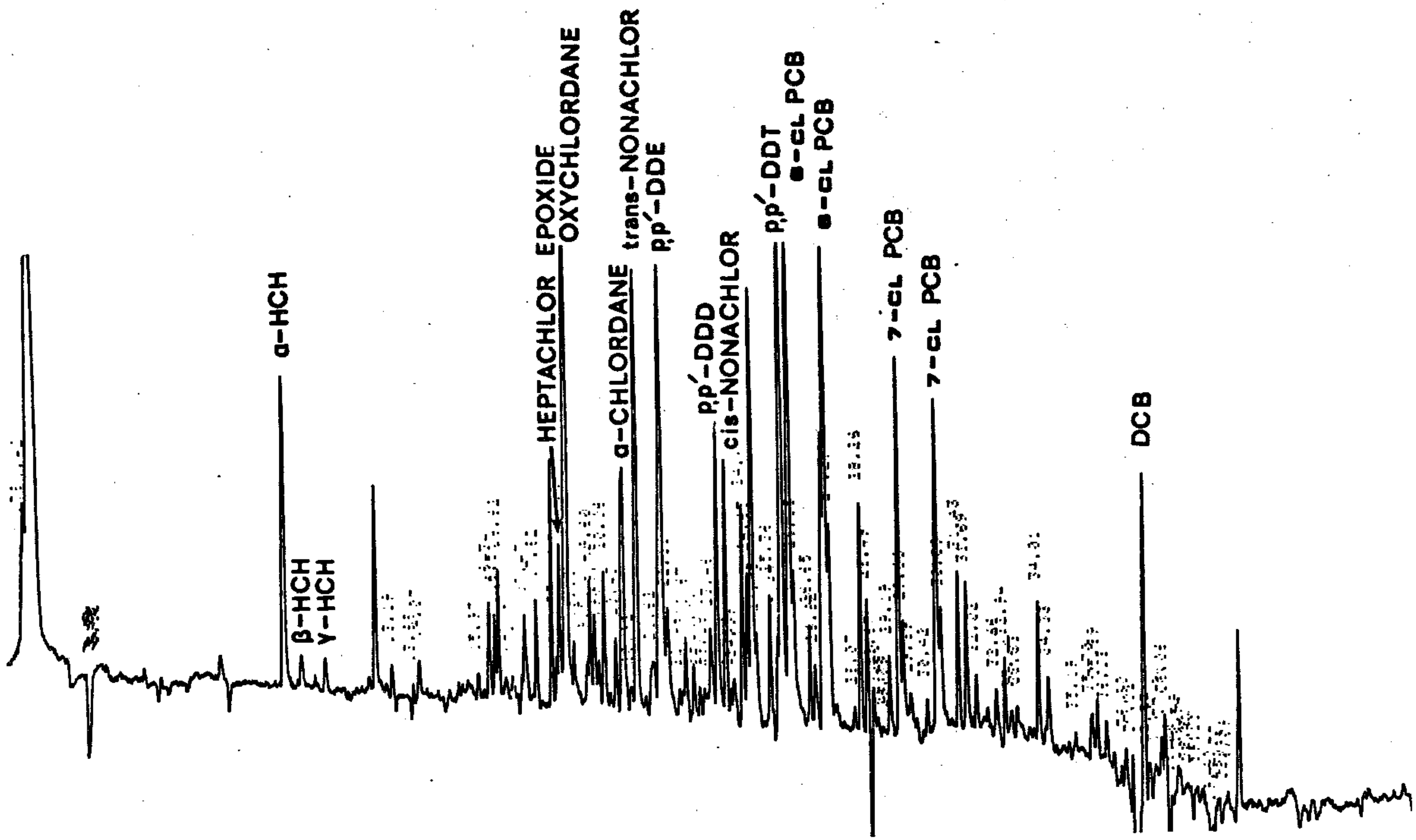

Figure 7. ECD chromatogram of the F2 fraction, BML 83-67. SE-30 column. Injection 80.3-1485. Compare Figure 6, DB5 column.

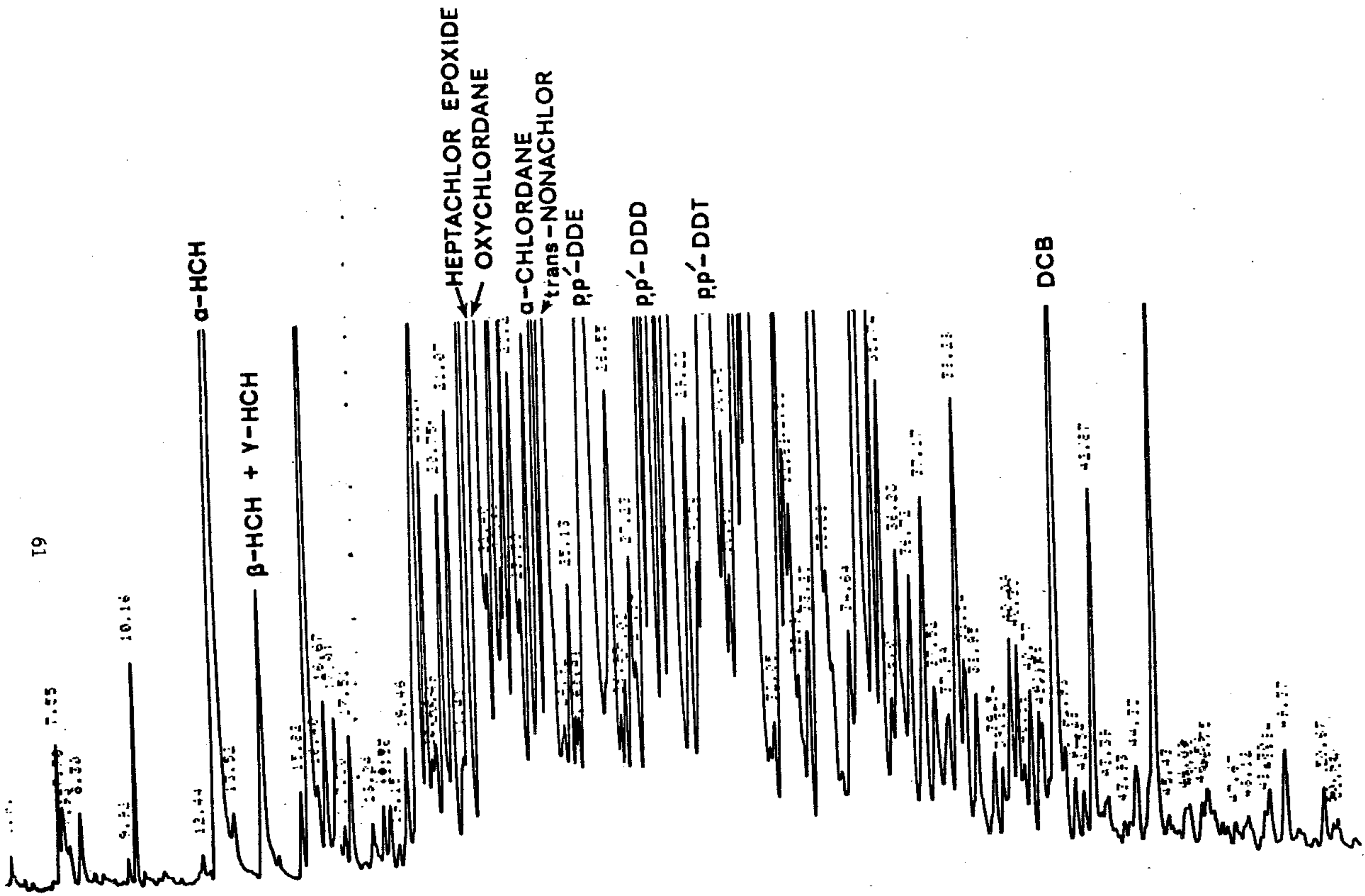

Figure 8. ECD chromatogram of the F2 fraction, BML 83-67. DB5 column. Injection 82.1-772. Extract of Figure 6, more concentrated.

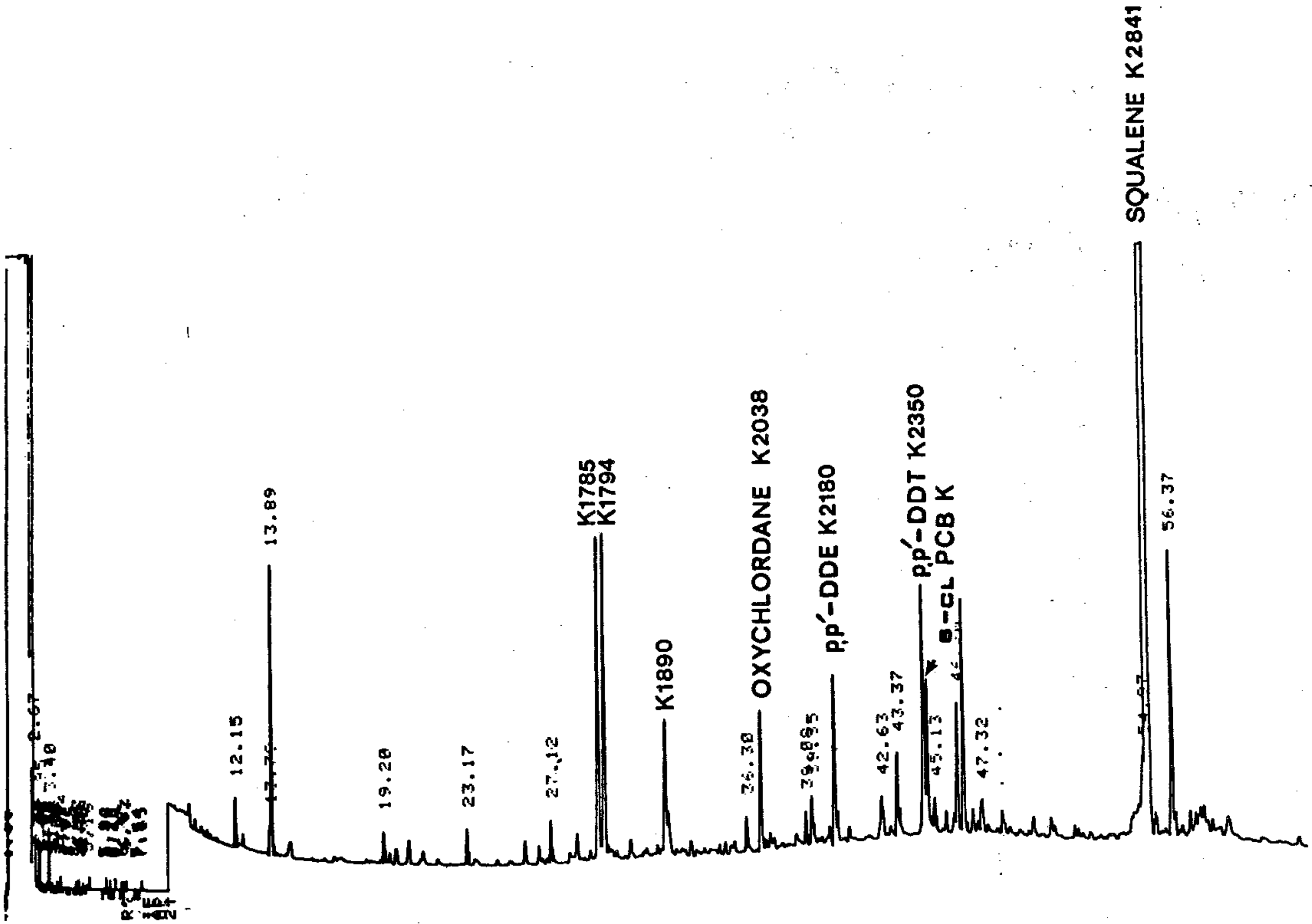

Figure 9. FID chromatogram of the F2 fraction, BML 83-67. SE-54 column. Injection 82.2-178.

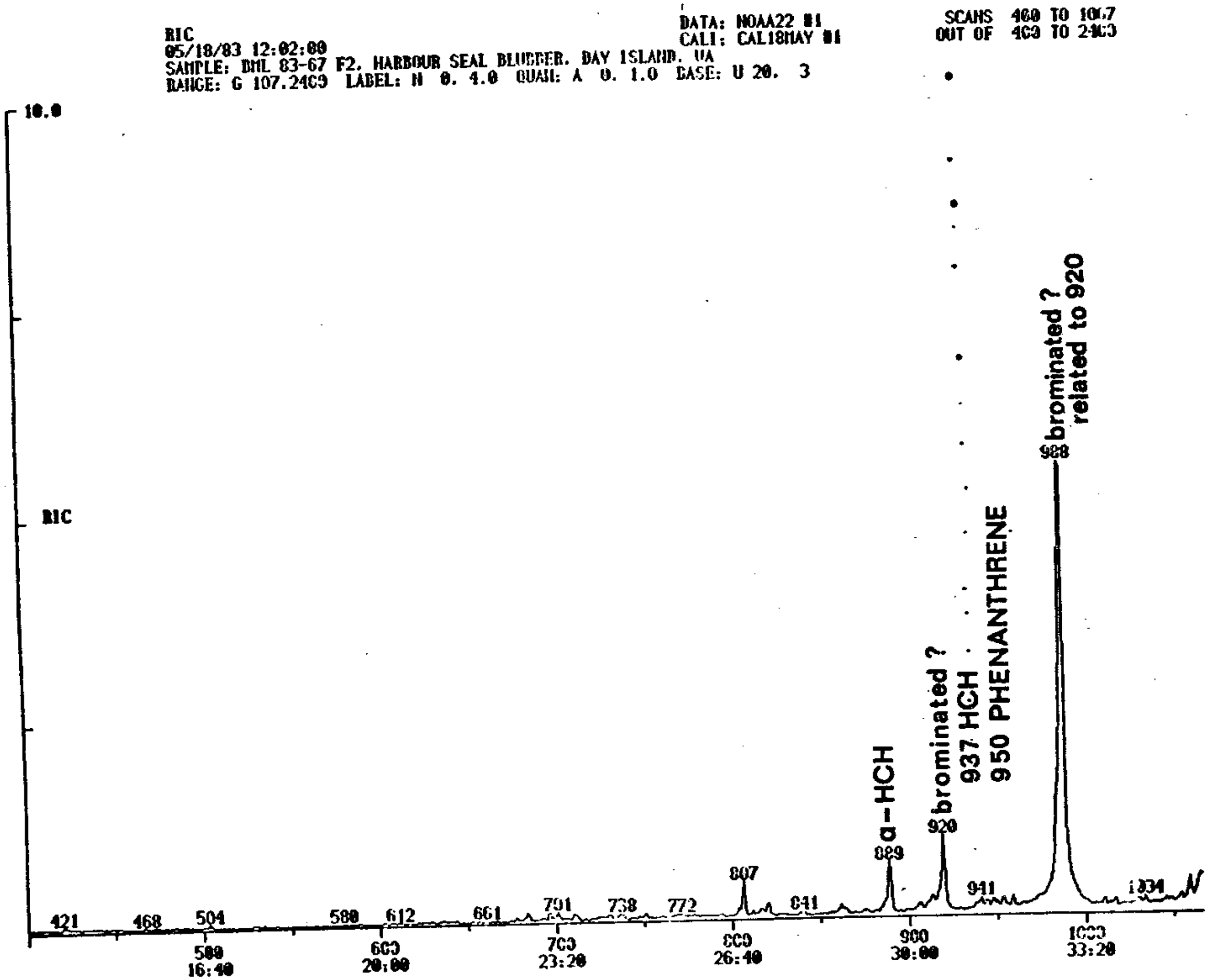

Figure 10. Total ion chromatogram of F2 fraction of 83-67, showing peaks identified by GC/MS. GC/MS conditions defined in the text.

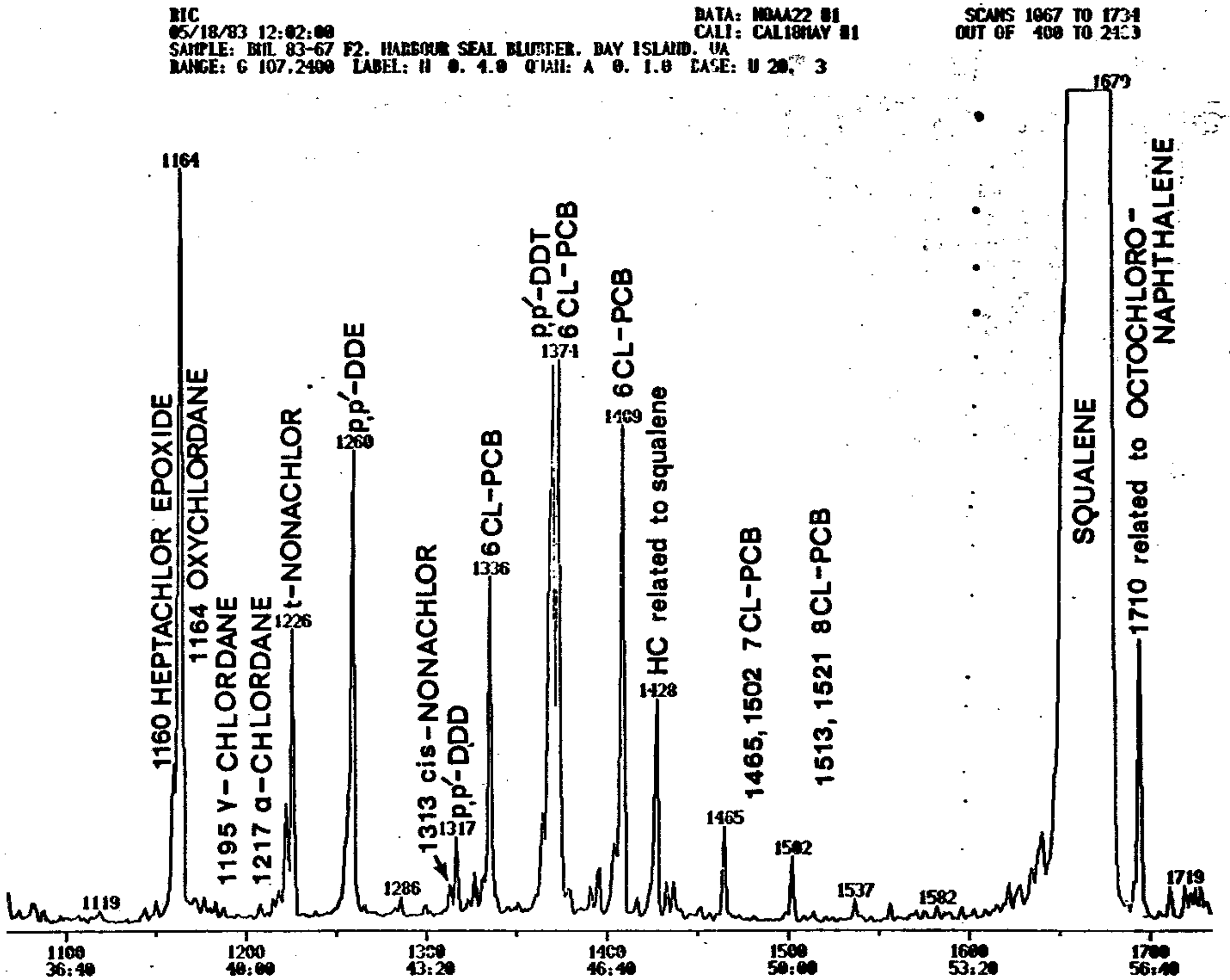

Figure 10, continued. Scans 1050 - 1750.

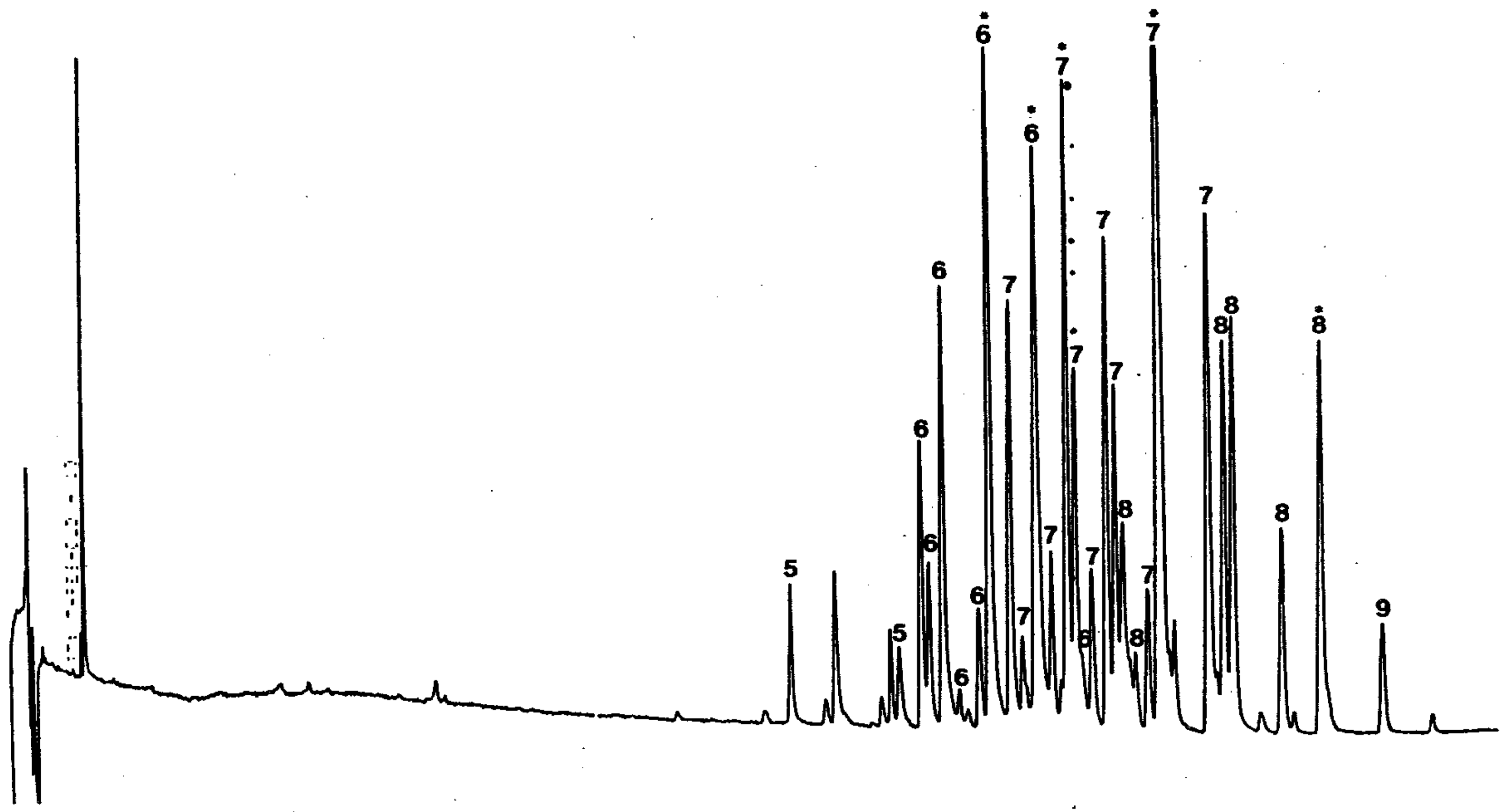

Figure 11. ECD chromatogram of Aroclor 1260. DB5 column. Numbers refer to chlorine atoms per PCB molecule.

Table 1. Summary of harbor seal samples analyzed at the Evergreen State College (TESC).

