The National Status and Trends Program for Marine Environmental Quality

Trends in DDT and PCBs in U.S. West Coast Fish and Invertebrates

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Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerece
Seattle, WA

THE NATIONAL STATUS AND TRENDS PROGRAM
FOR MARINE ENVIRONMENTAL QUALITY

TRENDS IN DDT AND PCBs IN U.S. WEST COAST FISH AND INVERTEBRATES

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PREFACE

This is one in a series of Coastal and Estuarine Assessment Reports which characterize environmental quality of the Nation's coastal and estuarine environments. The effort itself is part of NOAA's National Status and Trends (NS&T) Program. Other NS&T Program efforts involve the collection of new information on concentrations of contaminants and measures of biological effects using nationally uniform sampling and measurement techniques. The overall goal of the NS&T Program is to document current marine environmental conditions and determine whether marine environmental quality is improving or declining.

EXECUTIVE SUMMARY

Published and unpublished information from 65 federal, state, and local surveys or "data sets" were examined to assess long-term and large-scale regional trends in the concentrations of DDT and polychlorinated biphenyls (PCBs) in fish and invertebrates along the U.S. West Coast. These data represent over 4,800 samples from 103 species of fish, 13 species of bivalves, and 11 species of other invertebrates. All data associated with these samples were extracted and entered into a desktop computer data base management system and then sorted by species, habitat-type, geographic location, and time periods.

In order to produce a large-scale trend summary, data from these data sets were compared and combined to build a case, bit by bit, for a geographic or temporal trend. When a trend in one direction was observed in many studies, for many organisms, the direction of the trend was considered significant.

The highest concentrations of total DDT among all regions of the U.S. West Coast have and continue to occur in organisms from the Palos Verdes Peninsula in southern California. Santa Monica Bay has been, and continues to be, ranked second in frequency of highest levels of DDT in fish. Nonetheless, DDT levels in fish and shellfish have decreased dramatically over the last 20 years, with decreases of up to two orders of magnitude in southern California. In Monterey Bay and San Francisco Bay small increases in levels of DDT are suggested (up to four times higher than in 1969).

The area with the highest frequency of maximum levels of total PCBs in fish and shellfish was the Palos Verdes Peninsula, which produced highest levels of PCBs in mussels, shrimp, and benthic fish before 1976. Now Elliott Bay in Puget Sound, Washington, shares and exceeds that distinction. Since 1979, Vancouver, B.C. has been ranked second in its frequency of highest levels of PCBs in fish, which, although not above 250 ppb, were still higher than those from other areas. The long-term trends in levels of PCBs are variable along the coast, with mean levels decreasing slightly in Elliott Bay and in many parts of California, decreasing dramatically in some parts of southern California, and showing some small increases in southern Puget Sound and Santa Monica Bay.

It is concluded that national legislative and regulatory control of DDT and PCBs have been followed by declining concentrations of these substances in marine fish and shellfish. No region now produces large numbers of organisms exceeding FDA seafood limits. However, localized "hot-regions" and "hot-species" within regions remain. And based on application of new cancer risk models, concentrations in organisms from some regions may still be at levels potentially hazardous to major consumers of seafood.

The composited data presented in this report should only be considered as qualitative indicators of large-scale geographic and temporal trends. They are useful in determining relative contamination over space and time and were used to reinforce results of individual synoptic surveys, which have been presented intact.

TRENDS IN DDT AND PCBs IN U.S. WEST COAST FISH AND INVERTEBRATES

1. INTRODUCTION

This report evaluates long-term (10-20 year) and large-scale trends in the concentrations of DDT and polychlorinated biphenyls (PCBs) in fish and invertebrates along the U.S. West Coast.

There are several reasons why a report on long-term large-scale trends of DDT and PCB contamination is needed at this time. These two toxic and persistent synthetic chemicals were subject to intensive regulatory and legislative control over a decade ago. However, with a few notable and largely localized exceptions, no one has assessed the overall response of ocean resources to these regulatory controls.

Specific questions of immediate concern underscore this apparent lack of understanding. Seafood contaminated with these chemicals continues to be captured and consumed by the public in several regions, including southern California and Puget Sound. A few of the seafood organisms continue to exceed FDA action levels but many others also exceed levels now considered to be carcinogenic to heavy consumers of locally caught seafood. Likewise, there is growing concern among scientists that current levels of biological contamination at specific localities may be a threat to the health and reproductive potential of fish and wildlife. The public, local legislative bodies, and regulatory agencies are wondering why such contamination still occurs, whether the contamination is spreading to other valued resources along the coast, and whether new waste management actions will reverse perceived threats to human health, fisheries, and wildlife.

1.1 Objectives

As a result of these uncertainties, NOAA's Ocean Assessments Division (OAD) in 1983 elected to conduct an assessment of long-term and large-scale trends of DDT and PCB contamination in U.S. West Coast fish and invertebrate populations.

The objectives of the study were to:

a) determine where fish and invertebrates are currently most contaminated with DDT and PCB;
b) compare recent with past levels of DDT and PCB contamination; and
c) determine geographic regions and species which should be resampled to give a more complete picture of long-term and large-scale trends in DDT and PCB contamination.

1.2 Background

1.2.1 DDT

DDT was first synthesized in 1874 and in 1939 was discovered to be an effective insecticide. It was first widely used as a delousing powder for soldiers and against mosquitos to control malaria, but was soon discovered to be a widespread environmental pollutant. "Silent Spring" (Carson, 1962) documents the poisoning of wildlife by synthetic pesticides in the 1950s and began the environmental movement which led to a ban on DDT use in the United States in 1972.

The U.S. West Coast (figure 1.1) is noted for two potentially major sources of DDT to coastal waters: 1) wastes from DDT production and 2) DDT contaminated runoff from agriculture and forest lands receiving DDT applications prior to the bans of 1972. DDT was produced by Montrose Chemical Company in Torrance, California, from 1947 to 1982. Wastes from production were disposed into the ocean directly via barges (Chartrand et al., 1985) and indirectly, into sewage lines of the Los Angeles County Sanitation Districts which discharge to the ocean off the Palos Verdes Peninsula (Schafer, 1984). Ocean dumping was sporadic and banned by 1972. In contrast, sewage DDT emissions were continuous, but decreased from 20 tons per year in 1970 to less than 1 ton per year by 1982 (Schafer, 1984). Sediment deposits off Palos Verdes contained 200 tons of DDT in 1975 (Young et al., 1976) while MacGregor (1976) accounted for another 100 tons in sediments throughout a 900 square nautical mile area of the southern California shelf beyond the discharge zone. A history of DDT entering the southern California marine environment is recorded in layered sediments of the Santa Barbara Basin; analyses of dated layers indicate that offshore deposition of DDT began in the early 1950s (Hom et al., 1974). A comparable history of point source input trends from elsewhere is not available.

Trends in application of DDT to U.S. West Coast agriculture and forest lands were not reviewed for this report. However, we note that major potential inputs could have in the past entered waters of 1) Ventura County, 2) Monterey Bay, 3) San Francisco Bay, 4) southern Oregon, 5) the Columbia River Estuary and 6) embayments of Puget Sound and 7) the Fraser River estuary, since these drain productive agriculture valleys of 1) Ventura, 2) the Salinas Valley, 3) the San Joaquin-Sacramento Valley, 4) the Rogue River valley, 5) Eastern Washington, 6) the Skagit Valley and 7) the Canadian Fraser River Valley, respectively.