	Total	Regions			
		SPS	HC	NPS	OC
Total #	73	21	9	9	34
Males	44	11	8	3	22
Females	28	10	1	6	11
Sex not detm.	1	0	0	0	1
Adults	21	4	2	2	13
Subadults	24	10	0	0	14
Pups-neonate	28	7	7	7	7
Collected	28	0	0	0	28
Found dead	45	21	9	9	6
1972	1	1	0	0	0
1975	4	4	0	0	0
1976	15	7	0	2	6
1977	51	8	9	6	28
1981	2	1	0	1	0

SPS-Southern Puget Sound, HC-Hood Canal, NPS-Northern Puget Sound, OC-Outer Coast. See Figure 1 for map locating these regions.

Table 2. Deuterated internal standards used for organic chemical analyses, conducted at the Bodega Marine Laboratory. MW= molecular weight. Concentration in acetone is in nanograms per microliter (ng/ul).

Compound	Formula	MW	Concentration in acetone ng/ul
Acenaphthene	C12.D10	164	0.99
1,2-diphenyl ethane	C14.D14	196	1.07
Phenanthrene	C14.D10	188	1.00
Pyrene	C16.D10	212	0.97
p-terphenyl	C18.D14	244	1.01
n-C24	C24.D50	388	1.09
1,2-benzanthracene	C18.D12	240	1.04
Chrysene	C18.D12	240	1.08
Perylene	C20.D12	264	1.09

Table 3. Elution compositions from Florisil column chromatography cleanup used in analyses conducted at the Bodega Marine Laboratory.

Fraction 1	Fraction 2	Fraction 3
Hexachlorobenzene	Endosulfan I, 15%	Endosulfan I, 85%
Heptachlor	Dieldrin, 10%	Dieldrin 90%
trans-nonachlor, 75%	trans-nonachlor, 25%	Endrin
o,p'-DDT, 50%	o,p'-DDT, 50%	Fatty acid methyl esters
o,p'-DDE	o,p'-DDD	
p,p'-DDE	p,p'-DDT	
Aldrin	p,p'-DDD	
Mirex	p,p'-DDT	
PCB	alpha-HCH	
Alkanes, Triterpanes and other saturated hydrocarbons	beta-HCH	
	gamma-HCH	
	Heptachlor Epoxide	
	Oxychlordane	
	gamma-chlordane	
	alpha-chlordane	
	Toxaphene	
	TCDD	
	Polynuclear aromatic hydrocarbons	

Table 4. Catalog of Southern Puget Sound harbor seals and PCB and DDE concentrations found in blubber, analyzed at the Evergreen State College. Chemical concentrations are ppm wet weight. All animals were found dead.

Sample #	Date collected	Location	Sex	Age* Class	Bl** (mm)	Wgt (kg)	Length (cm)	PCB	DDE	PCB/DDE Ratio	Comments
SJJ 27	24 Feb 77	Gertrude	M	A	-	100.00	-	210	18	12.0	
SJJ 69	6 Dec 76	Gertrude	M	A	-	90.0	-	270	19	14.0	
SJJ 71	16 Jan 77	Gertrude	M	A	-	-	-	250	15	16.0	
SJJ 19	30 Sept 75	Gertrude	F	S	-	14.1	-	220	27	8.0	
SJJ 22	4 Jan 76	Gertrude	M	S	21	20.9	-	150	13	12.0	
SJJ 23	4 Jan 76	Gertrude	F	S	20	32.2	-	150	18	8.0	
SJJ 25	21 Jan 76	Gertrude	M	S	15	25.0	-	87	7.5	12.0	
SJJ 43	16 May 76	Gertrude	F	S	-	14.6	-	290	30	10.0	
SJJ 20	30 Sept 75	Gertrude	M	P	-	15.0	-	67	7.1	9.4	
SJJ 21	30 Sept 75	Gertrude	F	P	6	8.8	-	58	7.1	8.1	Stillbirth
SJJ 55	18 Sept 76	Gertrude	F	P	-	6.8	-	140	13	11.0	
SJJ 112	3 July 77	Rosedale	F	S	18	35.0	-	530	38	14.0	
SJJ 96	7 Dec 77	Rosedale	M	P	-	8.3	-	15	0.9	17.0	Stillbirth
SJJ 7	17 July 75	Vaughn	F	A	42	128.0	-	21	1.3	16.0	
GAB 115	8 Feb 77	Nisqually	M	S	-	-	-	59	5.5	11.0	
SJJ 109	25 Oct 77	Nisqually	M	S	-	-	-	35	3.7	9.4	
PVES 1	- Nov 72	Budd Inlet	F	P	25	9.8	61.0	160	25	6.3	
SJJ 93	5 Aug 77	Budd Inlet	M	P	8	5.8	-	28	2.8	10.0	With lanugo coat
PVES 19	12 Sept 77	Eld Inlet	F	S	3	23.6	119.0	620	42	15.0	
PVES 18	14 Aug 77	Eld Inlet	F	P	6	6.3	74.0	69	9.9	7.0	
CRC 1	13 Mar 81	Eld Inlet	M	S	25	55.0	139.7	54	ND	ND	

* A - adult, S - subadult, P - pup
** Bl - Blubber thickness (in millimeters)

Table 5. Catalog of Hood Canal harbor seals and PCB and DDE concentrations found in blubber, analyzed at the Evergreen State College. Chemical concentrations are ppm wet weight. All animals were found dead.

Sample #	Date collected	Location	Sex	Age* Class	Bl** (mm)	Wgt (kg)	Length (cm)	PCB	DDE	PCB/DDE Ratio	Comments
PVES 15	17 Aug 77	Quilcene	M	P	13	8.3	76.0	10	1.5	6.7	With lanugo coat
PVES 22	8 Oct 77	Dosewallips	M	A	16	61.8	153.3	100	14	7.4	
PVES 12	13 Aug 77	Dosewallips	M	P	11	10.9	83.2	9.3	1.1	8.1	
PVES 16	1 Sept 77	Dosewallips	M	P	12	11.2	88.5	13	1.6	7.8	
PVES 13	15 Aug 77	Duckabush	M	P	9	13.6	91.4	8.0	1.4	5.9	Stillbirth
PVES 14	28 Aug 77	Duckabush	M	P	13	13.5	94.0	11	1.8	6.0	
PVES 17	2 Sept 77	Duckabush	M	P	7	8.8	81.0	33	5.3	6.3	Stillbirth
PVES 6	1 July 77	Skokomish	M	A	17	64.1	136.8	85	12	7.2	
PVES 21	8 Oct 77	Skokomish	F	P	4	3.1	62.0	8.3	1.0	8.4	Premature

* A - adult, P - pup
** Bl - Blubber thickness (in millimeters)

Table 6. Catalog of Northern Puget Sound harbor seals and PCB and DDE concentrations found in blubber, analyzed at the Evergreen State College. Chemical concentrations are ppm wet weight. All animals were found dead.

Sample #	Date collected	Location	Sex	Age	Age* Class	Bl** (mm)	Wgt (kg)	Length (cm)	PCB	DDE	PCB/DDE Ratio	Comments
PVES 2	19 June 77	Smith Is	F	–	P	13	11.7	86.4	7.5	2.5	3.1	Stillbirth
PVES 8	14 July 77	Smith Is	F	–	P	12	11.4	84.0	6.7	0.8	9.0	
PVES 9	14 July 77	Smith Is	F	–	P	9	7.7	77.0	19	6.8	2.8	
PVES 10	14 July 77	Smith Is	F	–	P	12	10.0	82.0	6.0	1.7	3.5	
PVES 11	21 July 77	Smith Is	M	–	P	12	7.5	79.0	9.8	2.6	3.8	
SJJ 70	– Dec 76	Bellingham Bay	M	6	A	32	88.3	–	29	8.7	3.3	
SJJ 95	17 Aug 77	Bellingham Bay	F	0	P	39	23.3	–	16	3.8	4.2	
SJJ 24	17 Jan 77	Dungeness Spit	M	–	A	23	48.6	–	25	10	2.4	
CRC 9	13 Aug 81	Waldron Is	F		P	19	13.6	85.1	3.7	1.5	2.5	Stillbirth

* A – adult, P – pup
** Bl – Blubber thickness (in millimeters)

Table 7a. Catalog of Outer Coast harbor seals and PCB and DDE concentrations found in blubber, analyzed at the Evergreen State College. Chemical concentrations are ppm wet weight. All animals collected.

Sample #	Date collected	Location	Sex	Age	Age* Class	B1** (mm)	Wgt (kg)	Length (cm)	PCB	DDE	PCB/DDE Ratio	Comments
US 601	30 July 76	Grays Harbor	M	4	S	22	60.8	137.5	18	8.4	2.1	
US 602	30 July 76	Grays Harbor	M	3	S	25	57.7	124.9	13	10	1.2	
US 603	27 Aug 76	Grays Harbor	M	3	S	24	55.4	128.3	27	19	1.4	
US 619	17 Mar 77	Grays Harbor	F	4	S	47	68.4	134.6	7.8	1.6	4.9	Pregnant
US 621	20 May 77	Grays Harbor	F	8	A	44	99.0	140.1	5.8	2.6	2.3	Pregnant
US 623	20 May 77	Grays Harbor	F	11	A	64	120.0	149.2	22	7.9	2.8	Lactating
US 624	20 May 77	Grays Harbor	F	5	A	65	70.3	132.5	6.0	3.5	1.7	Lactating
US 626	20 May 77	Grays Harbor	F	11	A	38	101.0	151.5	14	4.7	2.9	
US 629	10 June 77	Grays Harbor	M	8	A	30	81.8	152.6	35	13	2.8	
US 639	22 July 77	Grays Harbor	F	15	A	16	65.8	142.0	63	19	3.3	
US 645	15 Aug 77	Grays Harbor	M	7	A	18	80.6	157.6	16	9.1	1.8	
US 646	15 Aug 77	Grays Harbor	F	14	A	12	53.3	143.2	11	2.7	4.0	
US 647	15 Aug 77	Grays Harbor	M	7	A	30	82.5	142.0	31	14	2.2	
US 653	6 Oct 77	Grays Harbor	M	6	A	28	63.3	137.0	35	19	1.8	
US 654	6 Oct 77	Grays Harbor	M	13	A	34	83.3	142.0	31	10	3.1	
US 608	3 Dec 76	Grays Harbor	M	1	S	35	26.5	98.0	29	15	2.0	
US 612	3 Feb 77	Grays Harbor	M	2	S	45	39.2	116.0	17	10	1.7	
US 620	17 Mar 77	Grays Harbor	F	1	S	32	25.4	96.2	22	13	1.7	
US 627	10 June 77	Grays Harbor	M	1	S	32	29.3	98.4	5.3	3.1	1.7	
US 630	10 June 77	Grays Harbor	F	5	A	20	42.3	119.6	49	22	2.2	
US 634	22 July 77	Grays Harbor	F	2	S	27	27.3	110.0	14	8.9	1.6	
US 635	22 July 77	Grays Harbor	M	4	S	22	48.3	121.0	16	11	1.5	
US 636	22 July 77	Grays Harbor	M	3	S	32	53.2	126.0	10	6.6	1.6	
US 642	15 Aug 77	Grays Harbor	M	2	S	15	27.3	102.5	18	11	1.7	
US 623A	20 May 77	Grays Harbor	M	0	P	20	15.3	–	3.2	1.6	2.0	Nursing
US 624	20 May 77	Grays Harbor	M	0	P	9	11.4	–	4.2	2.1	1.9	Nursing
US 619A	20 May 77	Grays Harbor	F	0	P	0	8.0	–	1.9	0.8	2.4	Near term fetus
US 621A	20 May 77	Grays Harbor	M	0	P	18	12.3	–	3.8	2.1	1.8	Near term fetus

* A – adult, S – subadult, P – pup
** B1 – Blubber thickness (in millimeters)

Table 7b. Catalog of Outer Coast harbor seals and PCB and DDE concentrations found in blubber, analyzed at the Evergreen State College. Chemical concentrations are ppm wet weight. All animals found dead.

Sample #	Date collected	Location	Sex	Age	Age* Class	B1** (mm)	Wgt (kg)	Length (cm)	PCB	DDE	PCB/DDE Ratio
SJJ 51	- Aug 76	Grayland	M	-	S	8	47.7	-	39	15	2.7
SJJ 42	9 May 76	Grays Harbor	M	-	P	0	5.9	-	13	3.6	3.7
PVES 5	22 June 77	Twin Harbor	M	-	A	21	-	162.0	12	11	1.0
PVES 4	22 June 77	Twin Harbor	M	-	S	25	31.7	120.0	11	5.6	2.0
PVES 7	30 June 77	Willapa Bay	-	-	P	18	-	72.0	8.9	6.2	1.4
PVES 20	7 Oct 77	Willapa Bay	M	-	P	15	13.5	92.0	13	8.7	1.5

* A - adult, S - subadult, P - pup
** B1 - Blubber thickness (in millimeters)

Table 8. Summary of PCB and DDE residues (ppm wet wt) in blubber of harbor seals separated by location, sex, and age class. Samples analyzed at the Evergreen State College. Geometric means and standard deviation intervals given. Two samples with incomplete results (one in Table 4, and one in Table 7) are not included in these summaries.

Description		n	PCB		DDE		PCB/DDE Ratio	
			geom. mean	s.d. int.	geom. mean	s.d. int.	geom. mean	s.d. int
Southern Puget Sound								
Male	Pup	3	31	15-64	2.6	0.93-7.4	12	8.4-16
	Subadult	4	72	38-130	6.7	3.9-11	11	9.7-12
	Adult	3	240	210-280	17	15-20	14	12-16
Female	Pup	4	97	58-160	12	7.2-21	7.9	6.2-10
	Subadult	5	310	170-570	30	21-41	10	7.8-14
	Adult	1	21	- -	1.3	- -	16	- -
All SPS samples		20	110	39-310	10	3.5-29	11	8.2-15
Hood Canal								
Male	Pup	6	12	7.4-21	1.8	1.0-3.1	6.8	5.8-7.9
	Subadult	0	-	- -	-	- -	-	-
	Adult	2	93	82-100	13	12-14	7.3	7.1-7.4
Female	Pup	1	8.3	- -	1.0	- -	8.3	-
	Subadult	0	-	- -	-	- -	-	-
	Adult	0	-	- -	-	- -	-	- -
All HC samples		9	18	6.7-51	2.6	0.95-7	7.0	6.2-8.0
Northern Puget Sound								
Male	Pup	1	9.8	- -	2.6	- -	3.8	-
	Subadult	0	-	- -	-	- -	-	-
	Adult	2	27	24-30	9.5	8.4-11	2.8	2.3-3.5
Female	Pup	6	8.3	4.5-15	2.3	1.1-4.8	3.7	2.4-5.7
	Subadult	0	-	- -	-	- -	-	-
	Adult	0	-	- -	-	- -	-	- -
All NPS samples		9	11	5.4-22	3.2	1.3-7.5	3.5	2.4-5.3
Outer Coast								
Male	Pup	5	6.2	3.1-13	2.9	1.5-5.8	2.1	1.5-2.9
	Subadult	11	16	9.4-28	9.3	5.6-15	1.7	1.4-2.1
	Adult	6	24	15-39	12	9.5-16	2.0	1.4-29
Female	Pup	1	1.9	- -	0.80	- -	2.4	-
	Subadult	3	13	7.9-22	5.7	1.9-17	2.3	1.2-4.4
	Adult	7	17	6.5-43	6.3	2.6-15	2.7	2.0-3.5
All OC samples		33	14	6.1-32	6.7	2.9-16	2.1	1.5-2.9

Table 9. Results of multiway ANOVA tests. Site and age category are factors compared against log transformed concentrations of PCB and DDE (ppm wet wt.) and the log transformed PCB/DDE ratio in blubber of harbor seals. Cells are weighted for cell size. All sites are included, n=71.

	PCB		DDE		PCB/DDE Ratio	
	F	p	F	p	F	p
Mean effect	1350	.0000	365	.0000	1531	.0000
Site(L)	38	.0000	8.3	.0001	132	.0000
Age Category(A)	15	.0000	22	.0000	7.4	.0014
Interactive L*A	0.8	NS	1.2	NS	1.5	NS
Site minus all other effects	39	.0000	3.3	.0259	128	.0000
Age Cat. minus all other effects	18	.0000	14	.0000	2.0	NS

NS = not significant (p>.05)

Table 10. Results of multiway ANOVA tests. Site, age category, and sex are factors compared against log transformed concentrations (ppm wet wt) of PCBs, DDE, and the log transformed PCB/DDE ratio in harbor seal blubber. Cells are weighted for cell size. Hood Canal data are excluded (too many empty cells). N=62.

	PCB		DDE		PCB/DDE Ratio	
	F	p	F	p	F	p
Mean effect	1684	.0000	565	.0000	1103	.0000
Site(L)	77	.0000	10	.0000	168	.0000
Sex(S)	1.2	NS	0.7	NS	15	.0004
Age Category(A)	14	.0000	20	.0000	2.7	.07(NS)
Interactive L*S	4.3	.0187	8.1	.0009	3.8	.0306
Interactive L*A	0.52	NS	1.4	NS	1.8	NS
Interactive S*A	18	.0000	7.9	.0011	8.9	.0005
Interactive L*S*A	9.2	.0004	10	.0002	0.2	NS
Site minus all other effects	67	.0000	5.2	.0095	0.147	.0000
Sex minus all other effects	0.01	NS	0.15	NS	0.9	NS
Age Cat. minus all other effects	11	.0001	9.3	.0004	0.9	NS
L*A minus "	0.7	NS	1.2	NS	0.7	NS
S*A minus "	3.2	.0485	3.57	.0359	0.9	NS

NS = not significant (p>.05)

Table 11a. Correlations of PCB with DDE concentrations (ppm wet wt) in the blubber of harbor seals from different regions. All age categories included.

	n	r	t	p
All regions	73	.82	12.3	.0000
Southern Puget Sound	21	.93	11.0	.0000
Hood Canal	9	.998	44.1	.0000
Northern Puget Sound	9	.953	8.32	.0001
Outer Coast	34	.879	10.5	.0000
between groups	73	F= 30.3		.0000

Table 11b. Spearman's rank correlation (non-parametric) of PCBs with DDE concentrations (ppm wet wt) in harbor seal blubber from different regions. All age categories included. This test is the non-parametric equivalent to that shown in Table 11a.

	n	r	t	p
All regions	73	.77	10.2	<.001
Southern Puget Sound	21	.96	15.2	<.001
Hood Canal	9	.93	6.88	<.001
Northern Puget Sound	9	.93	6.88	<.001
Outer Coast	34	.90	11.8	<.001

Table 12. Regression of PCB and DDE concentrations (ppm wet wt in blubber) and PCB/DDE ratio on age of harbor seals collected in Grays Harbor, Washington (Outer Coast). All collected and aged animals included.

Description	r^2	slope	Y int	F	p
Both sexes, n=28					
PCB	.25	1.62	10.7	8.55	<.01
DDE	.04	0.28	7.58	1.13	NS
PCB/DDE Ratio	.35	0.11	1.71	14.1	<.001
Males only, n=17					
PCB	.49	2.22	9.97	14.7	<.01
DDE	.21	0.70	7.06	3.90	<.10(NS)
PCB/DDE Ratio	.44	0.09	1.56	11.7	<.01
Females only, n=11					
PCB	.16	1.49	9.37	1.73	NS
DDE	.02	0.19	6.61	0.16	NS
PCB/DDE Ratio	.21	0.09	2.08	3.86	NS

NS = not significant (p>.05)

Table 13. Spearman's rank correlation between the age of harbor seals collected in Grays Harbor, Washington (Outer coast) and the PCB and DDE concentrations (ppm wet wt in blubber) and the PCB/DDE ratio. The same data is used in Table 12.

Description	n	PCB		DDE		PCB/DDE	
		r	p	r	p	r	p
Both sexes	28	.52	<.01	.30	NS	.54	<.01
Males only	17	.75	<.01	.47	NS	.30	NS
Females only	11	.39	NS	.23	NS	.55	NS

NS = not significant (p>.05)

Table 14. Results of multiway ANOVA tests. Collection method (collected or found dead) and age category are factors compared against concentrations of PCB and DDE (ppm wet wt in blubber) and their ratio. Cells are weighted for cell size. Only males from the Outer Coast are considered because this is the only site where animals were collected, and all six of the sexed seals that were found dead at this site were males. N=23.

	PCB		DDE		PCB/DDE Ratio	
	F	p	F	p	F	p
Collection method(C)	.00	NS	.02	NS	.42	NS
Age Category(A)	13.8	.0003	15.2	.0002	.82	NS
Interactive C*A	5.55	.0139	3.26	.063(NS)	3.35	.059(NS)
Col. Method minus other effects	2.74	NS	2.85	NS	.20	NS
Age Cat. minus other effects	15.1	.0002	16.6	.0001	.71	NS

Table 15. Comparison of PCB and DDE concentrations (ppm wet wt in blubber) in pregnant and lactating female harbor seals and their young. Collected at Grays Harbor, Washington (Outer Coast). Concentrations for all tests except PCB/DDE ratio were log transformed.

	PCB			DDE			PCB/DDE Ratio	
	mother	pup	pup: mother	mother	pup	pup: mother	mother	pup
Preg 1	7.8	1.9	0.24	1.6	0.77	0.48	4.9	2.4
Preg 2	5.8	3.8	0.65	2.6	2.1	0.83	2.3	1.8
Lact 1	22	3.2	0.14	7.9	1.6	0.20	2.8	2.0
Lact 2	6.0	4.2	0.69	3.5	2.1	0.61	1.7	1.9
Correlations								
r	-0.15			0.47			0.95	
t	-0.22			0.75			4.30	
p	>0.05			>0.05			=0.05	

Table 16. Concentrations of PCBs and DDE (ppm wet and lipid wt) in fish from Southern Puget Sound. Whole, individual fish analyzed, unless noted otherwise.

Site	Collection Date	Species (common name)	Wt. (grams)	Conc. wet wt. PCB	Conc. wet wt. DDE	Conc. lipid wt. PCB	Conc. lipid wt. DDE	PCB/DDE Ratio
Nisqually Reach	3 Nov 77	*Clupea harengus* (Herring)	172*	.86	.14	4.3	.72	6.0
	3 Nov 77	*Microgadus proximus* (Tomcod)	86.2	.22	.019	5.8	.50	11.6
	3 Nov 77	*Cymatogaster aggregata* (Shiner perch)	46.5	.29	.017	2.4	.14	17.2
	3 Nov 77	*Parophrys vetulus* (English sole)	51.4	.15	.009	6.7	.37	17.9
Budd Inlet	21 Nov 77	*Hypomesus pretiosus* (Surf smelt)	15.9	.16	.009	10	.54	18.4
	21 Nov 77	*Rhacochilus vacca* (Pile perch)	583*	.30	.034	15	1.7	8.9
	21 Nov 77	*Leptocottus armatus* (Pacific staghorn sculpin)	87.7	.077	.005	6.6	.46	14.5
	21 Nov 77	*Leptocottus armatus* (Pacific staghorn sculpin)	43.8	.094	.004	7.8	.31	25.4
	21 Nov 77	*Platichthys stellatus* (Starry flounder)	116*	.097	.003	9.1	.24	38.3
Eld Inlet	4 Sept 77	*Oncorhynchus nerka* (Sockeye salmon)	18.2	.036	.006	4.4	.76	5.8
	10 June 77	*Cymatogaster aggregata* (Shiner perch)	35.0	.29	.017	9.5	.56	17.0
	4 Sept 77	*Cymatogaster aggregata* (Shiner perch)	8.6**	.034	.003	.90	.074	12.3
	4 Sept 77	*Leptocottus armatus* (Pacific staghorn sculpin)	34.6	.014	.001	.91	.058	15.7
Heron Island	16 Aug 77	*Leptocottus armatus* (Pacific staghorn sculpin)	43.2	.11	.011	.80	.081	9.9

* cross section of muscle analyzed, ** composite of two fish

Table 17. Concentrations of PCBs and DDE (ppm wet and lipid wt) in fish from Hood Canal. Whole, individual fish analyzed unless noted otherwise.

Site	Collection Date	Species (common name)	Wt. (grams)	Concentration (wet wt) PCB	Concentration (wet wt) DDE	Concentration (lipid wt) PCB	Concentration (lipid wt) DDE	PCB/DDE Ratio
Skokomish Delta	8 July 77	Porichthys notatus (Plainfin midshipman)	24.3	.32	.031	7.7	.76	10.1
	26 Nov 77	Leptocottus armatus (Pacific staghorn sculpin)	50.9	.096	.004	5.8	.26	22.2
Hoodsport	16 Nov 77	Merlucius productus (Pacific hake)	282*	.015	.003	2.1	.37	5.6
	16 Nov 77	Merlucius productus (Pacific hake)	310*	.025	.001	4.7	.23	20.7
	16 Nov 77	Merlucius productus (Pacific hake)	339*	.008	.001	1.5	.083	17.5
	16 Nov 77	Merlucius productus (Pacific hake)	267*	.026	.001	4.8	.26	18.5

* cross section of muscle analyzed

Table 18. Concentrations of PCBs and DDE (ppm) and PCB/DDE ratio in harbor seal scat. Geometric means and standard deviation intervals are noted.

Location Sample #	Concentration (ppm lipid wt) PCB	DDE	Concentration (ppm dry wt) PCB	DDE	Concentration (ppm wet wt) PCB	DDE	PCB/DDE Ratio
Skokomish Delta, Hood Canal							
21SK	4.6	0.29	-	-	0.13	0.0078	16
28SK	17	4.2	4.0	0.99	1.8	0.43	4.1
30SK	-	-	0.58	0.041	0.20	0.014	14
36SK	21	2.5	0.48	0.056	0.15	0.018	8.5
37SK	7.9	1.9	0.30	0.073	0.11	0.027	4.1
38SK	39.	5.0	1.1	0.014	0.32	0.041	7.8
Geom mean	14	2.0	2.1	0.12	0.25	0.031	7.9
(Std dev int)	(6.0-32)	(0.62-6.1)	(0.73-5.7)	(0.033-0.42)	(0.089-0.70)	(0.0077-0.13)	(4.4-14)
Eld Inlet, S. Puget Sound							
31E1	36	2.2	-	-	0.014	0.0084	17
33E1	28	-	0.56	-	0.15	-	-
73E1	10	0.93	0.61	0.055	0.28	0.025	11
Geom mean	22	1.4	0.58	0.055	0.18	0.015	14
(Std dev int)	(11-42)	(0.78-2.6)	(0.55-0.62)	-	(0.12-0.26)	(0.0067-0.031)	(10-19)
Smith Island, N. Puget Sound							
80Sm	4.5	0.69	0.28	0.043	0.079	0.12	6.6

Table 19. Calculation of body burden of PCBs in adult male harbor seals from Southern Puget Sound and derivation of pollutant intake from prey.

Body burden calculation			
Mean weight of three adult males from SPS		95.	kg
% of body weight as lipid, conservative estimate based on Pitcher and Calkins (1977), Stirling and McEwan (1975) and Tarasoff (1974)		X 20%	
Weight of total body fat		19.	kg
Mean concentration of PCBs in fat of adult male seals (wet weight in blubber, assumes no moisture)(see Table 8)		X .24	g/kg
Body burden of PCBs in adult males	(A)	4.56	g
Yearly intake calculation			
Mean weight of three adult males		95.	kg
Daily food consumption as % of body weight, from Spalding (1964) and Scheffer and Slipp (1944)		X 6%	/day
Weight of daily food intake		5.7	kg/day
Days in a year		X 365	day/yr
Food intake per year for adult males		2,081	kg/yr
Approx. concentration of PCBs in prey of seals in SPS, midpoint of 0.075-0.33 ppm which includes 10 of 14 sampled prey items (see Section 3.1.7)		X .0002	g/kg
Total PCBs in fish consumed in a year		.416	g/yr
Portion not excreted (see Section 3.1.8)		X 95%	
Total estimated PCBs absorbed by adult male seals in one year	(B)	.40	g
Derived number of years for adult male to accumulate body burden (A/B)		11.	yr

Table 20. DDT concentrations in blubber of Southern Puget Sound harbor seals (ppm dry wt). These analyses were conducted at the Bodega Marine Laboratory. All animals found dead.

Sample #	Date collected	Location	Sex	Age* Class	% lipid	% H20	p,p'-DDE	o,p'-DDE	p,p'-DDD	o,p'-DDD	p,p'-DDT	o,p'-DDT	Total DDT
SJJ 43	16 May 76	Gertrude Is	F	S	53	36	57	<.029	4.0	<.063	6.3	<.029	67
SJJ 71	16 Jan 77	Gertrude Is	M	A	68	32	34	<.008	0.34	<.008	2.5	<.008	37
DB 13	2 Sep 82	Gertrude Is	M	P	18	50	5.0	<.0080	0.39	<.0080	0.77	<.0080	6.2
SJJ 112	3 Jul 77	Rosedale	F	S	77	10	38	<.013	0.17	<.013	2.6	<.013	41
SJJ 7	17 Jul 75	Vaughn	F	A	91	7	2.3	<.0060	0.087	<.0030	0.49	<.0060	2.9
GAB 115	8 Feb 77	Nisqually	M	S	89	8	8.3	<.014	0.16	<.014	1.0	<.014	9.5
SJJ 109	25 Oct 77	Nisqually	M	S	91	6	4.3	<.0060	0.13	<.0060	0.73	<.0060	5.2
SJJ 132	21 Aug 78	Nisqually	F	S	91	3	7.7	<.0070	0.14	<.0070	0.85	<.0070	8.7
PVES 1	- Nov 72	Budd Inlet	F	P	94	6	18	<.0050	0.33	.020	2.8	<.0050	21
SJJ 93	5 Aug 77	Budd Inlet	M	P	70	30	9.6	<.010	0.15	<.010	1.2	<.010	11
PVES 18	14 Oct 77	Eld Inlet	F	P	60	31	11	<.010	0.98	<.010	1.9	<.010	14
PVES 24	13 Mar 79	Eld Inlet	M	P	87	9	10	<.0040	0.067	.0045	0.67	<.0040	11
CRC 1	13 Mar 81	Eld Inlet	M	S	77	14	7.0	<.0070	0.099	<.013	0.45	<.0070	7.5
---	12 Feb 82	Gig Harbor	F	P	96	3	2.9	<.010	0.12	<.010	0.88	<.010	3.9
SJJ 114	3 Jan 78	Bremerton	F	P	68	28	45	<.014	0.99	<.014	6.4	<.014	52
SJJ 170	7 Apr 80	Raft Is	F	A	82	5	5.8	<.0060	0.076	<.0060	0.96	<.0060	6.8
SJJ	30 Mar 79	Days Is	M	A	54	21	20	<.010	0.23	<.055	1.5	<.010	22
n=17 geometric mean (standard deviation interval)													13 (5.1-32)

* A - adult, S - subadult, P - pup

Table 21. Chlorinated hydrocarbon concentrations in blubber of Southern Puget Sound harbor seals (ppm dry wt). These analyses were conducted at the Bodega Marine Laboratory. All animals were found dead.

Sample #	Date collected	Location	Sex	Age* Class	% lipid	% H20	PCB	HCB**	Dieldrin	Endrin	Mirex	Heptachlor Epoxide
SJJ 43	16 May 76	Gertrude Is	F	S	53	36	740	<.55	.051	<.0050	<.55	0.62
SJJ 71	16 Jan 77	Gertrude Is	M	A	68	32	1100	<.10	.084	<.0050	<.10	0.39
DB 13	2 Sep 82	Gertrude Is	M	P	18	50	77	<.010	.052	<.0030	<.010	0.10
SJJ 112	3 Jul 77	Rosedale	F	S	77	10	570	<.091	.040	<.0010	<.091	0.36
SJJ 7	17 Jul 75	Vaughn	F	A	91	7	12	<.12	.021	<.0010	<.12	0.023
GAB 115	8 Feb 77	Nisqually	M	S	89	8	100	<.13	.022	<.0010	<.13	0.088
SJJ 109	25 Oct 77	Nisqually	M	S	91	6	50	<.11	.023	<.0040	<.11	0.062
SJJ 132	21 Aug 78	Nisqually	F	S	91	3	91	<.14	.015	<.0010	<.14	0.091
PVES 1	– Nov 72	Budd Inlet	F	P	94	6	190	<.15	.051	<.0020	<.15	0.32
SJJ 93	5 Aug 77	Budd Inlet	M	P	70	30	110	<.089	.055	<.0030	<.089	0.16
PVES 18	14 Oct 77	Eld Inlet	F	P	60	31	110	<.12	.032	<.0020	<.12	0.24
PVES 24	13 Mar 79	Eld Inlet	M	P	87	9	160	<.15	.021	<.0010	<.15	0.094
CRC-1	13 Mar 81	Eld Inlet	M	S	77	14	100	<.12	.030	<.0020	<.12	0.083
---	12 Feb 82	Gig Harbor	F	P	96	3	32	<.098	.14	<.0040	<.098	0.048
SJJ 114	3 Jan 78	Bremerton	F	P	68	28	540	<.13	.052	<.0030	<.13	1.2
SJJ 170	7 Apr 80	Raft Is	F	A	82	5	130	<.086	.022	<.0010	<.086	0.14
SJJ	30 Mar 79	Days Is	M	A	54	21	720	<.050	.030	<.0010	<.050	0.20
n=17												
geometric mean (standard deviation interval)							150 (45–510)		.037 (.021–.065)			0.15 (0.057–0.42)

* A – adult, S – subadult, P – pup
** HCB – Hexachlorobenzene

Table 22. Chlordane and Hexachlorocyclohexane concentrations in blubber of Southern Puget Sound harbor seals (ppm dry wt). Analyses conducted at the Bodega Marine Laboratory. All animals were found dead.

										Chlordane compounds				
Sample #	Date collected	Location	Sex	Age* Class	% lipid	% H20	alpha -HCH	beta -HCH	gamma -HCH	trans -non	cis -non	gamma -chlor	alpha -chlor	oxy-chlor
SJJ 43	16 May 76	Gertrude Is	F	S	53	36	.43	.025	.025	.81	.70	<.050	.26	2.1
SJJ 71	16 Jan 77	Gertrude Is	M	A	68	32	.18	.013	.019	.42	.12	<.049	.088	1.2
DB 13	2 Sep 82	Gertrude Is	M	P	18	50	.15	.016	.023	.18	.15	<.0070	.058	0.52
SJJ 112	3 Jul 77	Rosedale	F	S	77	10	.16	<.018	<.018	.62	.12	<.0090	.070	0.83
SJJ 7	17 Jul 75	Vaughn	F	A	91	7	.059	<.0090	<.0090	.077	.037	<.010	.025	0.11
GAB 115	8 Feb 77	Nisqually	M	S	89	8	.10	.0030	.012	.10	.095	<.0070	.053	0.33
SJJ 109	25 Oct 77	Nisqually	M	S	91	6	.14	.0050	.021	.22	.095	<.012	.038	0.23
SJJ 132	21 Aug 78	Nisqually	F	S	91	3	.13	.0050	.015	.19	.096	<.011	.054	0.30
PVES 1	- Nov 72	Budd Inlet	F	P	94	6	.21	.0040	.030	.43	.11	<.0050	.058	0.66
SJJ 93	5 Aug 77	Budd Inlet	M	P	70	30	.12	.0050	.021	.15	.11	<.035	.056	0.56
PVES 18	14 Oct 77	Eld Inlet	F	P	60	31	.20	<.019	<.019	.15	.13	<.0050	.050	1.3
PVES 24	13 Mar 79	Eld Inlet	M	P	87	9	.072	.0034	.010	.052	.062	<.0023	.037	0.011
CRC-1	13 Mar 81	Eld Inlet	M	S	77	14	.080	.0070	.020	.086	.068	<.0030	.038	0.24
---	12 Feb 82	Gig Harbor	F	P	96	3	.12	.0026	.018	.27	.078	<.0078	.069	0.15
SJJ 114	3 Jan 78	Bremerton	F	P	68	28	.65	.020	.049	.88	.43	<.083	.12	2.40
SJJ 170	7 Apr 80	Raft Is	F	A	82	5	.095	.0020	.0030	.22	.073	<.0070	.037	0.35
SJJ	30 Mar 79	Days Is	M	A	54	21	.27	.030	.030	1.0	.17	<.083	.14	1.80
n=17														
geometric mean (standard deviation interval)							.15 (.082-.28)			.24 (.098-.59)	.12 (.058-.23)		.061 (.035-.11)	0.44 (0.12-1.6)

* A - adult, S - subadult, P - pup

Table 23a. Interlaboratory comparisons of PCB and DDT levels (ppm wet wt) found in blubber of harbor seals. All samples from animals found dead in Southern Puget Sound. Results of samples analyzed at the Evergreen State College (TESC) are reported in Table 4. Results from the Bodega Marine Laboratory analyses (BML#1), reported in Risebrough (1978), have been converted to wet weight.

Sample #	PCB		Total DDT		PCB/DDT Ratio	
	TESC	BML #1	TESC	BML #1	TESC	BML #1
SJJ 7	21	19	1.3	6.0	16	3.2
SJJ 19	220	320	27	43	8.1	7.4
SJJ 20	67	84	7.1	12	9.4	7.0
SJJ 21	58	71	7.1	17	8.2	4.2
SJJ 22	150	94	13	14	12	6.7
SJJ 23	150	140	18	22	8.3	6.4
SJJ 25	87	110	7.5	14	12	7.9
SJJ 27	210	220	18	13	12	17
SJJ 43*	290	210	30	32	9.7	6.6
SJJ 55	140	130	13	21	11	6.2

* BML #1 values corrected due to a typographical error in Risebrough (1978) and are not included in mean calculations in Table 24.

Table 23b. Interlaboratory comparisons of PCB and DDT levels (ppm wet wt) found in blubber of harbor seals. All samples from animals found dead in Southern Puget Sound. Results for samples analyzed at the Evergreen State College (TESC) are reported in Table 4. Analyses from the Bodega Marine Laboratory (BML#2)(this study), have been calculated from the results reported in Tables 20-21.

Sample #	PCB		Total DDT		PCB/DDT Ratio	
	TESC	BML #2	TESC	BML #2	TESC	BML #2
SJJ 7	21	11	1.3	2.7	16	4.1
SJJ 43	290	470	30	43	9.7	11
SJJ 71*	250	750	15	25	17	30
SJJ 93	28	77	2.8	7.7	10	10
SJJ 109	35	47	3.7	4.9	9.5	9.6
SJJ 112	530	510	38	37	14	14
PVES 1	160	180	25	20	6.4	9.0
PVES 18	69	76	9.9	9.6	7.0	7.9
GAB 115	59	92	5.5	8.7	11	11

* not included in mean calculations in Table 24

Table 24a. Interlaboratory comparisons of geometric mean levels (ppm wet wt) of PCB, total DDT,and PCB/DDT ratio found in blubber of Southern Puget Sound harbor seals. Results of samples analyzed at the Evergreen State College (TESC) are reported in Table 4. Results from the Bodega Marine Laboratory analyses (BML#1), reported in Risebrough (1978), have been converted to wet weight.

PCB*		Total DDT*		PCB/DDT Ratio*	
TESC	BML #1	TESC	BML #1	TESC	BML #1
100	100	9.6	16	9.9	6.6

* geometric mean of nine samples reported in Table 23a

Table 24b. Interlaboratory comparisons of geometric mean levels (ppm wet wt) of PCB, total DDT, and PCB/DDT ratio found in blubber of Southern Puget Sound harbor seals. Results of samples analyzed at the Evergreen State College (TESC) are reported in Table 4. Analyses from the Bodega Marine Laboratory (BML#2)(this study),have been calculated from the results reported in Tables 20-21.

PCB*		Total DDT*		PCB/DDT Ratio*	
TESC	BML #2	TESC	BML #2	TESC	BML #2
82	100	8.2	11	10	9.5

* geometric mean of eight samples reported in Table 23b

Table 25. Metal concentrations in livers of Southern Puget Sound harbor seals. Analyzed by atomic absorption. Reported as ppm dry weight. Undetected values are not used in computing the mean. Analyses conducted at Moss Landing Marine Laboratory.

Sample No.	Date collected	Location	Sex	Age* Class	% H20	Ag	Al	Cd	Cu	Cr	Mn	Pb	Zn	Hg
SJJ 43	16 May 76	Gertrude Is	F	S	69	nd	200	0.47	20	nd	17	0.41	92	24
SJJ 71	16 Jan 77	Gertrude Is	M	A	67	0.34	720	1.8	56	0.33	12	1.2	140	23
DB 13	2 Sep 82	Gertrude Is	M	P	70	0.79	140	0.66	87	0.41	13	0.29	410	12
SJJ 7	17 Jul 75	Vaughn	F	A	64	0.45	2200	2.0	28	0.22	8.0	0.87	96	1100
GAB 115	8 Feb 77	Nisqually	M	S	84	0.36	5100	1.1	77	0.48	31	1.5	250	28
SJJ 109	25 Oct 77	Nisqually	M	S	69	0.056	490	0.67	29	0.41	6.7	0.63	180	7.7
SJJ 132	21 Aug 78	Nisqually	F	S	67	0.42	83	0.47	46	0.086	8.4	0.49	110	19
PVES 1	- Nov 72	Budd Inlet	F	P	45	0.007	590	0.88	4.6	0.25	4.8	0.15	54	1.7
SJJ 93	5 Aug 77	Budd Inlet	M	P	66	0.10	120	nd	23	0.42	7.3	0.33	230	14
PVES 18	14 Oct 77	Eld Inlet	F	P	70	0.59	23	nd	48	0.65	11	0.19	82	4.3
PVES 24	13 Mar 79	Eld Inlet	M	P	73	0.077	69	nd	36	0.38	11	0.52	180	8.5
CRC-1	13 Mar 81	Eld Inlet	M	S	63	0.35	470	0.65	13	0.81	5.2	0.36	130	100
---	12 Feb 82	Gig Harbor	F	P	71	0.027	7.6	0.47	18	0.04	6.6	0.34	170	3.2
SJJ 114	3 Jan 78	Bremerton	F	P	72	0.11	650	0.62	32	nd	11	0.27	120	8.5
n						13	14	11	14	12	14	14	14	14
geometric mean						0.16	240	0.78	30	0.37	9.6	0.44	140	16
(standard deviation interval)						(.039-.63)	(43-1400)	(.47-1.3)	(14-63)	(.13-.69)	(5.9-16)	(.23-.85)	(84-240)	(3.3-78)

* A - adult, S - subadult, P - pup
nd= not detected

Table 26. Metal concentrations in kidneys of Southern Puget Sound harbor seals. Analyzed by atomic absorption. Reported as ppm dry weight. Undetected values are not computed in the mean. Analyses were conducted at the Moss Landing Marine Laboratory.

Sample no.	Date collected	Location	Sex	Age* Class	% H20	Ag	Al	Cd	Cu	Cr	Mn	Pb	Zn	Hg
SJJ 43	16 May 76	Gertrude Is	F	S	69	.007	260	3.7	13	.91	3.7	.53	110	120
SJJ 71	16 Jan 77	Gertrude Is	M	A	67	.011	240	16	20	.32	6.2	.38	220	30
SJJ 7	17 Jul 75	Vaughn	F	A	64	.023	230	13	50	.39	8.3	.57	64	21
GAB 115	8 Feb 77	Nisqually	M	S	84	.002	640	0.62	6.8	.15	1.7	.086	37	3.6
SJJ 109	25 Oct 77	Nisqually	M	S	69	.003	110	nd	14	.26	1.7	.28	160	13
SJJ 132	21 Aug 78	Nisqually	F	S	67	.006	90	2.6	13	.25	4.2	.37	75	6.9
PVES 1	- Nov 72	Budd Inlet	F	P	45	.006	1700	1.0	9.3	.13	4.2	.11	130	8.0
SJJ 93	5 Aug 77	Budd Inlet	M	P	66	.034	2900	1.3	24	.37	3.9	.37	290	12
PVES 18	14 Oct 77	Eld Inlet	F	P	70	.004	160	nd	9.6	.33	7.2	.34	81	3.5
CRC-1	13 Mar 81	Eld Inlet	M	S	63	.006	180	46	120	.74	6.0	.43	120	20
---	12 Feb 82	Gig Harbor	F	P	71	.004	43	1.3	24	.97	3.9	.36	270	9.4
SJJ 114	3 Jan 78	Bremerton	F	P	72	.008	460	2.0	21	.89	3.9	.34	150	9.7
n						12	12	10	12	12	12	12	12	12
geometric mean						.007	280	3.4	19	.39	4.1	.31	120	13
(standard deviation interval)						(.003-.015)	(85-940)	(.83-14)	(8.6-42)	(.20-.77)	(2.5-6.8)	(.17-.55)	(66-220)	(4.8-33)

* A - adult, S - subadult, P - pup
nd = not detected

Table 27. Concentrations of selected metals in the liver of Southern Puget Sound harbor seals. Reported as ppm dry weight. Analyzed by x-ray fluorescence at the Lawrence Berkeley Laboratory. All animals found dead.

Sample #	Age* Class	Mn	Fe	Ni	Cu	Zn	Ga	As	Se	Br	Rb	Sr	Hg	Pb
GAB 115	S	4.0	1800	<1.0	43	110	<2.0	<2.0	4.7	30	4.0	<1.0	8	<2.0
SJJ 132	S	3.0	1300	<1.0	43	110	<1.0	<2.0	6.4	32	4.0	<1.0	16	<2.0
CRC 1	S	3.0	1200	<1.0	16	120	<1.0	<2.0	34	35	3.0	<2.0	81	<3.0
SJJ 112**	S	3.0	4400	<1.0	78	250	<1.0	<2.0	29	30	5.0	<2.0	90	<3.0
SJJ 7	A	5.0	1500	<1.0	38	110	<2.0	—	210	29	4.0	—	530	—
geometric mean		3.5	1800		39	130			23	31	3.9		55	
(Std dev interval)		(2.8-4.4)	(1100-3000)		(22-69)	(93-190)			(5-100)	(29-34)	(3.3-4.7)		(11-280)	

* S=subadult, A=adult. See Table 26 for description of sex, location, date collected, % lipid, and % H20 for all samples except SJJ 112.

** This animal was a female, collected 3 July 1977 at Rosedale, WA.

Table 28. Concentrations of selected metals in kidneys of Southern Puget Sound harbor seals. Reported as ppm dry weight. Analyzed by x-ray fluorescence at the Lawrence Berkeley Laboratory. All animals found dead.

Sample #	Age* Class	Mn	Fe	Ni	Cu	Zn	Ga	As	Se	Br	Rb	Sr	Hg	Pb
GAB 115	S	3.0	780	<1.0	14	77	<1.0	<2.0	8.6	54	4.0	<2.0	6.0	<2.0
SJJ 132	S	3.0	680	<1.0	13	79	<1.0	<2.0	7.4	61	5.0	<2.0	7.0	<3.0
CRC 1	S	3.0	770	<1.0	12	76	<1.0	<2.0	11	48	4.0	<1.0	10	<2.0
SJJ 112**	S	<3.0	640	<1.0	15	180	<1.0	<2.0	7.2	41	4.0	<1.0	17	<2.0
SJJ 7	A	3.0	1000	<1.0	9.0	60	<1.0	<2.0	12	77	20.0	<1.0	19	<2.0
geometric mean (Std dev interval)			760 (640-910)		12 (10-15)	87 (57-130)			9.0 (7.2-11)	55 (43-70)	5.8 (2.9-12)		11 (6.3-18)	

* S=subadult, A=adult. See Table 26 for description of sex, location, date collected, % lipid, and % H2O for all samples except SJJ 112.

** This animal was a female, collected 3 July 1977 at Rosedale, WA.

Table 29. Levels and atomic weight ratios of mercury, selenium, and bromine in liver of harbor seals, analyzed by x-ray fluorescence at the Lawrence Berkeley Laboratory. All animals found dead in Southern Puget Sound (ppm dry wt).

Sample no.	Hg	Se	Br	Atomic wt ratio Hg:Se	Atomic wt ratio Hg:Br
GAB 115 (subadult)	8.0	4.7	30	0.67	0.11
SJJ 132 (subadult)	16	6.4	32	0.98	0.20
CRC 1 (subadult)	81	34	35	0.94	0.92
SJJ 112 (subadult)	90	29	30	1.2	1.2
SJJ 7 (adult)	530	210	29	0.99	7.3
			geom. mean (std dev inter)	0.94 (0.76-1.2)	0.71 (0.14-3.7)

Table 30. Concentrations of PCB and DDE (ppm wet wt) in the blubber of Washington marine mammals other than harbor seals. All animals found dead. Samples analyzed at The Evergreen State College, see Methods Section 2.2.1.

Common name	Species	Sample no.	Date collected	Location	Sex	Concentration (ppm wet wt) PCB	Concentration (ppm wet wt) DDE	PCB/DDE Ratio
Minke whale	Balaenoptera acutorostrata	SJJ 38	11 Mar 76	Nisqually Delta S. Puget Sound	M	0.15	0.55	0.27
Killer whale	Orcinus orca	L-8	28 Sept 77	off San Juan Is. N. Puget Sound	M	38	59	0.64
Killer whale	Orcinus orca	0-1	- Jan 79	Boundary Bay British Columbia	M	250	640	0.39
Pigmy sperm whale	Kogia breviceps	-	5 Oct 77	off Whidbey Is. N. Puget Sound	M	0.15	1.3	0.12
Harbor porpoise	Phocoena phocoena	JR 308	- Sept 79	Carr Inlet S. Puget Sound	-	55	14	3.9
Harbor porpoise (fetus)	Phocoena phocoena	-	15 Aug 77	off San Juan Is. N. Puget Sound	M	1.7	1.4	1.2
Dall's porpoise	Phocoenoides dalli	-	14 Aug 81	off Lopez Is. N. Puget Sound	M	9.0	5.0	1.8
Sea lion	unknown	PVES 3	24 June 77	Twin Harbor Outer Coast	-	2.6	4.8	0.54
River otter	Lutra canadensis	CRC 10	4 Sept 81	Nisqually Delta S. Puget Sound	F	6.7	0.60	11

Table 31. DDT plus PCB concentrations (ppm wet wt) in the blubber of harbor seals collected in 1971 from Southern Puget Sound, reported by Anas (1974a). Author did not separate PCB from DDT residues.

Location	Tissue	Age (yrs)	N	PCB+DDT geom mean (range) ppm wet wt
Puget Sound, WA	blubber	1	2	862.7 (459-1620)

Table 32. PCB and DDE concentrations (ppm wet wt) in the blubber of harbor seals from Washington State, reported by Arndt (1973).

Location	Tissue	N	Total DDT arith mean(range) ppm wet wt	PCB arith mean(range) ppm wet wt
Southern Puget Sound	blubber	10	9.7 (.52-30.)	131 (4.1-374)
	liver	11	0.18 (0-.55)	2.5 (0-9.6)
Northern Puget Sound	blubber	7	6.6 (2.1-16.5)	44 (12.8-78)
	liver	8	.11 (.04-.43)	.69 (.28-2.2)
Grays Harbor	blubber	13	5.34 (.88-14.4)	47.8 (13.8-136)
	liver	14	.16 (.04-.33)	1.1 (.17-2.4)

Tables 33-64. Contaminant concentrations in various tissues of pinnipeds. Explanations of headings and footnotes.

LOC = location code:
- 1 = North Pacific, east coast (south of Arctic)
- 2 = North Pacific, west coast (south of Arctic)
- 3 = North Atlantic, west coast (south of Arctic)
- 4 = North Atlantic, east coast (south of Arctic)
- 5 = Arctic
- 6 = Antarctic
- 8 = Protected European

SPEC. LOCATION = specific location

YR = year sample collected,, if samples were collected over several years, the midpoint was reported

AGE = age class of sample:
- A = adults
- S = subadults
- N = pup
- T = all age classes mixed
- M = mixed age classes, select groups (e.g., mothers and pups)
- L = lactating female
- P = pregnant female
- F = fetus
- U = unknown

SEX = sex of sample:
- F = female
- M = male
- B = mixed sexes
- U = unknown

W = weight basis of the pollutant concentration:
- L = lipid weight
- D = dry weight
- W = wet weight

N = number in sample

MEAN, LOW, and HIGH -- Concentrations as reported or calculated for each data set, all values listed with 2 decimal places regardless of number of significant figures reported, 0 = below level of detection or <.01 ppm.

REFERENCE -- source of information, see References section for full citation

<u>Footnotes</u>
- a = some samples of a different species may be mixed in
- b = sample consists of animals that were showing some type of dysfunction
- c = residue values for these animals identified as unusually high by the author, possibly due to the condition of the animal (or other unknown factors)
- d = residue levels reported as p,p'DDE only, not total DDT
- e = Total DDT = sum of all DDT and metabolites reported, may include combinations of some or all of the following: p,p'DDE, o,p'DDE, p,p'DDD, o,p'DDD, p,p'DDT, and o,p'DDT.
- g = geometric mean

Table 33. PCB concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	69	N	B	W	5	0.00			Anas and Wilson 1970b
1	Pribilof Is	80	S	M	W	4	2.49	1.51	4.00	Calambokidis and Peard 1983
1	Pribilof Is	72	L	F	W	2	5.80	4.70	6.80	Kurtz and Kim 1976
1	Pribilof Is	72	N	U	W	2	5.50	3.80	7.20	Kurtz and Kim 1976
1	Pribilof Is	72	N	U	W	3	33.00	1.30	81.00	Kurtz and Kim 1976
Cystophora cristata										
3	Gulf of St Lawr, Can	0	U	U	W	1	3.00			Holden 1972
5	W coast Greenland	72	U	U	W	5	2.74	0.30	4.90	Clausen et al 1974
Erignathus barbatus										
5	W coast Greenland	72	U	U	W	5	1.80	0.60	3.00	Clausen et al 1974
Halichoerus grypus										
3	Sable Is,Nova Scotia	76	L	F	L	6	14.50	7.10	24.60	Addison and Brodie 1977
3	Sable Is,Nova Scotia	76	N	B	L	6	2.30	1.40	3.20	Addison and Brodie 1977
3	Sable Is,Nova Scotia	76	N	B	L	6	2.30	1.40	3.20	Addison and Brodie 1977
3	Gulf of St Lawr, Can	0	U	U	W	7	29.00	12.00	55.00	Holden 1972
4	Farne Is England	72	T	B	L	19	32.60	4.10	89.10	Donkin et al 1981
4	Farne Is England	72	P	F	L	5	13.90	8.20	20.50	Donkin et al 1981
4	Outer Hebrides,Eng	71	U	U	W	6	14.40			Heppleston 1973
4	Shetland, Eng	71	U	U	W	8	11.10			Heppleston 1973
4	Farne Is, N Sea	71	U	U	W	7	19.20			Heppleston 1973
4	East Anglia, N Sea	71	U	U	W	4	152.00			Heppleston 1973
4	Orkney, N Scotland	0	M	B	W	8	18.00	3.00	30.00	Holden 1972
4	Hebrides, W Scotland	0	M	B	W	3	30.00	19.00	40.00	Holden 1972
4	Summer Is, Scotland	0	M	B	W	4	16.00	11.00	19.00	Holden 1972
4	Aberdeen, E Scotland	68	M	B	W	16	38.00	12.00	88.00	Holden 1972
4	Cornwall, England	0	N	B	W	3	160.00	118.00	187.00	Holden 1972
4	Farne Is, E England	0	N	B	W	5	40.00	25.00	50.00	Holden 1972
4	Scroby, E England	0	M	B	W	2	123.00	100.00	146.00	Holden 1972
4	Wales/England	0	M	B	W	3	212.00	200.00	235.00	Holden 1972
4	SW England	0	N	U	L		1800.00			Holden 1972

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
4	NE England		N	U	L		50.00			Holden 1972
8	Baltic, Sweden	75	A	U	L	5	830.00			Jannson et al 1979
8	Baltic	75	A	U	L	38	940.00			Olsson 1978
8	N. Baltic Proper,Swe	71	T	B	L	18	140.00	47.00	290.00	Olsson et al 1975
8	Aland Sea, Sweden	71	T	B	L	27	100.00	20.00	320.00	Olsson et al 1975
8	Gulf of Bothnia,Swed	71	T	B	L	15	100.00	49.00	330.00	Olsson et al 1975
	Hydrurga leptonyx									
6	Antarctica	75	U	U	L	1	0.04			Risebrough et al 1976
	Phoca groenlandicus									
3	Gulf of St Lawrence	71	S	B	W	9	5.20	2.00	15.00	Addison et al 1973
3	Gulf of St Lawrence	71	A	B	W	9	11.10	3.00	22.00	Addison et al 1973
3	Gulf of St Lawrence	73	L	F	W	1	6.05			Jones et al 1976
3	Gulf of St Lawrence	73	N	U	W	15	1.08			Jones et al 1976
3	Gulf of St. Lawrence	71	A	B	W	11	3.20	0.49	13.30	Rosewell et al 1979
3	Gulf of St. Lawrence	73	N	B	W	20	2.30	1.15	6.20	Rosewell et al 1979
	Phoca hispida									
4	North Sea	76	S	F	W	1	15.00			Harms et al 1978
5	Holman Is, NWT	72	T	M	L	15	4.10	1.00	6.00	Addison and Smith 1974
5	Holman Is, NWT	72	T	F	L	13	2.00	1.00	4.00	Addison and Smith 1974
5	W coast Greenland	72	U	U	W	5	0.90	0.60	3.00	Clausen et al 1974
5	Canadian Arctic		U	U	W	3	3.00	2.00	4.00	Holden 1972
5	Arctic (Norway)		U	U	W	2	1.50	1.00	2.00	Holden 1972
8	N Bothnian Bay	74	A	F	L	40	69.00			Helle et al 1976a
8	N Bothnian Bay	75	P	F	L	24	73.00			Helle et al 1976b
8	N Bothnian Bay	75	A	F	L	29[b]	110.00			Helle et al 1976b
8	N Bothnian Bay	75	A	F	L	8	89.00			Helle et al 1976b
8	N Bothnian Bay	75	F	U	L	24	49.00			Helle et al 1976b
8	N Bothnian Bay	75	U	M	L	24	100.00			Helle et al 1976b
8	Baltic (N Sweden)		U	U	W	1	22.00			Holden 1972
8	Gulf of Bothnia	75	U	U	L	21	210.00			Olsson 1978
8	Gulf of Bothnia,Swed	71	T	B	L	33	110.00	27.00	390.00	Olsson et al 1975
	Phoca vitulina									
1	Southern Puget Sound	72	M	M	W	9	145.00	16.20	374.00	Arndt 1973

See Table Explanations for footnote descriptions.

Table 33. PCB concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
1	Northern Puget Sound	72	M	M	W	7	44.00	12.80	77.70	Arndt 1973
1	Grays Harbor,WA	72	M	M	W	13	47.80	13.80	136.00	Arndt 1973
1	California coast	75	N	B	L	4	43.10	4.50	120.00	Risebrough 1978
1	San Francisco Bay	76	N	B	L	4	66.00	16.00	120.00	Risebrough 1978
1	San Francisco Bay	76	A	F	L	2	195.00	140.00	250.00	Risebrough 1978
1	San Francisco Bay	75	A	M	L	1	500.00			Risebrough 1978
1	Willipa Bay, WA	76	A	F	D	1	46.00			Risebrough 1978
1	So.Puget Sound, WA	75	T	B	D	10	134.00	20.00	370.00	Risebrough 1978
3	Gulf of Maine	71	U	B	W	6	92.50	27.90	240.20	Gaskin et al 1973
3	New Brunswick	71	U	M	W	3	52.30	43.00	63.00	Gaskin et al 1973
3	New Brunswick	71	L	F	W	1	7.10			Gaskin et al 1973
3	New Brunswick	71	U	F	W	1	7.10			Gaskin et al 1973
4	German N Sea coast	75	T	U	W	56	152.00	27.30	564.00	Drescher et al 1977
4	Shetland, Scotland		N	B	W	4	4.00	2.00	6.00	Holden 1972
4	Scotland	69	M	B	W	17	12.00	5.00	20.00	Holden 1972
4	Clyde, W. Scotland		M	B	W	3[a]	75.00	58.00	99.00	Holden 1972
4	Scroby, E England		M	P	W	3	131.00	93.00	185.00	Holden 1972
4	Wash, E England		N	B	W	12	15.00	7.00	24.00	Holden 1972
4	W. Scotland		A	U	W	8	65.80			Holden 1978
4	Swedish west coast		U	U	N	3	12.00	5.70	18.00	Jensen and Olsson 1976
4	North Sea, E of Scot	78	S	B	L	3	446.00	120.00	661.00	Kerkhoff et al 1981
8	Dutch Wadden Sea	78	M	M	W	7	189.00	22.00	576.00	Duinker et al 1979
8	Baltic proper		U	U	N	1	31.00			Jensen and Olsson 1976
8	**Sweden**, Baltic	68	U	U	W	2[a]	15.00	8.50	21.00	Jensen et al 1969
8	Wadden Sea, Dutch	71	M	U	W	8	1009.00	47.00	2530.00	Koeman et al 1972
8	**W Coast of Sweden**	75	U	U	L	11	230.00			Olsson 1978
8	**W Coast of Sweden**	71	T	B	L	6	60.00	28.00	110.00	Olsson et al 1975
8	Baltic, Sweden	71	T	B	L	3	707.00[c]	630.00	750.00	Olsson et al 1975
8	Wadden Sea,Ger & Dan	75	S	U	W	8	113.80	23.00	340.00	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	6	76.40	40.50	123.00	Reijnders 1980
8	Wadden Sea, Neth	75	S	U	W	6	134.00	5.00	680.00	Reijnders 1980
8	Wadden Sea, Neth	75	A	U	W	8	701.00	87.00	1447.00	Reijnders 1980
8	Wadden Sea, S Dutch	81	U	U	L	7		119.00	2516.00	**Reijnders 1982b**

See Table Explanations for footnote descriptions.

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Table 33. PCB concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Zalophus californianus										
1	Oregon coast	71	A	U	W	6	34.10			Buhler et al 1975
1	Oregon coast	73	A	M	W	3	21.20			Buhler et al 1975
1	SanMiguel Is, CA	70	S	F	W	6[b]	112.40	85.00	145.00	DeLong et al 1973
1	SanMiguel Is,CA	70	A	F	W	4	17.10	12.00	25.00	DeLong et al 1973
1	San Miguel Is, CA	72	S	F	W	8[b]	57.20	33.00	92.40	Gilmartin et al 1976
1	San Miguel Is, CA	72	A	F	W	10	13.20	4.73	39.50	Gilmartin et al 1976

See Table Explanations for footnote descriptions.

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Table 34. Total DDT[e] concentrations (ppm) in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	69	M	B	W	5	16.10	0.67	48.00	Anas and Wilson 1970b
1	Pribilof Is	80	S	M	W	4	7.52[d]	2.69	12.50	Calambokidis and Peard 1983
1	Pribilof Is	72	L	F	W	2	5.20	3.30	7.00	Kurtz and Kim 1976
1	Pribilof Is	72	M	U	W	2	5.60	5.30	5.80	Kurtz and Kim 1976
1	Pribilof Is	72	M	U	W	3	63.00	5.30	106.00	Kurtz and Kim 1976
Cystophora cristata										
3	Gulf of St Lawr, Can		U	U	W	1	10.20			Holden 1972
5	W coast Greenland	72	U	U	W	5	0.29[d]	0.06	0.49	Clausen et al 1974
Erignathus barbatus										
5	W coast Greenland	72	U	U	W	5	0.46[d]	0.20	0.80	Clausen et al 1974
Halichoerus grypus										
3	Sable Is,Nova Scotia	74	L	F	L	5	12.00	6.80	17.90	Addison and Brodie 1977
3	Sable Is,Nova Scotia	76	L	F	L	6	15.40	9.90	31.20	Addison and Brodie 1977
3	Sable Is,Nova Scotia	74	M	B	L	5	8.30	4.20	10.50	Addison and Brodie 1977
3	Sable Is,Nova Scotia	76	M	B	L	6	7.30	4.10	13.90	Addison and Brodie 1977
3	Gulf of St Lawr, Can		U	U	W	7	47.00	15.00	85.00	Holden 1972
3	Magdalen Is,Can	67	M	U	W	2[a]	1.70	0.83	2.60	Holden and Marsden 1967
3	Cabot Straits, Can	67	M	U	W	6[a]	12.20	3.70	35.00	Holden and Marsden 1967
4	Farne Is England	72	T	B	L	19	17.90	4.30	36.20	Donkin et al 1981
4	Farne Is England	72	P	F	L	4	8.00	5.00	12.50	Donkin et al 1981
4	Outer Hebrides,Eng	71	U	U	W	6	7.40			Heppleston 1973
4	Shetland, Eng	71	U	U	W	8	8.90			Heppleston 1973
4	Farne Is, N Sea	71	U	U	W	7	10.71			Heppleston 1973
4	East Anglia, N Sea	71	U	U	W	4	15.53			Heppleston 1973
4	Orkney, N Scotland		M	B	W	8	13.00	2.90	25.00	Holden 1972
4	Hebrides, W Scotland		M	B	W	3	15.00	9.00	23.20	Holden 1972
4	Summer Is, Scotland		M	B	W	4	9.80	4.00	18.00	Holden 1972
4	Aberdeen, E Scotland	68	M	B	W	16	20.10	8.40	36.00	Holden 1972
4	Farne Is, E England		M	B	W	5	13.00	6.40	19.00	Holden 1972

See Table Explanations for footnote descriptions.

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Table 34. Total DDT concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.
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LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
4	Scroby, E England		M	B	W	2	39.70	27.00	52.00	Holden 1972
4	Wales/England		M	B	W	3	17.50	14.00	21.00	Holden 1972
4	Cornwall, England		N	B	W	3	11.10	5.20	15.00	Holden 1972
4	SW England		N	U	L		108.00			Holden 1972
4	NE England		N	U	L		16.60			Holden 1972
4	E Scotland, N Sea	66	A	U	W	18	14.50	2.80	34.00	Holden and Marsden 1967
4	N and W Scotland	66	A	U	W	6	7.60	3.10	15.50	Holden and Marsden 1967
4	NW Scotland	66	N	U	W	9	5.10	2.20	8.30	Holden and Marsden 1967
8	Baltic, Sweden	75	A	U	L	5	970.00			Jannson et al 1979
8	Baltic	75	A	U	L	38	1300.00			Olsson 1978
8	N. Baltic Proper,Swe	71	T	B	L	18	420.00	170.00	970.00	Olsson et al 1975
8	Aland Sea, Sweden	71	T	B	L	27	270.00	68.00	850.00	Olsson et al 1975
8	Gulf of Bothnia,Swed	71	T	B	L	15	210.00	110.00	560.00	Olsson et al 1975
Hydrurga leptonyx										
6	Antarctica	75	U	U	L	1	0.08			Risebrough et al 1976
Leptonychotes weddelli										
6	Antarctica	65	U	U	N	5	0.06	0.04	0.08	Brewerton 1969
6	Antarctica	67	U	U	N	15	0.05	0.02	0.10	Brewerton 1969
6	Antarctica	64	A	B	W	4	0.06	0.04	0.12	George and Frear 1966
Lobodon carcinophagus										
6	Ross Is Antarctica	64	S	M	W	1	0.03			Sladen et al 1966
Phoca groenlandicus										
3	Gulf of St Lawrence	71	S	B	W	9	5.70	3.10	12.10	Addison et al 1973
3	Gulf of St Lawrence	71	A	B	W	9	13.00	4.90	22.60	Addison et al 1973
3	Gulf of St Lawrence	73	L	F	W	1	4.40			Jones et al 1976
3	Gulf of St Lawrence	73	N	U	W	15	1.34			Jones et al 1976
3	Gulf of St. Lawrence	71	A	B	W	11	4.00	1.64	9.88	Rosewell et al 1979
3	Gulf of St. Lawrence	73	N	B	W	20	1.98	0.56	3.70	Rosewell et al 1979
Phoca hispida										
4	North Sea	76	S	F	W	1	7.00			Harms et al 1978

See Table Explanations for footnote descriptions.

Table 34. Total DDT concentrations (ppm) in blubber of pinnipeds. See Table Explanation for description.
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LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
5	Baffin Is,E Arctic	69	M	F	L	13	1.71	1.00	4.00	Addison 1973
5	Baffin Is,E Arctic	69	M	M	L	3	1.38			Addison 1973
5	Holman Is,W Arctic	73	M	F	L	9	0.57			Addison 1973
5	Holman Is,W Arctic	73	M	M	L	15	1.32			Addison 1973
5	Holman Is, NWT	72	T	M	L	15	1.30	0.39	2.45	Addison and Smith 1974
5	Holman Is, NWT	72	T	F	L	13	0.61	0.17	1.08	Addison and Smith 1974
5	W coast Greenland	72	U	U	W	5	0.15[d]	0.02	0.26	Clausen et al 1974
5	Canadian Arctic		U	U	W	3	2.70	1.00	3.90	Holden 1972
5	Arctic (Norway)		U	U	W	2	2.40	1.80	2.90	Holden 1972
8	N Bothnian Bay	74	A	F	L	40	110.00			Helle et al 1976a
8	N Bothnian Bay	75	P	F	L	24	88.00			Helle et al 1976b
8	N Bothnian Bay	75	A	F	L	29[b]	130.00			Helle et al 1976b
8	N Bothnian Bay	75	A	F	L	8	100.00			Helle et al 1976b
8	N Bothnian Bay	75	F	U	L	24	62.00			Helle et al 1976b
8	N Bothnian Bay	75	U	M	L	24	130.00			Helle et al 1976b
8	Baltic (N Sweden)		U	U	W	1	23.80			Holden 1972
8	Gulf of Bothnia	75	U	U	L	21	250.00			Olsson 1978
8	Gulf of Bothnia,Swed	71	T	B	L	33	200.00	31.00	770.00	Olsson et al 1975
	Phoca vitulina									
1	Southern Puget Sound	72	M	M	W	9	9.49	0.27	29.60	Arndt 1973
1	Northern Puget Sound	72	M	M	W	7	6.63	2.07	16.50	Arndt 1973
1	Grays Harbor,WA	72	M	M	W	13	5.34	0.88	14.40	Arndt 1973
1	California coast	75	N	B	L	4	26.30	13.00	37.20	Risebrough 1978
1	San Francisco Bay	76	N	B	L	4	14.80	9.50	21.00	Risebrough 1978
1	San Francisco Bay	76	A	F	L	2	55.70	46.90	64.40	Risebrough 1978
1	San Francisco Bay	75	A	M	L	1	163.00			Risebrough 1978
1	Willapa Bay, WA	76	A	F	D	1	38.00[d]			Risebrough 1978
1	So.Puget Sound, WA	75	T	B	D	10	22.70[d]	6.30	51.00	Risebrough 1978
1	So.Puget Sound, WA	75	T	B	D	10	22.70[d]	6.30	51.00	Risebrough 1978
1	Central Calif waters	70	U	M	W	1	18.00			Shaw 1971
1	Central Calif waters	70	U	F	W	1	158.00			Shaw 1971
3	Gulf of Maine	71	U	B	W	6	65.40	25.30	139.10	Gaskin et al 1973

See Table Explanations for footnote descriptions.

Table 34. Total DDT concentrations (ppm) in blubber of pinnipeds. See Table Explanation for description.
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LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
3	New Brunswick	71	U	M	W	3	38.40	29.10	52.10	Gaskin et al 1973
3	New Brunswick	71	L	F	W	1	8.64			Gaskin et al 1973
4	German N Sea coast	75	T	U	W	56	8.75	2.20	27.20	Drescher et al 1977
4	Shetland, Scotland		M	B	W	4	2.60	1.60	3.50	Holden 1972
4	Mull, W Scotland	69	M	B	W	17	5.40	1.80	8.80	Holden 1972
4	Clyde, W Scotland		M	B	W	3[a]	25.20	19.00	31.00	Holden 1972
4	Wash, E England		M	B	W	12	6.50	3.50	9.70	Holden 1972
4	Scroby, E England		M	B	W	3	23.90	15.60	23.00	Holden 1972
4	W. Scotland		A	U	W	8	22.30			Holden 1978
4	Swedish west coast		U	U	N	3	22.00	6.90	49.00	Jensen and Olsson 1976
4	North Sea, E of Scot	78	S	B	L	3	24.70	12.00	47.00	Kerkhoff et al 1981
8	Dutch Wadden Sea	78	M	M	W	7	10.90	1.70	25.40	Duinker et al 1979
8	Baltic proper		U	U	N	1	210.00			Jensen and Olsson 1976
8	Sweeden, Baltic	68	U	U	W	2[a]	66.00	58.00	74.00	Jensen et al 1969
8	Wadden Sea,Netherlan	64	U	U	W	3	16.40	9.60	27.40	Koeman and Genderen 1966
8	Wadden Sea, Dutch	71	A	U	W	5	9.50	6.50	17.30	Koeman et al 1972
8	W Coast of Sweeden	75	U	U	L	11	84.00			Olsson 1978
8	West coast,Sweden	71	T	B	L	6	46.00	12.00	82.00	Olsson et al 1975
8	Baltic, Sweden	71	T	B	L	3	1063.00[c]	340.00	1900.00	Olsson et al 1975
8	Wadden Sea,Ger & Dan	75	S	U	W	8	16.90	4.00	47.10	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	6	8.50	3.70	15.20	Reijnders 1980
8	Wadden Sea, Neth	75	S	U	W	6	29.80	3.30	127.00	Reijnders 1980
8	Wadden Sea, Neth	75	A	U	W	8	47.30	6.60	178.00	Reijnders 1980
Zalophus californianus										
1	Oregon coast	71	A	U	W	6	253.00[d]			Buhler et al 1975
1	Oregon coast	73	A	M	W	3	342.00[d]			Buhler et al 1975
1	SanMiguel Is, CA	70	S	F	W	6[b]	824.40	626.00	1039.00	DeLong et al 1973
1	SanMiguel Is,CA	70	A	F	W	4	103.20	51.00	203.00	DeLong et al 1973
1	San Miguel Is, CA	72	S	F	W	8[b]	651.00	365.00	974.00	Gilmartin et al 1976
1	San Miguel Is, CA	72	A	F	W	10	87.60	18.50	351.00	Gilmartin et al 1976
1	California coast	70	U	U	W	25	911.00	41.00	2678.00	LeBoeuf and Bonnell 1971

See Table Explanations for footnote descriptions.

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Table 35. HCB concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca groenlandicus										
3	Gulf of St. Lawrence	73	N	B	W	20	0.07	0.02	0.13	Rosewell et al 1979
Phoca vitulina										
8	Wadden Sea, Dutch	71	M	U	W	3	0.06	0.04	0.09	Koeman et al 1972
8	Wadden Sea, Dutch	71	A	U	W	5		0.00	0.46	Koeman et al 1972

See Table Explanations for footnote descriptions.

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Table 36. Dieldrin concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	69	N	B	W	5	0.04	0.00	0.08	Anas and Wilson 1970b
1	Pribilof Is	80	S	M	W	1	0.31			Calambokidis and Peard 1983
1	Pribilof Is	72	L	F	W	2	0.12	0.07	0.16	Kurtz and Kim 1976
1	Pribilof Is	72	N	U	W	2	0.06	0.00	0.12	Kurtz and Kim 1976
Cystophora cristata										
3	Gulf of St Lawr, Can		U	U	W	1	0.09			Holden 1972
Halichoerus grypus										
3	Gulf of St Lawr, Can		U	U	W	7	0.20	0.08	0.49	Holden 1972
3	Magdalen Is,Can	67	M	U	W	2[a]	0.03	0.02	0.04	Holden and Marsden 1967
3	Cabot Straits, Can	67	M	U	W	6[a]	0.07	0.03	0.10	Holden and Marsden 1967
4	Farne Is England	72	T	B	L	19	0.38	0.12	1.30	Donkin et al 1981
4	Farne Is England	72	P	F	L	5	0.31	0.17	0.41	Donkin et al 1981
4	Outer Hebrides,Eng	71	U	U	W	6	0.16			Heppleston 1973
4	Shetland, Eng	71	U	U	W	8	0.14			Heppleston 1973
4	Farne Is, N Sea	71	U	U	W	7	0.24			Heppleston 1973
4	East Anglia, N Sea	71	U	U	W	4	0.46			Heppleston 1973
4	Orkney, N Scotland		M	B	W	8	0.18	0.06	0.31	Holden 1972
4	Hebrides, W Scotland		M	B	W	3	0.29	0.24	0.32	Holden 1972
4	Summer Is, Scotland		M	B	W	4	0.38	0.07	1.10	Holden 1972
4	Aberdeen, E Scotland	68	M	B	W	16	0.83	0.46	1.70	Holden 1972
4	Farne Is, E England		N	B	W	5	0.46	0.20	0.59	Holden 1972
4	Scroby, E England		M	B	W	2	2.30	1.80	2.80	Holden 1972
4	Wales/England		M	B	W	3	0.58	0.20	1.20	Holden 1972
4	Cornwall, England		N	B	W	3	0.25	0.08	0.44	Holden 1972
4	SW England		N	U	L		1.90			Holden 1972
4	NE England		N	U	L		0.60			Holden 1972
4	E Scotland, N Sea	66	A	U	W	18[a]	0.79	0.15	2.10	Holden and Marsden 1967
4	N and W Scotland	66	A	U	W	6[a]	0.20	0.08	0.39	Holden and Marsden 1967
4	NW Scotland	66	N	U	W	9[a]	0.18	0.06	0.44	Holden and Marsden 1967
Phoca groenlandicus										
3	Gulf of St Lawrence	71	S	B	W	6	0.13	0.10	0.30	Addison et al 1973

See Table Explanations for footnote descriptions.

Table 36. Dieldrin concentrations (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
3	Gulf of St Lawrence	71	A	B	W	7	0.20	0.10	0.30	Addison et al 1973
3	Gulf of St Lawrence	73	L	F	W	1	0.15			Jones et al 1976
3	Gulf of St Lawrence	73	N	U	W	15	0.05			Jones et al 1976
3	Gulf of St. Lawrence	71	A	B	W	11	0.08	0.01	0.32	Rosewell et al 1979
3	Gulf of St. Lawrence	73	N	B	W	20	0.09	0.07	0.18	Rosewell et al 1979
	Phoca hispida									
4	North Sea	76	S	F	W	1	0.24			Harms et al 1978
5	Canadian Arctic		U	U	W	3	0.13	0.09	0.18	Holden 1972
5	Arctic (Norway)		U	U	W	2	0.18	0.15	0.20	Holden 1972
8	Baltic (N Sweden)		U	U	W	1	0.14			Holden 1972
	Phoca vitulina									
3	Gulf of Maine	71	U	B	W	5	0.23	0.06	0.38	Gaskin et al 1973
3	New Brunswick	71	U	M	W	3	0.58	0.27	1.16	Gaskin et al 1973
3	New Brunswick	71	L	F	W	1	0.04			Gaskin et al 1973
4	German N Sea coast	75	T	U	W	56	0.24	0.04	0.90	Drescher et al 1977
4	Shetland, Scotland		N	B	W	4	0.06	0.06	0.07	Holden 1972
4	Mull, W Scotland	69	M	B	W	17	0.14	0.07	0.25	Holden 1972
4	Clyde, W Shetland		M	B	W	3[a]	1.30	1.20	1.50	Holden 1972
4	Wash, E England		N	U	W	12	0.33	0.16	0.66	Holden 1972
4	W. Scotland		A	U	W	8	0.37			Holden 1978
4	North Sea, E of Scot	78	S	B	L	3	0.36	0.10	0.71	Kerkhoff et al 1981
8	Dutch Wadden Sea	78	M	M	W	7	0.42	0.00	1.40	Duinker et al 1979
8	Wadden Sea,Netherlan	64	U	U	W	3	1.33	0.30	2.30	Koeman and Genderen 1966
8	Wadden Sea, Dutch	71	A	U	W	5	0.09	0.00	0.09	Koeman et al 1972
8	Wadden Sea, Dutch	71	M	U	W	3	0.05	0.00	0.05	Koeman et al 1972
8	Wadden Sea,Ger & Dan	75	S	U	W	8	0.20	0.00	0.20	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	6	0.00			Reijnders 1980
8	Wadden Sea, Neth	75	S	U	W	6	0.50	0.00	0.90	Reijnders 1980
8	Wadden Sea, Neth	75	A	U	W	8	0.40	0.00	0.40	Reijnders 1980

See Table Explanations for footnote descriptions.

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Table 37. Heptachlor epoxide conc. (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	80	S	M	W	1	0.11			Calambokidis and Peard 1983
Cystophora cristata										
5	W coast Greenland	72	U	U	W	5	0.04	0.00	0.07	Clausen et al 1974
Erignathus barbatus										
5	W coast Greenland	72	U	U	W	5	0.03	0.00	0.12	Clausen et al 1974
Phoca hispida										
5	W coast Greenland	72	U	U	W	5	0.02	0.00	0.05	Clausen et al 1974
Phoca vitulina										
4	North Sea, E of Scot	78	S	B	L	3	1.15	0.68	1.70	Kerkhoff et al 1981

See Table Explanations for footnote descriptions.

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Table 38. Conc. of HCH compounds (ppm) reported in blubber of pinnipeds. See Table Explanation for description.

Concentrations reported as total HCH:

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
8	Dutch Wadden Sea	78	M	M	W	7	0.49	0.12	1.09	Duinker et al 1979
8	Wadden Sea,Ger & Dan	75	S	U	W	8	0.80	0.20	2.80	Reijnders 1980

Concentrations reported as a-HCH

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
8	Wadden Sea,Ger & Dan	75	A	U	W	6	0.20	0.10	0.30	Reijnders 1980
8	Wadden Sea, Neth	75	S	U	W	6	0.30	0.00	0.60	Reijnders 1980
8	Wadden Sea, Neth	75	A	U	W	8	0.40	0.00	0.70	Reijnders 1980

Concentrations reported as Lindane

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Cystophora cristata										
5	W coast Greenland	72	U	U	W	5	0.00	0.00	0.01	Clausen et al 1974
Erignathus barbatus										
5	W coast Greenland	72	U	U	W	5	0.16	0.00	0.64	Clausen et al 1974
Phoca hispida										
4	North Sea	76	S	F	W	1	0.24			Harms et al 1978
5	W coast Greenland	72	U	U	W	5	0.00	0.00	0.02	Clausen et al 1974
Phoca vitulina										
4	German N Sea coast	75	T	U	W	56	0.32	0.04	0.98	Drescher et al 1977

See Table Explanations for footnote descriptions.

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Table 39. Chlordane compound conc.(ppm) reported in blubber of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N		LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	80	S	M	W	1	0.15			Calambokidis and Peard 1983
Halichoerus grypus										
8	Baltic, Sweden	75	A	U	L	5	10.00			Jansson et al 1979
Phoca vitulina										
4	Coast Netherlands	79	U	U	L	1	2.70			Kerkhoff and de Boer 1982
4	Coast Netherlands	79	U	U	L	1	3.00			Kerkhoff and de Boer 1982

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Table 40. PCB conc. (ppm) reported in blubber of harbor porpoise. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
1	So. Calif. coast	75	S	F	W	1	84.00			OShea et al 1980
3	Rhode Is	73	A	F	W	1	74.00			Taruski et al 1975
4	Coast of France	77	F	U	D	1	1.46			Alzieu and Duguy 1979
4	Coast of France	77	P	F	D	1	6.18			Alzieu and Duguy 1979
4	North Sea, Ger coast	76	U	F	W	1	15.20			Harms et al 1978
4	North Sea	70	U	U	W	7	88.00	35.00	148.00	Koeman et al 1972
5	W coast Greenland	72	U	U	W	2	6.65	1.90	11.40	Clausen et al 1974
8	Netherlands	78	F	U	L	1	59.00			Duinker and Hillebrand 1979
8	Baltic, German coast	76	U	B	W	2	114.00	88.60	140.00	Harms et al 1978
8	Baltic Sea	72	U	B	L	8	93.40	28.00	190.00	Otterlind 1976
8	West coast, Sweden	74	U	U	L	6	159.00	56.40	260.00	Otterlind 1976
8	East coast, Denmark	75	U	U	L	4	142.00	68.00	210.00	Otterlind 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 41. Total DDT[a] conc. (ppm) reported in blubber of harbor porpoise. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
1	So. Calif. coast	75	S	F	W	1	335.00			OShea et al 1980
3	Canada Atlantic	70	A	M	W	12	306.74	150.80	520.00	Gaskin et al 1971
3	Canada Atlantic	70	N	M	W	2	130.90	75.10	186.70	Gaskin et al 1971
3	Canada Atlantic	70	N	F	W	1	154.80			Gaskin et al 1971
3	Canada Atlantic	70	A	F	W	15	214.27	111.60	447.90	Gaskin et al 1971
3	Canada Atlantic	70	L	F	W	6	69.03	40.00	122.00	Gaskin et al 1971
3	Rhode Is	73	A	F	W	1	57.50			Taruski et al 1975
4	Coast of France	77	F	U	D	1	0.37			Alzieu and Duguy 1979
4	Coast of France	77	P	F	D	1	1.66			Alzieu and Duguy 1979
4	North Sea, Ger coast	76	U	F	W	1	2.40			Harms et al 1978
4	Orkney,N Scotland	67	A	U	W	1	3.90			Holden and Marsden 1967
4	East Scotland, N Sea	66	A	U	W	3	43.00	27.90	55.30	Holden and Marsden 1967
4	North Sea	70	U	U	W	7	41.20	11.10	102.00	Koeman et al 1972
8	Netherlands	78	F	U	L	1	6.68			Duinker and Hillebrand 1979
8	Baltic, German coast	76	U	B	W	2	37.60	29.30	45.90	Harms et al 1978
8	Baltic Sea	72	U	B	L	8	171.00	30.00	289.00	Otterlind 1976
8	West coast, Sweden	74	U	U	L	6	160.00	24.80	560.00	Otterlind 1976
8	East coast, Denmark	75	U	U	L	4	8.10	2.20	12.00	Otterlind 1976

See Table Explanations for footnote descriptions.

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Table 42. Mercury residues in the liver of harbor seals collected in Washington State. From Anas (1974b)

Location	Date collected	Sex	Total Hg (ug/g wet wt)
Puget Sound, WA	24 Nov 70	M	60.
Puget Sound, WA	21 June 71	M	12.
Outer Coast, WA	2 Sept 71	F	1.3

Table 43. Mercury and methylmercury residues in tissues of harbor seals from Grays Harbor, WA, (Outer Coast). From Northrup (1981). Samples collected 1976 - 1978.

Location	Tissue	N	Total mercury (ug/g wet wt) Range	Methylmercury (ug/g wet wt) Range
Grays Harbor, WA	Liver	41	0.08-89.3	0.01-.027
Grays Harbor, WA	Kidney	39	0.4 -1.2	0.01-0.16
Grays Harbor, WA	Muscle	38	0.06-0.24	0.2 -0.21

Table 44. Hg concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Pribilof Is	70	N	U	W	10	0.20	0.05	0.35	Anas 1973
1	Pribilof Is	70	S	M	W	29	10.80	3.00	19.00	Anas 1973
1	Washington coast	70	A	F	W	29	67.20	19.00	172.00	Anas 1973
1	Pribilof Is	70	N	B	W	10		0.10	0.30	Anas 1974b
1	Pribilof Is	70	S	M	W	29		3.00	19.00	Anas 1974b
1	Washington coast	70	A	F	W	29		19.00	172.00	Anas 1974b
1	Washington coast	71	M	M	W	2		0.40	3.70	Anas 1974b
1	Washington coast	71	M	F	W	8		7.10	132.00	Anas 1974b
Cystophora cristata										
3	E Canada	71	A	M	W	3	37.20	27.20	45.20	Sergeant and Armstrong 1973
Erignathus barbatus										
5	Holman, NWT	73	T	B	W	6	143.00	0.00	420.00	Smith and Armstrong 1975
5	W. Victoria Is	73	A	U	W	6	143.00			Smith and Armstrong 1978
5	E. Hudson Bay	74	S	U	W	56	26.18			Smith and Armstrong 1978
5	Barrow strait	76	a	U	W	1	79.20			Smith and Armstrong 1978
5	Barrow strait	76	S	U	W	1	9.42			Smith and Armstrong 1978
Halichoerus grypus										
3	Nova Scotia	72	A	M	N	2	28.00	26.00	30.00	Freeman and Horne 1973
3	E Canada	71	M	B	W	11	88.20	0.46	387.00	Sergeant and Armstrong 1973
4	North Sea	76	S	M	W	1	19.50			Harms et al 1978
4	Farne Is, Britain	72	T	U	W	7	84.20			Heppleston and French 1973
4	Outer Hebrides	72	T	U	W	6	113.00			Heppleston and French 1973
4	Shetland, Britain	72	T	U	W	8	4.90			Heppleston and French 1973
4	Tay Region UK,N Sea	71	U	F	W	1	66.00			Jones et al 1972
5	Nova Scotia	72	N	M	N	2	3.45	2.80	4.10	Freeman and Horne 1973
5	Nova Scotia	72	S	M	N	2	10.50	10.00	11.00	Freeman and Horne 1973
Phoca groenlandicus										
3	Gulf of St Lawrence	73	N	B	W	16	0.25	0.09	0.45	Jones et al 1976
3	E Canada	71	M	B	W	20	3.69	0.84	10.00	Sergeant and Armstrong 1973

See Table Explanations for footnote descriptions.

Table 44. Hg concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca hispida										
4	North Sea	76	S	F	W	1	0.64			Harms et al 1978
5	Holman Is, N.W.T.	78	U	U	W	119	26.20	5.20	87.50	Eaton et al 1980
5	Holman, NWT	72	T	B	W	80	27.50			Smith and Armstrong 1975
5	Aston Bay,Somerset I	75	U	U	W	88	19.33			Smith and Armstrong 1978
5	Barrow Strait	76	A	U	W	27	16.14			Smith and Armstrong 1978
5	N. Baffin Is	76	N	U	W	36	0.32			Smith and Armstrong 1978
5	N.E. Baffin Is	76	A	U	W	33	3.76			Smith and Armstrong 1978
5	S.E. Beaufort Sea	72	S	U	W	13	1.00			Smith and Armstrong 1978
5	W. Victoria Is	73	A	U	W	83	27.50			Smith and Armstrong 1978
5	W. Victoria Is	77	A	U	W	112	25.54			Smith and Armstrong 1978
8	Bothnian Bay	74	U	U	W	12	91.00	14.00	300.00	Kari and Kauranen 1978
8	Saimaa Lake, Finland	74	U	U	W	3	230.00	72.00	510.00	Kari and Kauranen 1978
Phoca vitulina										
1	San Miguel, CA	71	U	B	W	4	269.00	81.00	700.00	Anas 1974b
1	Columbia River, OR	71	U	B	W	3	23.80	0.30	68.00	Anas 1974b
1	Washington coast	71	U	F	W	1	1.30			Anas 1974b
1	Puget Sound WA	71	U	M	W	2	36.00	12.00	60.00	Anas 1974b
1	San Francisco Bay,CA	75	A	U	D	2	82.00[g]	75.00	90.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	5.80[g]	2.40	8.50	Risebrough 1978
1	California coast	75	N	U	D	7		5.90	31.00	Risebrough 1978
3	Gulf of Maine	71	U	B	W	6	3.10	0.52	7.90	Gaskin et al 1973
3	New Brunswick	71	U	M	W	3	6.00	1.72	13.10	Gaskin et al 1973
3	New Brunswick	71	L	F	W	1	50.90			Gaskin et al 1973
3	E Canada	71	M	B	W	8	8.18	2.14	21.70	Sergeant and Armstrong 1973
4	E. Anglia, Britain	72	T	U	W	15[a]	29.90			Heppleston and French 1973
4	W Scotland, Britain	72	T	U	W	9	30.10			Heppleston and French 1973
4	West Scotland	70	U	U	W	6		0.05	113.00	Roberts et al 1976
4	East Anglia	70	U	U	W	7		1.50	106.00	Roberts et al 1976
4	Dutch coast	74	N	B	W	2	5.50	1.30	9.70	van de Ven et al 1979
4	Dutch coast	74	S	B	W	3	61.00	46.00	74.00	van de Ven et al 1979

See Table Explanations for footnote descriptions.

Table 44. Hg concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
4	Dutch coast	74	A	B	W	2	189.00	66.00	312.00	van de Ven et al 1979
8	Wadden Sea,Ger & Dan	75	S	U	W	6	10.20	1.10	27.30	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	5	214.00	13.60	751.00	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	8.40	0.90	23.00	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	8	293.00	58.60	573.00	Reijnders 1980
Unknown										
5	N. Quebec	79	U	U	W	1	5.26			Cappon and Smith 1981
Zalophus californianus										
1	Oregon coast	71	A	U	W	5	74.10			Buhler et al 1975
1	Oregon coast	73	A	M	W	3	95.70			Buhler et al 1975
1	S. California	72	A	F	D	10[b]	204.00	73.00	355.00	Martin et al 1976
1	S. California	72	A	F	D	10	747.00	284.00	1026.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	1.79	0.91	3.19	Martin et al 1976
1	S. California	72	N	U	D	10	9.56	2.28	15.95	Martin et al 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 45. Hg concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Washington coast	71	N	M	W	2		0.20	0.70	Anas 1974b
1	Washington coast	71	M	F	W	8		0.60	1.60	Anas 1974b
Halichoerus grypus										
3	Nova Scotia	72	N	M	N	2	1.50			Freeman and Horne 1973
3	Nova Scotia	72	S	M	N	2	2.90	2.80	3.00	Freeman and Horne 1973
3	Nova Scotia	72	A	M	N	2	5.35	5.00	5.70	Freeman and Horne 1973
3	E Canada	71	M	B	W	1	3.04			Sergeant and Armstrong 1973
4	Tay Region UK,N Sea	71	U	F	W	1	4.83			Jones et al 1972
Phoca groenlandicus										
3	Gulf of St Lawrence	73	N	B	W	12	0.12	0.00	0.34	Jones et al 1976
Phoca hispida										
8	Bothnian Bay	74	U	U	W	2	4.00	2.80	5.20	Kari and Kauranen 1978
8	Saimaa Lake, Finland	74	U	U	W	3	7.40	1.90	13.00	Kari and Kauranen 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	28.00[g]	15.00	54.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	3.80[g]	1.90	6.80	Risebrough 1978
1	California coast	75	N	U	D	8		4.60	26.00	Risebrough 1978
4	E. Anglia, Britain	72	U	U	W	2	13.70			Heppleston and French 1973
4	West Scotland	70	U	U	W	6		0.40	3.50	Roberts et al 1976
4	East Anglia	70	U	U	W	9		0.20	4.70	Roberts et al 1976
4	Dutch coast	74	N	B	W	2	4.30	1.10	7.40	van de Ven et al 1979
4	Dutch coast	74	S	B	W	2	5.80	4.70	6.80	van de Ven et al 1979
4	Dutch coast	74	A	B	W	2	16.20	10.60	21.80	van de Ven et al 1979
8	Wadden Sea,Ger & Dan	75	S	U	W	6	4.30	1.60	8.30	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	4	7.50	2.20	17.90	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	3.30	0.70	3.20	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	4	17.00	5.40	28.20	Reijnders 1980
Zalophus californianus										
1	Oregon coast	71	A	U	W	5	6.96			Buhler et al 1975

See Table Explanations for footnote descriptions.

Table 45. Hg concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
1	Oregon coast	73	A	M	W	3	5.43			Buhler et al 1975
1	S. California	72	A	F	D	9[b]	7.06	4.13	15.71	Martin et al 1976
1	S. California	72	A	F	D	10	28.40	12.05	43.15	Martin et al 1976
1	S. California	72	N	U	D	9[b]	0.89	0.56	1.25	Martin et al 1976
1	S. California	72	N	U	D	10	4.62	1.56	6.69	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 46. Ag concentrations (ppm) reported in kidney and liver of pinnipeds.
See Table Explanations for descriptions of entries

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
					KIDNEY					
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	0.00			Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6		0.00	0.30	Risebrough 1978
1	California coast	75	N	U	D	8	0.00			Risebrough 1978
					LIVER					
Leptonychotes weddelli										
6	Antarctic		U	U	D	1	1.50			Denton et al unpublished
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	1.10[g]	1.00	1.10	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.30[g]	0.10	0.80	Risebrough 1978
1	California coast	75	N	U	D	7		0.00	0.80	Risebrough 1978
Zalophus californianus										
1	S. California	72	A	F	D	10[b]	0.40	0.10	1.20	Martin et al 1976
1	S. California	72	A	F	D	10	0.50	0.10	0.90	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 47. Cd concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Washington coast	71	T	B	W	10	1.70	0.50	4.60	Anas 1974b
Eumetopias jubata										
2	Coast of Japan	77	T	B	D	20	2.59	0.52	4.72	Hamanaka et al 1982
Halichoerus grypus										
4	North Sea	76	S	M	W	1	0.02			Harms et al 1978
Histriophoca fasciata										
2	Okhotsk Sea,W Pac	75	M	B	D	2	9.27	7.47	11.00	Hamanaka et al 1977
Leptonychotes weddelli										
6	Antarctic	0	U	U	D	1	2.30			Denton et al unpublished
Phoca hispida										
4	North Sea	76	S	F	W	1	0.31			Harms et al 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	3.10[g]	2.30	4.10	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6		0.00	0.60	Risebrough 1978
1	California coast	75	N	U	D	7		0.00	1.60	Risebrough 1978
2	Okhotsk Sea,W Pac	75	A	F	D	1	1.89			Hamanaka et al 1977
4	West Scotland	70	U	U	W	6		0.20	1.10	Roberts et al 1976
4	East Anglia	70	U	U	W	7		0.20	0.80	Roberts et al 1976
8	Dutch Wadden Sea	78	M	M	W	8		0.03	0.21	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	0.00			Duinker et al 1979
Zalophus californianus										
1	Oregon coast	73	A	M	W	3	1.61			Buhler et al 1975
1	Oregon coast	71	A	U	W	4	2.29			Buhler et al 1975
1	S. California	72	A	F	D	10	10.00	4.30	15.30	Martin et al 1976
1	S. California	72	A	F	D	10[b]	15.10	5.70	90.00	Martin et al 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 48. Cd concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Washington coast	71	T	B	W	10	5.20	0.10	15.60	Anas 1974b
Eumetopias jubata										
2	Coast of Japan	77	T	B	D	21	20.90	3.86	50.20	Hamanaka et al 1982
Halichoerus grypus										
4	Farne Is, Britain	72	T	U	W	5	5.30			Heppleston and French 1973
4	Outer Hebrides	72	T	U	W	4	11.60			Heppleston and French 1973
4	Shetland, Britain	72	T	U	W	8	2.20			Heppleston and French 1973
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	16.50[g]	13.20	20.60	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	8		0.00	7.60	Risebrough 1978
4	West Scotland	70	U	U	W	8		0.10	1.90	Roberts et al 1976
4	East Anglia	70	U	U	W	9		0.10	0.60	Roberts et al 1976
8	Dutch Wadden Sea	78	M	M	W	2	0.16	0.15	0.17	Duinker et al 1979
Zalophus californianus										
1	Oregon coast	73	A	M	W	3	7.22			Buhler et al 1975
1	Oregon coast	71	A	U	W	5	12.00			Buhler et al 1975
1	S. California	72	A	F	D	9[b]	97.00	68.00	155.00	Martin et al 1976
1	S. California	72	A	F	D	10	115.00	85.00	569.00	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 49. Cu concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Halichoerus grypus										
4	North Sea	76	S	M	W	1	20.90			Harms et al 1978
Leptonychotes weddelli										
6	Antarctic	0	U	U	D	1	17.00			Denton et al unpublished
Phoca hispida										
4	North Sea	76	S	F	W	1	2.10			Harms et al 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	N	U	D	6	109.00[g]	29.00	330.00	Risebrough 1978
1	California coast	75	N	U	D	7		31.00	226.00	Risebrough 1978
8	North Germ Waddensea	75	T	U	W	58	7.20	2.60	17.00	Drescher et al. 1977
8	Dutch Wadden Sea	78	M	M	W	8	11.00	2.00	20.00	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	49.00			Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	10[b]	135.00	112.00	206.00	Martin et al 1976
1	S. California	72	A	F	D	10	86.00	61.00	285.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	194.00	57.00	386.00	Martin et al 1976
1	S. California	72	N	U	D	10	146.00	83.00	241.00	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 50. Cu concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	21.00[g]	20.00	22.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	16.80[g]	8.50	26.00	Risebrough 1978
1	California coast	75	N	U	D	8		13.00	48.00	Risebrough 1978
8	North Germ Waddensea	75	T	U	W	16	3.00	2.30	4.00	Drescher et al. 1977
8	Dutch Wadden Sea	78	M	M	W	2	4.95	4.80	5.10	Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	29.30	23.10	36.30	Martin et al 1976
1	S. California	72	A	F	D	10	22.40	21.20	52.30	Martin et al 1976
1	S. California	72	N	U	D	9[b]	19.00	14.50	31.10	Martin et al 1976
1	S. California	72	N	U	D	10	28.40	21.50	33.50	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 51. Cr concentrations (ppm) reported in kidney and liver of pinnipeds.
See Table Explanations for descriptions of entries

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
	KIDNEY									
	Phoca vitulina									
1	San Francisco Bay,CA	75	A	U	D	2	0.00			Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	8	0.00			Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	2	0.37	0.15	0.59	Duinker et al 1979
	LIVER									
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	7	0.00			Risebrough 1978
1	San Francisco Bay	75	A	U	D	2	6.50[g]	5.40	7.90	Risebrough 1978

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 52. Mn concentrations (ppm) reported in kidney and liver of pinnipeds.
See Table Explanations for descriptions of entries

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
	KIDNEY									
	Phoca vitulina									
1	San Francisco Bay,CA	75	A	U	D	2	1.50[g]	1.40	1.60	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	2	2.60[g]	2.00	3.10	Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	2	2.65	1.90	3.40	Duinker et al 1979
	Zalophus californianus									
1	S. California	72	A	F	D	9[b]	4.50	3.60	5.80	Martin et al 1976
1	S. California	72	A	F	D	10	4.70	4.10	5.60	Martin et al 1976
1	S. California	72	N	U	D	9[b]	2.70	2.30	3.60	Martin et al 1976
1	S. California	72	N	U	D	10	2.90	1.50	3.60	Martin et al 1976
	LIVER									
	Leptonychotes weddelli									
6	Antarctic	0	U	U	D	1	6.80			Denton et al unpublished
	Phoca vitulina									
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	2	7.90	6.10	10.10	Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	8		2.00	6.00	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	0.70			Duinker et al 1979
	Zalophus californianus									
1	S. California	72	A	F	D	10[b]	15.70	10.30	21.00	Martin et al 1976
1	S. California	72	A	F	D	10	19.20	14.70	24.40	Martin et al 1976
1	S. California	72	N	U	D	9[b]	9.20	3.20	13.30	Martin et al 1976
1	S. California	72	N	U	D	10	12.20	8.90	16.10	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/85

Table 53. Zn concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Eumetopias jubata										
2	Coast of Japan	77	T	B	D	17	135.00	102.00	247.00	Hamanaka et al 1982
Halichoerus grypus										
4	North Sea	76	S	M	W	1	61.00			Harms et al 1978
Histriophoca fasciata										
2	Okhotsk Sea,W Pac	75	M	B	D	2	187.00	111.00	264.00	Hamanaka et al 1977
Leptonychotes weddelli										
6	Antarctic		U	U	D	1	335.00			Denton et al unpublished
Phoca hispida										
4	North Sea	76	S	F	W	1	40.00			Harms et al 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	145.00[g]	140.00	150.00	Risebrough 1978
1	San Francisco Bay,CA	75	M	U	D	6	249.00[g]	137.00	517.00	Risebrough 1978
1	California coast	75	M	U	D	7		79.00	439.00	Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	8		16.00	64.00	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	89.00			Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	10[b]	201.00	167.00	258.00	Martin et al 1976
1	S. California	72	A	F	D	10	220.00	166.00	346.00	Martin et al 1976
1	S. California	72	M	U	D	9[b]	425.00	158.00	985.00	Martin et al 1976
1	S. California	72	M	U	D	10	505.00	316.00	610.00	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 54. Zn concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Eumetopias jubata										
2	Coast of Japan	77	T	B	D	17	135.00	99.00	202.00	Hamanaka et al 1982
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	167.00[g]	164.00	170.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	187.00[g]	99.00	460.00	Risebrough 1978
1	California coast	75	N	U	D	8		105.00	333.00	Risebrough 1978
8	North Germ Waddensea	75	T	U	W	16	22.50	16.30	32.50	Drescher et al. 1977
8	Dutch Wadden Sea	78	M	M	W	2	20.00	15.00	25.00	Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	149.00	129.00	195.00	Martin et al 1976
1	S. California	72	A	F	D	10	173.00	146.00	353.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	103.50	77.60	134.60	Martin et al 1976
1	S. California	72	N	U	D	10	117.00	97.30	144.30	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 55. Pb concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Washington coast	71	T	B	W	10	0.57	0.20	0.80	Anas 1974b
Halichoerus grypus										
4	North Sea	76	S	M	W	1	0.31			Harms et al 1978
Leptonychotes weddelli										
6	Antarctic		U	U	D	1	0.00			Denton et al unpublished
Phoca hispida										
4	North Sea	76	S	F	W	1	0.24			Harms et al 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	7	0.00			Risebrough 1978
4	Britain	70	U	U	W	15	2.31			Roberts et al 1976
8	Dutch Wadden Sea	78	M	M	W	8		0.00	2.30	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	0.00			Duinker et al 1979
Zalophus californianus										
1	California coast	71	S	B	D	6	1.30	0.20	3.00	Braham 1973

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 56. Pb concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Callorhinus ursinus										
1	Washington coast	71	T	B	W	10	0.93	0.30	1.80	Anas 1974b
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	0.00			Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.00			Risebrough 1978
1	California coast	75	N	U	D	8	0.00			Risebrough 1978
4	Britain	70	U	U	W	17	1.17			Roberts et al 1976
8	Dutch Wadden Sea	78	M	M	W	2	0.19	0.16	0.23	Duinker et al 1979
Zalophus californianus										
1	California coast	71	S	B	D	6	2.00	0.00	5.10	Braham 1973

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 57. Se concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Erignathus barbatus										
5	Holman, NWT	73	T	B	W	6	34.00			Smith and Armstrong 1975
5	W. Victoria Is	73	A	U	W	6	34.42			Smith and Armstrong 1978
5	E. Hudson Bay	74	S	U	W	10	20.83			Smith and Armstrong 1978
Phoca hispida										
5	Holman Is, N.W.T.	78	U	U	W	119	15.10	5.10	42.30	Eaton et al 1980
5	Holman, NWT	73	T	B	W	40	15.52			Smith and Armstrong 1975
5	Aston Bay, Somerset I	75	U	U	W	12	16.35			Smith and Armstrong 1978
5	Barrow Strait	76	A	U	W	10	9.44			Smith and Armstrong 1978
5	N.E. Baffin Is	76	A	U	W	8	4.13			Smith and Armstrong 1978
5	W. Victoria Is	73	A	U	W	42	15.24			Smith and Armstrong 1978
5	W. Victoria Is	77	A	U	W	112	14.96			Smith and Armstrong 1978
8	Bothnian Bay	74	U	U	W	8	0.63	0.44	0.92	Kari and Kauranen 1978
8	Bothnian Bay	74	U	U	W	12	35.00	6.10	110.00	Kari and Kauranen 1978
8	Saimaa Lake, Finland	74	U	U	W	3	81.00	29.00	170.00	Kari and Kauranen 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	119.00[g]	118.00	120.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	5.80[g]	3.20	11.00	Risebrough 1978
1	California coast	75	N	U	D	7		4.30	14.00	Risebrough 1978
4	Dutch coast	74	N	B	W	2	3.00	2.00	4.00	van de Ven et al 1979
4	Dutch coast	74	S	B	W	3	20.00	13.00	29.00	van de Ven et al 1979
4	Dutch coast	74	A	B	W	2	76.00	22.00	130.00	van de Ven et al 1979
8	Wadden Sea,Ger & Dan	75	S	U	W	6	2.60	0.00	8.00	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	5	112.00	9.20	409.00	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	2.80	0.70	6.50	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	8	109.00	3.90	350.00	Reijnders 1980
Unknown										
5	N. Quebec	79	U	U	W	1	3.52			Cappon and Smith 1981
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	79.00	28.00	151.00	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 57. Se concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
1	S. California	72	A	F	D	10	260.00	92.00	352.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	2.90	2.10	3.70	Martin et al 1976
1	S. California	72	N	U	D	10	4.10	2.10	3.70	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 58. Se concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca hispida										
8	Bothnian Bay	74	U	U	W	2	2.90	2.50	3.30	Kari and Kauranen 1978
8	Saimaa Lake, Finland	74	U	U	W	3	2.00	0.34	3.00	Kari and Kauranen 1978
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	14.00[g]	9.00	22.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	7.10[g]	5.30	11.10	Risebrough 1978
1	California coast	75	N	U	D	8		3.40	12.00	Risebrough 1978
4	Dutch coast	74	N	B	W	2	1.80	1.20	2.30	van de Ven et al 1979
4	Dutch coast	74	S	B	W	2	2.00	1.90	2.10	van de Ven et al 1979
4	Dutch coast	74	A	F	W	1	7.10			van de Ven et al 1979
8	Wadden Sea,Ger & Dan	75	S	U	W	6	0.60	0.00	1.30	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	4	3.50	1.90	7.30	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	1.20	0.60	1.60	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	4	7.10	2.30	10.00	Reijnders 1980
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	12.10	8.40	16.90	Martin et al 1976
1	S. California	72	A	F	D	10	22.00	9.20	33.80	Martin et al 1976
1	S. California	72	N	U	D	9[b]	3.70	2.20	5.40	Martin et al 1976
1	S. California	72	N	U	D	10	6.10	3.80	8.40	Martin et al 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 59. Br concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	49.00[g]	44.00	54.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	72.00[g]	66.00	94.00	Risebrough 1978
1	California coast	75	N	U	D	7		46.00	119.00	Risebrough 1978
8	Wadden Sea,Ger & Dan	75	S	U	W	6	16.60	12.90	20.70	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	5	13.60	8.90	19.00	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	19.30	10.00	24.00	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	8	20.70	13.40	34.40	Reijnders 1980
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	38.00			Martin et al 1976
1	S. California	72	A	F	D	10	270.00	140.00	359.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	74.00	42.00	116.00	Martin et al 1976
1	S. California	72	N	U	D	10	53.00	39.00	79.00	Martin et al 1976

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 60. Br concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	74.00[g]	62.00	89.00	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	85.00[g]	71.00	91.00	Risebrough 1978
1	California coast	75	N	U	D	8		54.00	129.00	Risebrough 1978
8	Wadden Sea,Ger & Dan	75	S	U	W	6	18.50	12.40	28.60	Reijnders 1980
8	Wadden Sea,Ger & Dan	75	A	U	W	4	10.60	7.10	13.90	Reijnders 1980
8	Wadden Sea,Dutch	75	S	U	W	5	14.90	11.40	23.90	Reijnders 1980
8	Wadden Sea,Dutch	75	A	U	W	4	21.10	17.10	24.90	Reijnders 1980
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	98.00	71.00	105.00	Martin et al 1976
1	S. California	72	A	F	D	10	121.00	96.00	140.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	85.60	63.60	116.40	Martin et al 1976
1	S. California	72	N	U	D	10	96.70	76.00	113.90	Martin et al 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 61. Fe concentrations (ppm) reported in liver of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Leptonychotes weddelli										
6	Antarctic		U	U	D	1	4783.00			Denton et al unpublished
Phoca vitulina										
1	San Francisco Bay,CA	75	N	U	D	6	2600.00[g]	1170.00	8310.00	Risebrough 1978
1	California coast	75	N	U	D	7	2349.00[g]	910.00	4660.00	Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	8		28.00	600.00	Duinker et al 1979
8	Dutch Wadden Sea	78	F	U	W	1	510.00			Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	10[b]	1125.00	750.00	1910.00	Martin et al 1976
1	S. California	72	A	F	D	10	2000.00	730.00	5590.00	Martin et al 1976
1	S. California	72	N	U	D	9[b]	4540.00	860.00	8540.00	Martin et al 1976
1	S. California	72	N	U	D	10	3340.00	1210.00	9120.00	Martin et al 1976

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

Table 62. Fe concentrations (ppm) reported in kidney of pinnipeds. See Table Explanation for description.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	870.00[g]	755.00	1000.00	Risebrough 1978
1	San Francisco Bay,CA	75	M	U	D	6	1000.00[g]	790.00	1420.00	Risebrough 1978
1	California coast	75	M	U	D	8		454.00	1060.00	Risebrough 1978
8	Dutch Wadden Sea	78	M	M	W	2		31.00	66.00	Duinker et al 1979
Zalophus californianus										
1	S. California	72	A	F	D	9[b]	446.00	330.00	593.00	Martin et al 1976
1	S. California	72	A	F	D	10	448.00	349.00	618.00	Martin et al 1976
1	S. California	72	M	U	D	9[b]	413.00	240.00	629.00	Martin et al 1976
1	S. California	72	M	U	D	10	280.00	206.00	385.00	Martin et al 1976

See Table Explanations for footnote descriptions.

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Table 63. As concentrations (ppm) reported in kidney and liver of pinnipeds.
See Table Explanations for descriptions of entries

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
					KIDNEY					
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2		0.00	1.50	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.90[g]	0.40	1.20	Risebrough 1978
1	California coast	75	N	U	D	8		0.60	2.00	Risebrough 1978
					LIVER					
1	San Francisco Bay,CA	75	A	U	D	2	1.50[g]	1.00	2.10	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	0.80[g]	0.30	1.40	Risebrough 1978
1	California coast	75	N	U	D	7		0.40	2.10	Risebrough 1978

See Table Explanations for footnote descriptions.

Cascadia Research, 10/15/83

Table 64. Rb concentrations (ppm) reported in kidney and liver of pinnipeds.
See Table Explanations for descriptions of entries.

LOC	SPEC. LOCATION	YR	AGE	SEX	W	N	MEAN	LOW	HIGH	REFERENCE
							KIDNEY			
Phoca vitulina										
1	San Francisco Bay,CA	75	A	U	D	2	4.40[g]	3.60	5.40	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	3.60[g]	1.30	5.50	Risebrough 1978
1	California coast	75	N	U	D	8		1.40	9.50	Risebrough 1978
							LIVER			
1	San Francisco Bay,CA	75	A	U	D	2	5.90[g]	5.20	6.60	Risebrough 1978
1	San Francisco Bay,CA	75	N	U	D	6	2.70[g]	1.40	4.50	Risebrough 1978
1	California coast	75	N	U	D	7		2.50	6.10	Risebrough 1978

See Table Explanations for footnote descriptions. Cascadia Research, 10/15/83

APPENDIX A

Marine Mammal Tissues in Storage

Three major repositories of tissues of Washington marine mammals were identified. Tables A-1 to A-6 list or summarize the tissues stored at these three locations.

In storage at The Evergreen State College (TESC) in Olympia are samples of blubber and other tissues from approximately 100 marine mammals, mostly harbor seals. Tissues at Evergreen include samples collected by Steve Jeffries (Table A-1), those collected by TESC students through 1979 (Table A-2) and samples collected by T.C. Newby in the early 1970's (Table A-3). Almost all the blubber samples in this collection have been analyzed for PCB and DDE.

Samples in storage at the National Marine Mammal Lab in Seattle consist of tissues from approximately 112 animals, most (110) are harbor seals collected by Steve Jeffries and Murray Johnson of the University of Puget Sound or people working with them (Table A-4). A large portion of the tissues are from harbor seals collected at Grays Harbor. A majority of these samples have been analyzed for residues of PCB and DDE at TESC or by Risebrough (1978).

The third major repository of samples is with the Marine Mammal Investigations unit of the Washington State Game Department in Astoria, Oregon. This group has 56 tissue sets from 11 species that are suitable for environmental contaminant analysis. The majority of the samples taken for contaminant analysis are from harbor seals stranded in the Columbia River and adjacent waters in Washington or Oregon between 1980 and Aug. 1982 (Table A-5). Table A-6 lists a variety of samples that were taken from cetaceans. Samples in Table A-5 and A-6 have not been analyzed for pollutants.

In addition to these sources, several other individuals and groups occasionally collect and store marine mammal tissues. Groups that have collected marine mammal tissues in the past include the Burke Museum at the University of Washington, the Whale Museum at Friday Harbor, Dr. Tag Gornal of the Marine Animal Resource Center, and the Seattle Aquarium.

Serious deficiencies exist in the condition of many archived samples. Sampling techniques varied between research groups and proper procedures were not always followed. Sample labels are sometimes unclear and not traceable to field records. Many of the older samples (pre-1980) are in poor condition; some aluminum foil wrappers are almost completely corroded.

Sample collection could be improved with a number of changes. We recommend the following: (1) Preparation of an instruction manual of sampling protocol to be distributed to researchers potentially involved in collecting tissues, (2) development of a standardized data record for tissues taken and (3) a sampling kit that includes appropriate solvents, instruments, and glass storage vials.

Table A-1. Marine mammal sample inventory -- The Evergreen State College, Olympia, WA. Rm. 044. 6 Dec 1982. Harbor seal tissue samples collected by Steve Jeffries. All in aluminum foil. Most are subsamples.

Sample no.	Date	Location	Blubber
SJJ 7	17 Jul 75	Vaughn Bay	x
SJJ 19	30 Sep 75	Gertrude Is	x
SJJ 24	17 Jan 76	Dungeness	x
SJJ 27	24 Feb 76	Gertrude	x
SJJ 42	9 May 76	Grays Harbor	x
SJJ 43	16 May 76	Gertrude Is	x
SJJ 51	- Aug 76	Gertrude Is	x
SJJ 55	18 Sep 77	Gertrude Is	x
SJJ 109	25 Oct 77	Nisqually	x
USS 653	6 Oct 77	Grays Harbor	x

Table A-2. Marine Mammal Sample Inventory -- The Evergreen State College, Olympia, WA. Room 044, 6 Dec. 1982. Harbor seal tissues collected by TESC students. All in aluminum foil. Analysis numbers in comments refer to tissues which were subsampled for pollutant analysis.

Sample no.	Date	Location	Tissue Bl	M	K	L	H	Sp	Comments
PVES 1	- Oct 72	Budd Inlet	x	x	x	x	x	x	#92 analyzed
PVES 2	19 Jun 77	Smith Is	x	x	x	x	x	x	#125 analyzed
PVES 4	22 Jun 77	Twin Harbor	x	x	x	x	x		#98 analyzed
PVES 5	22 Jun 77	Twin Harbor	x	x	x	x			#97 analyzed, poor condition
PVES 6	1 Jul 77	Skokomish Delta	x	x		x		x	#144 analyzed
PVES 7	30 Jun 77	Willipa Bay	x						#147 analyzed, poor condition
PVES 8	14 Jul 77	Smith Is	x						#160 analyzed, poor condition
PVES 9	14 Jul 77	Smith Is	x			x			#162 analyzed, good condition
PVES 10	14 Jul 77	Smith Is	x		x	x			#164 analyzed
PVES 11	21 Jul 77	Smith Is	x						#171 analyzed
PVES 12	13 Aug 77	Dosewallips Delta	x	x	x	x		x	#183 analyzed, good condition
PVES 13	15 Aug 77	Duckabush Delta	x		x	x		x	#207 analyzed, poor condition
PVES 14	28 Aug 77	Duckabush Delta	x	x		x		x	#233 analyzed
PVES 15	17 Aug 77	Quilcene Bay	x			x			#239 analyzed, poor condition
PVES 16	1 Sep 77	Dosewallips Delta	x		x	x			#265 analyzed, good condition
PVES 17	2 Sep 77	Duckabush Delta	x		x	x			#268 analyzed, good condition
PVES 18	14 Aug 77	Eld Inlet	x		x	x			#271 analyzed, good condition
PVES 19	12 Sep 77	Eld Inlet	x	x		x			#275&276 analyzed, poor condition
PVES 20	7 Oct 77	Willipa Bay	x	x		x			#300 analyzed, tooth
PVES 21	8 Oct 77	Skokomish Delta	x	x					#306 analyzed
PVES 22	8 Oct 77	Dosewallips Delta	x	x		x			#309 analyzed, baculum
PVES 24	13 Mar 79	Eld Inlet	x			x			jaws and teeth, good condition

Bl-Blubber, M-Muscle, K-Kidney, L-Liver, H-Heart, Sp-Spleen

Table A-3. Marine Mammal Sample Inventory - The Evergreen State College, Olympia, WA. - Rm 044, 6 Dec. 1982. Samples collected by T.C.Newby, obtained from the University of Puget Sound by John Calambokidis in 1977. Most samples are in poor condition, the majority were rewrapped with aluminum foil. No catalog of specimens exists at Evergreen. Tissues labelled with a "B" are probably blubber, "L" is probably liver

Sample I.D. Number	Sample I.D. Number
B82	106 repro test
94 placenta	107B
94 liver	109B
96F	109 repro
96R	growth I-112
96K	112 growth g.o.
B97	112R
97R	112B
98B	113B
98L	114L
98R	115B
99R	B115
99B	115 (K or B)
100B	liver, killer whale, coll. 10/3/72
100-stom cont	kidney, killer whale, coll. 10/3/72
100R	muscle only (?)
101 R and F	brain 4 (?)
101B	brain 2 (?)
102 liver	brain (?)
M103	
B103	
B103	
B103 (?)	
M103	
105 gr. musc.	
105B	
105K	
105K ground	
105 (?)	

Table A-4. Marine mammal samples inventory -- National Marine Mammal Lab, Seattle, WA. Collected by Steve Jeffries and others. Dr. Robert DeLong is the contact person. All samples are harbor seals unless otherwise noted. Tissues : Bl-blubber, M- muscle, K-kidney, L-Liver, Br-brain, H-heart, and Sp-spleen. Age: A-adult, S-subadult, N-neonate.

Sample no.	Date	Location	Sex	Age	Tissue Bl	M	K	L	Br	H	Sp
74-507*	-	-	-	-	x	x	x	x			
74-601	30 July 76	Grays Harbor	-	-	x	x	x	x	x		
74-602	30 July 76	"	-	-	x	x	x	x	x		
74-603	27 Aug 76	"	-	-	x				x		
74-604	24 Sept 76	"	-	-	x	x	x	x	x		
74-605	24 Sept 76	"	-	-	x	x	x	x	x		
74-606	24 Sept 76	"	-	-	x	x	x	x			
74-607	24 Sept 76	"	-	-	x	x	x	x	x		
74-608	3 Dec 76	"	M	-	x	x	x	x	x		
74-609	3 Dec 76	"	M	-	x	x	x		x		
74-610	-	"	M	-	x			x	x		
74-611	3 Dec 76	"	M	-	x			x	x		
74-612	3 Feb 77	"	-	-	x	x	x	x	x		
74-613	3 Feb 77	"	-	-	x			x	x		
74-614	3 Feb 77	"	-	-	x	x	x	x	x		
74-615	3 Feb 77	"	-	-	x	x	x		x		
74-616	3 Feb 77	"	-	-	x	x	x	x	x		
74-617	17 Mar 77	"	-	-	x	x	x	x	x		
74-618	3 Feb 77	"	-	-	x	x	x	x	x		
74-619	17 Mar 77	"	-	-	x	x	x		x		
74-620	17 Mar 77	"	F	-	x	x	x	x	x		
74-621	-	-	-	-	x				x		
74-621a	-	-	-	-	x				x		
74-622	-	-	-	-	x	x	x	x	x		
74-623	-	-	-	-	x				x		
74-623a	-	-	-	-	x				x		
74-624	-	-	-	-	x	x	x				
74-624a	-	-	-	-	x				x		
74-625	-	-	-	-	x			x	x		
74-626	-	-	-	-	x						
74-627	10 June 77	Grays Harbor	-	-	x	x	x	x	x		
74-628	10 June 77	"	-	-	x				x		
74-629	10 June 77	"	-	-					x		
74-630	10 June 77	"	-	-	x				x		
74-631	10 June 77	"	-	-	x			x	x		
74-632	10 June 77	"	-	-	x			x	x		
74-633	10 June 77	"	-	-	x	x	x	x	x		
74-634	22 July 77	"	-	-	x				x		

* radio-tagged
** with fetus
*** stillbirth

Table A-4. Continued

Sample no.	Date	Location	Sex	Age	Tissue Bl	M	K	L	Br	H
74-635	22 July 77	Grays Harbor	–	–	x			x		
74-636	22 July 77	"	–	–	x				x	
74-637	22 July 77	"	–	–	x	x	x	x		
74-638	22 July 77	"	–	–				x		
74-639	22 July 77	"	–	–	x				x	
74-640	22 July 77	"	–	–	x				x	
74-641	22 July 77	"	–	–	x				x	
74-642	15 Aug 77	"	M	–	x	x	x	x	x	
74-643	15 Aug 77	"	F	–	x				x	
74-644	15 Aug 77	"	M	–	x	x	x	x	x	
74-645	15 Aug 77	"	–	–	x			x	x	
74-646	15 Aug 77	"	F	–	x				x	
74-647	15 Aug 77	"	M	–	x	x	x	x	x	
74-648	16 Sept 77	"	–	–	x			x	x	
74-650	6 Oct 77	"	F	–	x	x	x	x	x	
74-651	6 Oct 77	"	–	–	x				x	
74-652	6 Oct 77	"	–	–	x	x	x	x	x	
74-653	6 Oct 77	"	M	–	x				x	
74-654	6 Oct 77	"	–	–	x				x	
74-655	6 Oct 77	"	–	–	x				x	
74-656	9 Dec 77	"	–	–	x			x		
74-657	30 Dec 77	"	M	–	x	x		x	x	
74-658	30 Dec 77	"	–	–		x		x	x	
74-659	3 Feb 78	"	M	–	x	x	x	x		
74-660	–	–	–	–	x					
74-661	3 Feb 78	Grays Harbor	–	–	x					
74-662	3 Feb 78	"	F	–	x					
74-663	3 Feb 78	"	–	–	x					
74-664	3 Feb 78	"	–	–	x			x		
74-665	14 Apr 78	"	M	–	x	x	x	x		
74-666	14 Apr 78	"	F**	A	x					
74-667	9 June 78	"	M	–		x	x	x	x	
74-668	9 June 78	"	F	–	x	x	x	x		
74-670	7 Aug 78	"	F	–	x	x	x	x		
74-671	8 Aug 78	"	F	–	x	x	x	x		
74-672	7 Aug 78	"	M	–	x	x	x	x		
74-673	8 Aug 78	"	M	–	x	x	x	x		
74-674	8 Aug 78	"	F	–	x	x	x	x		x
74-699	9 June 78	"	F	–	x			x	x	
SJJ 02	6 June 75	"	–	–			x	x		
SJJ 07	17 July 75	Vaughn, WA	F	A	x		x	x		
SJJ 20	30 Sept 75	S Puget Sound	M	N	x					
SJJ 21	30 Sept 75	S Puget Sound	F	N***	x					

* radio-tagged
** with fetus
*** stillbirth

Table A-4. Continued, p. 3.

Sample no.	Date	Location	Sex	Age	Tissue Bl	M	K	L	Br	H	Sp
SJJ 22	4 Jan 76	Gertrude Is.	M	–	x						
SJJ 23	4 Jan 76	Gertrude Is.	F	–	x						
SJJ 42	9 May 76	Grays Harbor	–	–	x		x	x		x	x
SJJ 43	16 May 76	Gertrude Is.	–	–	x	x	x	x	x	x	x
SJJ 51	–	S.of Grayland	F	–	x	x	x	x	x		
SJJ 52	27 Aug 76	Kalalock,WA	M	–	x	x		x	x		
SJJ 55	20 Sept 76	Gertrude Is.	F	–	x				x		
SJJ 57	25 Aug 76	Gertrude Is.	F	–	x				x		
SJJ 69	6 Dec 76	Gertrude Is.	M	–		x	x	x	x		
SJJ 70	–	Bellingham Bay?	M	–	x	x	x	x	x		
SJJ 71	16 Jan 77	Gertrude Is.	M	–	x	x	x	x	x		
SJJ 83	?										
SJJ 85	?										
SJJ 93	5 Aug 77	Budd Inlet	–	–	x		x	x			
SJJ 95	17 Aug 77	Bellingham Bay	F	–	x	x	x	x	x		
SJJ 96	3 July 77	Rosedale,WA	M	N	x						
SJJ 98	?										
SJJ 105	–	Dosewallips	–	N							
SJJ 109	25 Oct 77	Olympia,WA	M	–	x	x	x	x	x		
SJJ 112	7 Dec 77	Rosedale,WA	F	S	x	x	x	x			
SJJ 113	17 Dec ?	Ocean Shores	–	–	x						
SJJ 114	3 Jan 78	Bremerton	F	–	x		x	x			
SJJ 119	30 Apr 78	Pacific Beach,WA	–	–	x						
SJJ 131	19 Aug 78	S of Pt Grenville	M	–	x	x	x	x			
SJJ 132	21 Aug 78	Nisqually Riv	F	–	x	x	x	x			
SJJ 133	24 Aug 78	Sequim,WA	–	N		x	x	x			
SJJ 134	24 Aug 78	Duckabush Riv	–	–	x						
SJJ 135	24 Aug 78	Duckabush Riv	M	–	x	x		x			
GAB 115	2 Aug 77	Nisqually ?	M?	–	x	x		x	x	x	
SJJ 38<u>Ba</u>	11 Mar 76	Nisqually Delta	M	–	x	x	x	x	x	x	
SJJ 68<u>Zc</u>	30 Nov 76	Ocean shores	M	–	x	x	x	x	x		

* radio-tagged

** with fetus

*** stillbirth

<u>Ba</u>- Minke whale (<u>Balaenoptera acutorostrata</u>)

<u>Zc</u>- California sea lion (<u>Zalophus californianus</u>)

Table A-5. Marine mammal sample inventory -- Summary of pinniped specimens collected 4 March 1980 - 12 August 1982. From : Draft of Marine Mammal-Fishery interaction on the Columbia River and Adjacent Waters, 1980-1982, Third annual report. Washington Game Department, Marine Mammal Investigations.

	Species					
	Pv	Zc	Ej	Cu	Ma	Total
No. of Animals	105	57	23	16	5	
Males	63	56	5	5	3	
Females	37	0	16	10	2	
Unknown	5	1	2	1	0	
Samples Taken						
Skulls	67	33	12	11	4	127
Reproductive Organs	41	6	6	2	1	56
Histopath	25	5	2	2	2	36
Environ. Contaminants	31	7	2	2	2	44
Stomach	47	15	4	3	2	71
Intestine	45	11	2	1	2	61
Baculum	50	41	7	4	3	105

Species key: Pv=*Phoca vitulina r.*; Zc=*Zalophus californianus*; Ej=*Eumetopias jubatus*; Cu=*Callorhinus ursinus*; Ma=*Mirounga angustirostis*.

Table A-6. Marine mammal sample inventory -- Summary of cetacean specimens collected 4 March 1980 through 12 August 1982. From: Draft of Marine Mammal-Fishery interaction on the Columbia River and Adjacent Waters, 1980-1982, Third annual report. Washington Game Department, Marine Mammal Investigation.

	Species										
	Pp	Pd	Er	Lo	Lb	Ba	Gm	Ms	Sc	Pm	Total
No. of Animals	12	6	3	3	2	2	1	1	1	1	36
Males	6	3	3	2	0	1	1	0	1	1	18
Females	6	3	0	1	2	0	0	1	0	0	13
Unknown	0	0	0	0	0	1	0	0	0	0	1
Samples Taken											
Skulls	9	5	2	3	2	2	1	1	1	1	27
Reproductive Organs	8	4	0	3	2	0	0	1	1	0	19
Histopath	4	2	2	0	2	0	0	1	1	0	14
Environ. Contaminants	4	2	2	0	2	0	0	1	1	0	12
Stomach	6	4	2	2	2	0	0	1	1	0	18
Intestine	5	4	2	2	2	0	0	1	1	0	17

Species key: Pp=Phocoena phocoena; Pd=Phocoenoides dalli; Er=Eschrichtius robustus; Lo= Lagernorhunchus obliquidens; Lb=Lissodelphis borealis; Ba=Balaenoptera acutorostrata; Gm=Globicephala macrocephalus; Ms=Mesoplodon stejnegeri; Sc=Stenella coeruleoalba; Pm=Physeter macrocephalus.

APPENDIX B

Selected chromatograms and chemical data summaries from the organic analyses conducted by Bodega Marine Laboratory are given in Figures B-1 to B-6 and Tables B-1 to B-7 respectively. Table B-1 lists the sample analysis numbers and the corresponding field identification numbers. Figures B-1 and B-2 and Tables B-2 to B-4 are chromatograms and corresponding chemical data summaries for harbor seal blubber sample BML 83-67. Figures B-3 and B-4 and Table B-5 are chromatograms and corresponding chemical data summary for a sample blank. Figures B-5 and B-6 and Tables B-6 and B-7 are chromatograms and the corresponding chemical data summaries for the internal standards used in the analyses.

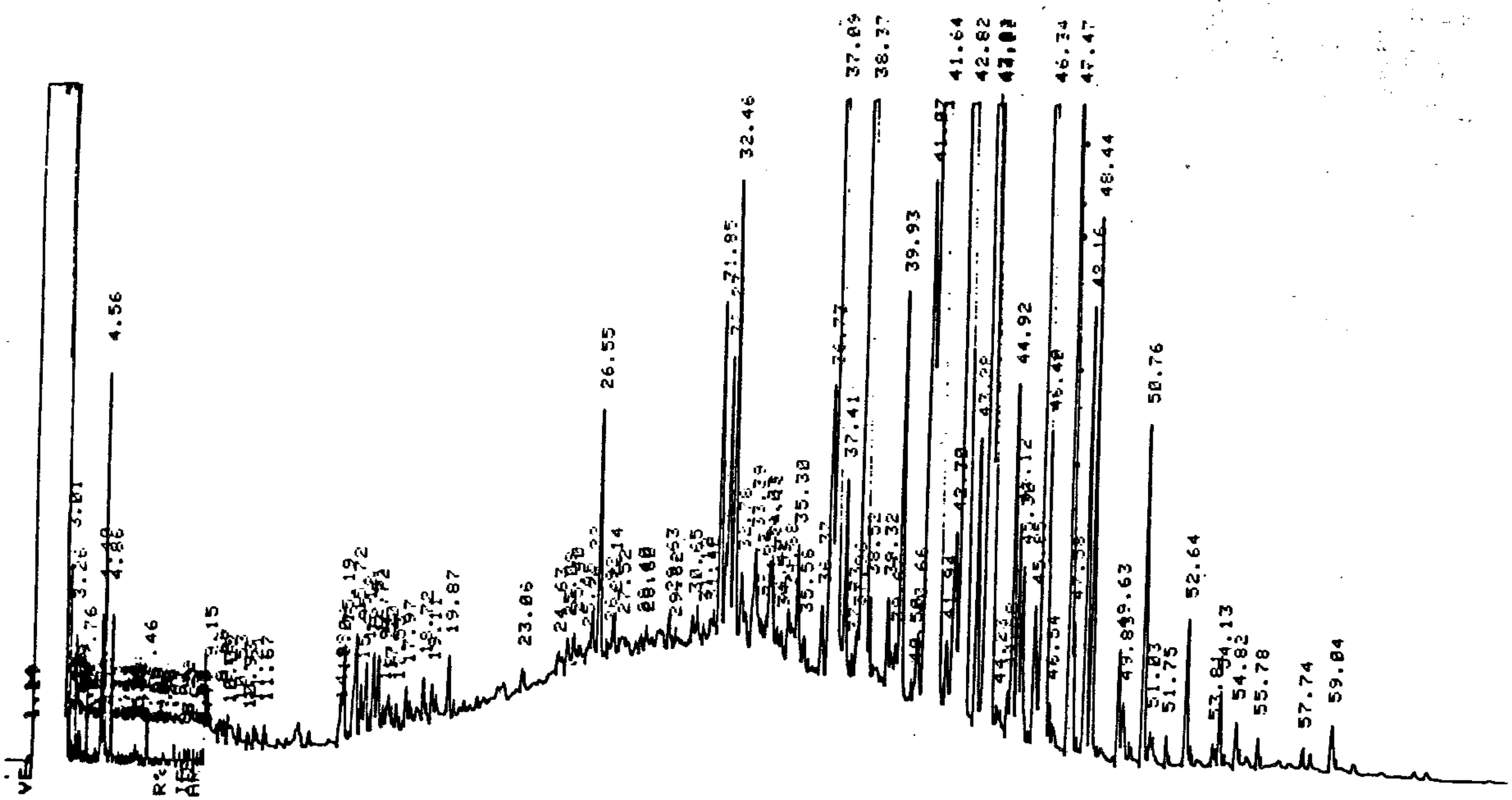

Figure B1. Chromatogram - harbor seal, BML 83-67, F1, FID. SE-30 column, injection 81.2-372.

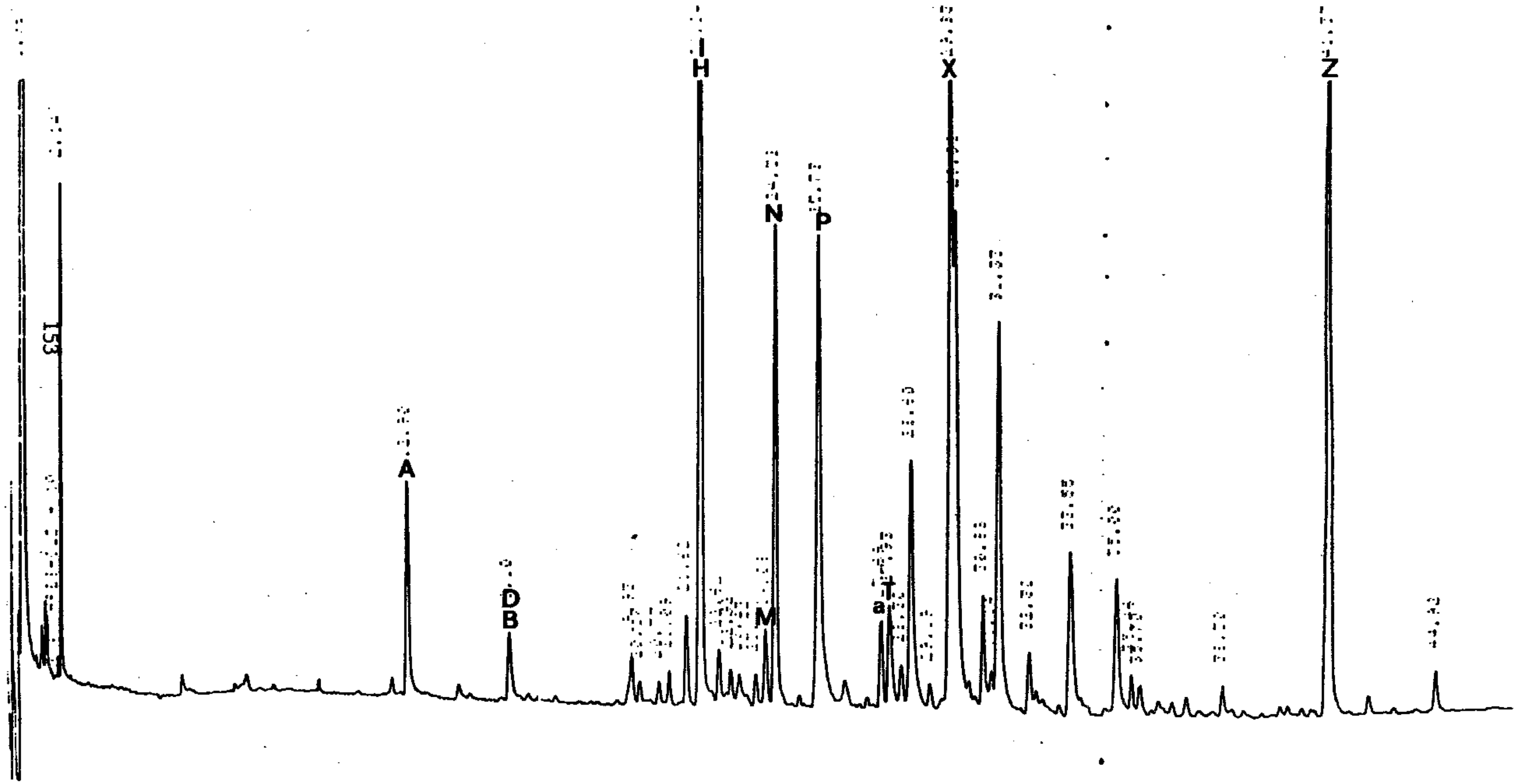

Figure B2. Chromatogram - harbor seal, BML 83-67, F2, ECD. DB-5 column, injection 82.1-773.

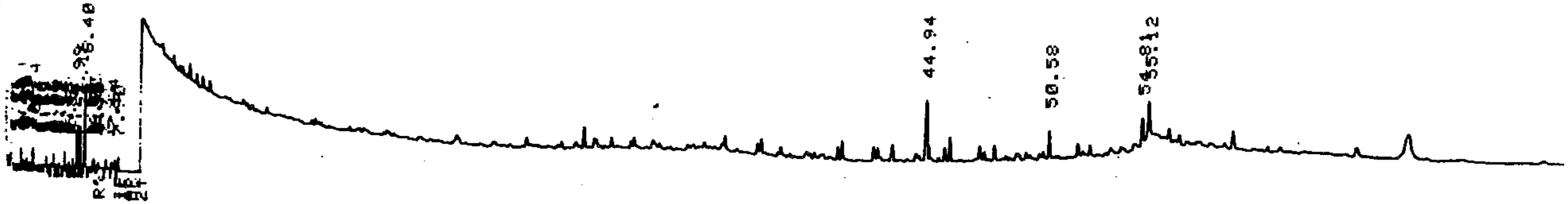

Figure B3. Chromatogram - sample blank, BML 83-73, F2, FID. Injection 82.2-209.

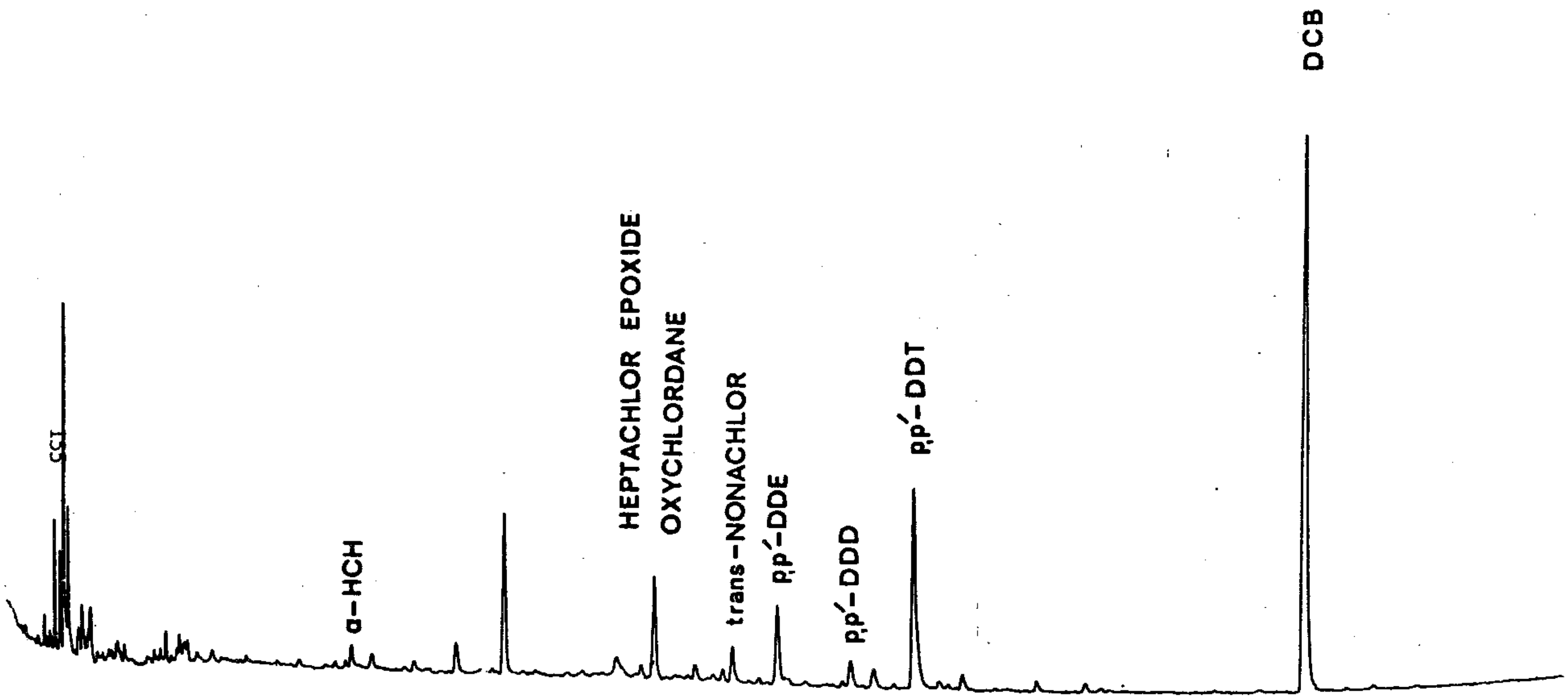

Figure B4. Chromatogram - sample blank, BML 83-73, F2, ECD. Level of p,p'-DDT is equivalent to 6 ng in the total extract and represents carryover from previous sample analysed.

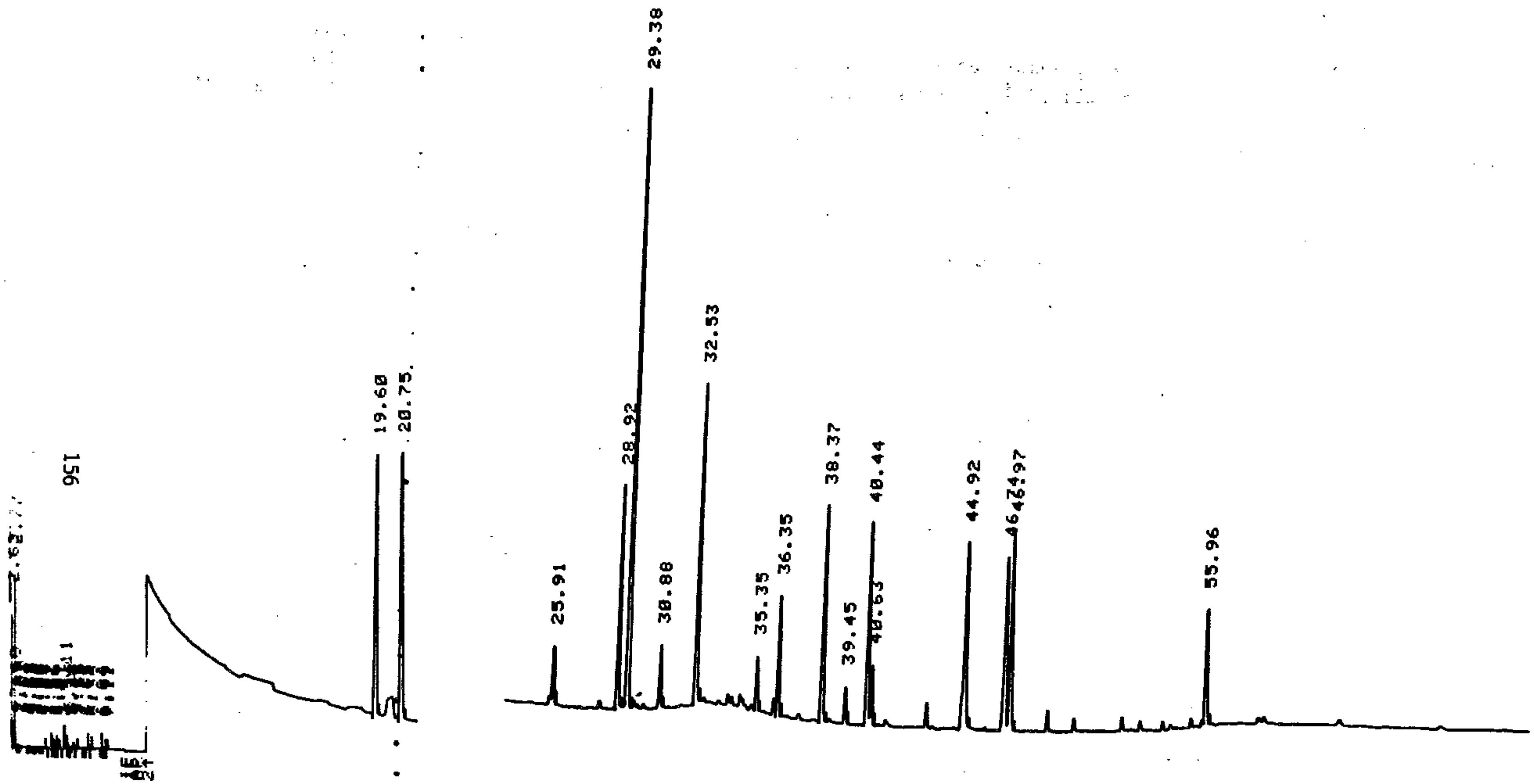

Figure B5. Chromatogram - deuterated internal standard, FID. Three hundred microliters reduced to 40, 2 microliters injected, SE-54 column, injection 82.2-252.

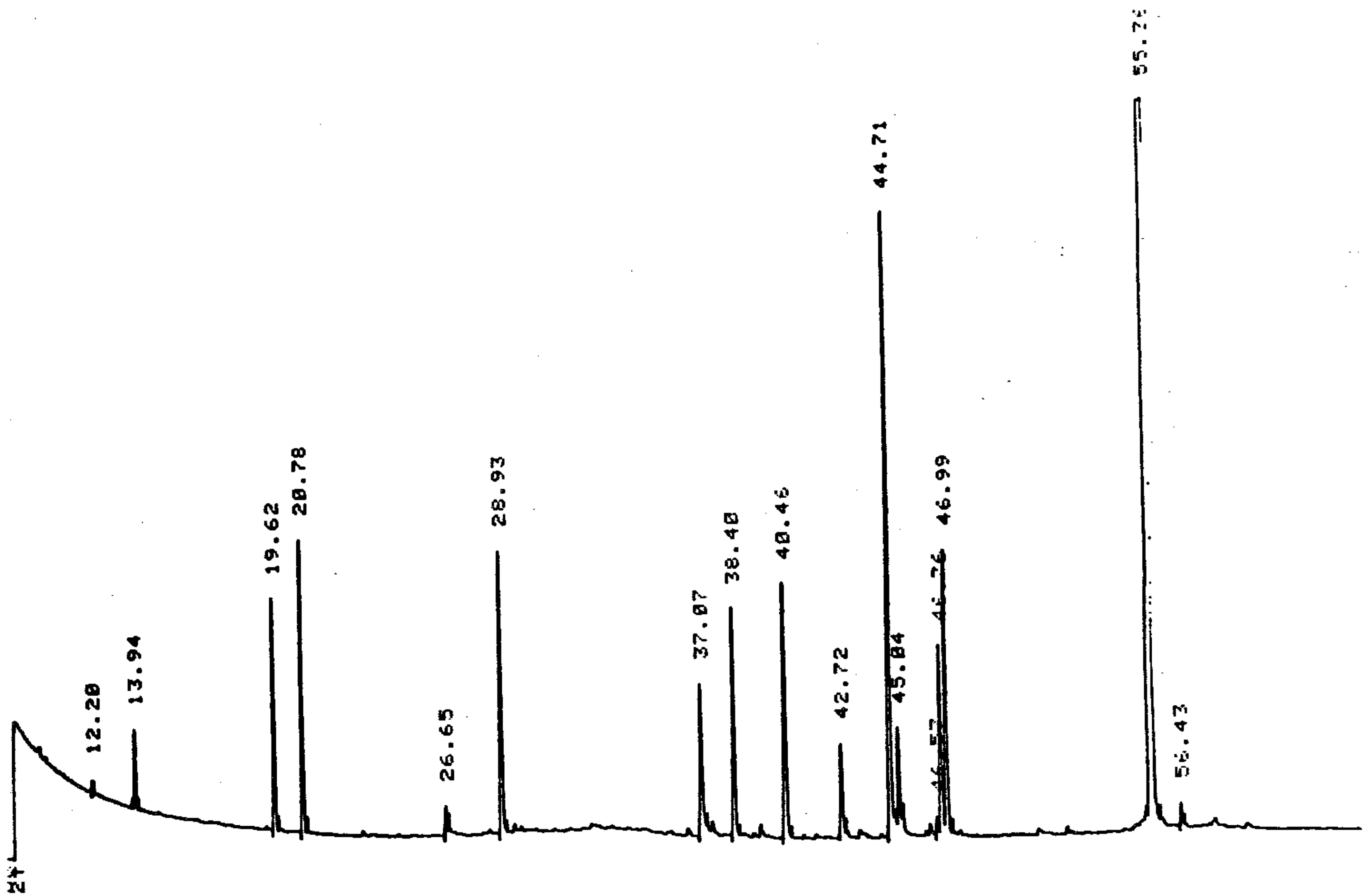

Figure B6. Chromatogram - recovery perdeuterated internal standard, F2, FID. Injection 82.2-170.

Table B-1. List of collector's numbers and their corresponding BML analysis number.

Coll. No.	BML No.
SJJ 7	83-61
SJJ 43	83-70
SJJ 71	83-56
SJJ 93	83-66
SJJ 109	83-57
SJJ 112	83-46
SJJ 114	83-71
SJJ 132	83-62
SJJ 170	83-39
SJJ	83-67
PVES 1	83-36
PVES 18	83-69
PVES 24	83-64
---	83-107
CRC-1	83-68
GAB 115	83-65
DB 13	83-72

Table B2. Chemical data summary - harbor seal, BML 83-67, F1, FID.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Phoca vitulina adult male

Locality: Day Island Date of Collection: 30 March, 1979

Tissue: blubber Percent water: 21 Percent lipid: 54

FRACTION: 1 COLUMN: SE30 FID

INJECTION ID: 81.2-372 Nanograms/gram (ppb), dry weight

RT	NAME	KOVAT	AMOUNT	FACTOR
26.550	pristane	1710	1141.993	0.98
31.850	4-Cl	1887	1645.276	1.00
32.070		1895	122.920	1.00
32.230	n-C19	1900	851.060	0.95
32.460	contam ?	1909	2093.897	1.00
32.780		1923	437.105	1.00
33.390		1948	664.419	1.00
34.030		1974	117.412	1.00
34.880		2009	145.702	1.00
35.300	5-Cl	2026	441.110	1.00
36.370		2070	406.312	1.00
36.730	5-Cl	2084	1299.047	1.00
37.090	5-Cl	2099	8894.807	1.00
37.410	trans-non	2112	734.516	1.00
38.370	p,p'-DDE	2152	14394.917	1.00
38.520	5-Cl	2158	139.693	1.00
39.320	6-Cl	2191	294.157	1.00
39.930	6-Cl	2216	1938.182	1.00
40.660		2245	248.594	1.00
41.070	6-Cl	2262	2144.467	1.00
41.640	6-Cl	2286	33896.899	1.00
41.940		2298	231.570	1.00
42.300		2313	951.817	1.00
42.820	6-Cl	2334	23557.594	1.00
43.280	7-Cl	2353	1419.965	1.00
43.810	7-Cl	2375	5367.426	1.00
43.870	7-Cl	2377	270.624	1.00
44.000	7-Cl	2382	1700.353	1.00
44.680		2410	110.903	1.00
44.920	7-Cl	2420	1499.074	1.00
45.120	8-Cl	2428	633.627	1.00

Table B2, continued.

45.300		2436	498.940	1.00
45.850	contam ?	2458	667.173	1.00
46.340	7-C1	2478	11293.125	1.00
47.470	7-C1	2525	4263.399	1.00
48.160	8-C1	2553	2318.207	1.00
48.440	8-C1	2564	2291.671	1.00
49.630	8-C1	2613	442.112	1.00
49.830		2621	214.046	1.00
50.760	8-C1	2659	1725.387	1.00
51.750	n-C27	2700	119.552	1.11
52.640	9-C1	2744	684.948	1.00
54.130		2818	293.156	1.00
54.820		2852	207.287	1.00
55.780	n-C29	2900	112.474	1.13
59.040		3062	237.829	1.00

Table B3. Chemical data summary - harbor seal, BML 83-67, F2, ECD.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Phoca vitulina adult male

Locality: Day Island Date of Collection: 30 March, 1979

Tissue: blubber Percent water: 19 Percent lipid: 54

FRACTION: 2 COLUMN: DB5 ECD

INJECTION ID: 82.1-773 Nanograms/gram (ppb), dry weight

RT	NAME	KOVAT	AMOUNT	FACTOR
0.960		126	4279.373	1.00
2.140		280	250.120	1.00
12.900	a-HCH	1689	267.706	0.67
16.100		1813	144.840	1.00
19.930		1961	119.254	1.00
20.170		1970	42.186	1.00
20.770		1993	44.194	1.00
21.090		2005	54.520	1.00
21.620		2026	165.937	1.00
	hept. epox.		136	0.94
22.040	oxychlor	2042	1740	0.94
22.620		2063	123.221	1.00
22.980		2077	74.448	1.00
23.260	g-chlor	2087	75.050	0.80
23.770		2107	65.199	1.00
24.080	a-chlor	2120	136.546	0.92
24.380	t-nonachl	2131	1039.206	1.08
25.730	p,p'-DDE	2176	1117.419	0.89
27.690		2254	160.817	1.00
27.930	p,p'-DDD	2263	235.187	0.92
28.300		2278	87.693	1.00
28.600		2291	636.190	1.00
29.190		2315	45.322	1.00
29.830	p,p'-DDT	2342	1464.385	1.01
29.980		2349	1357.017	1.00
30.880		2392	203.674	1.00
31.140		2404	70.547	1.00
31.330		2413	992.187	1.00
32.300		2459	117.259	1.00
33.550		2518	450.541	1.00
35.000		2586	381.404	1.00
35.460		2608	85.109	1.00
35.700		2620	39.371	1.00
38.300		2742	62.686	1.00
41.570	DCB	2897	1752.192	1.00
44.920		3055	90.873	1.00

Table B4. Chemical data summary - harbor seal, BML 83-67, F2, FID. See, text Figure 9.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Phoca vitulina male adult

Locality: Day Island Date of Collection: 7 April 80

Tissue: blubber Percent water: 19 Percent lipid: 54

Dry weight analysed: 0.46 g

FRACTION: 2 COLUMN: SE-54 FID

INJECTION ID: 82.2-178 Nanograms/gram (ppb), dry weight

RT	NAME	KOVAT	AMOUNT	FACTOR
13.890		1296	556.625	1.00
29.350	contaminant	1785	1007.166	1.00
29.630	bromodecane ?	1794	1085.355	1.00
32.490	contaminant	1890	371.506	1.00
36.980	Oxychlordane	2038	474.209	1.00
40.420	p,p'-DDE	2180	519.432	1.00
43.370		2300	203.293	1.00
44.610	p,p'-DDT	2350	733.714	1.00
44.790		2358	311.490	1.00
46.200		2416	365.166	1.00
46.500		2429	717.653	1.00
55.320	squalene	2841	52915.298	1.00
56.370		2894	928.976	1.00

Confirmed by GC/MS; see GC/MS run.
Quantified on response of n-C23

Table B5. Chemical data summary - sample blank, BML 83-73, F2, FID.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Sample blank

FRACTION: 2 COLUMN: SE-54 FID

INJECTION ID: 82.2-209 Nanograms/gram (ppb), dry weight

RT	NAME	KOVAT	AMOUNT	FACTOR
44.940		2365	60.333	1.00
55.120	squalene	2832	30.167	1.00

Assume dry weight of 1.0 g.

Run as sample, after two samples had been soxhlet-extracted.

Table B6. Chemical data summary - deuterated internal standard, BML 83-00, FID.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Deuterated internal standard, 300 microliters reduced to 40.

FRACTION: 0 COLUMN: SE-54 FID

INJECTION ID: 82.2-252 Nanograms/ microliter of original

RT	NAME	KOVAT	AMOUNT	FACTOR
19.600	Acenaphthene *	1477	0.588	1.00
20.750	Diphenyl ethane *	1513	0.622	1.00
25.910		1675	0.137	1.00
28.920	Phenanthrene *	1769	0.587	1.00
29.380		1784	2.270	1.00
30.880		1836	0.134	1.00
32.530		1894	0.867	1.00
35.350		1993	0.136	1.00
36.350		2027	0.297	1.00
38.370	Pyrene *	2098	0.597	1.00
40.440	p-terphenyl *			
44.920	n-C24 *	2360	0.544	1.00
46.740	Benzanthracene *	2444	0.483	1.00
46.970	Chrysene *	2455	0.474	1.00
55.960	Perylene *	2869	0.296	1.00

* perdeuterated, quantified as n-C23

Other peaks are contaminants

Table B7. Chemical data summary - recovery perdeuterated standards, BML 83-71, F2, FID.

SOUTHERN PUGET SOUND HARBOR SEAL STUDY, 1983

Recovery of perdeuterated standards; 1 ml added to lipid before florisil cleanup.

FRACTION: 2 COLUMN: SE-54 FID

INJECTION ID: 82.2-170

Total nanograms recovered

RT	NAME	KOVAT	AMOUNT	FACTOR	% RECOVERY
19.620	Acenaphthene	1478	687	1.00	70
20.780	Diphenyl ethane	1513	909	1.00	85
28.930	Phenanthrene	1769	910	1.00	92
38.400	Pyrene	2099	739	1.00	77
40.460	Terphenyl	2179	960	1.00	96
46.760	Benzanthracene	2439	563	1.00	55
46.990	Chrysene	2450	847	1.00	78

Quantified on the response of n-C_{23}

APPENDIX C

Scientific and common names of marine mammals referenced in this report.

Order Carnivora

Callorhinus ursinus	northern fur seal
Cytophora cristata	hooded seal
Erignathus barbatus	bearded seal
Eumetopias jubata	Steller sea lion, northern sea lion
Halichoerus grypus	grey seal
Hydrurga leptonyx	leopard seal
Leptonychotes weddelli	weddell seal
Lobodon carcinophagus	crabeater seal
Phoca fasciata	ribbon seal
Phoca groenlandica	harp seal
Phoca hispida	ringed seal
Phoca sibirica	Baikal seal
Phoca vitulina	harbor seal
Zalophus californianus	California sea lion
Lutra canadensis	river otter
Lutra lutra	otter

Order Cetacea

Balaenoptera acutorostrata	minke whale
Kogia breviceps	pygmy sperm whale
Orcinus orca	killer whale
Phocena phocena	harbor porpoise
Phocoenoides dalli	Dall's porpoise

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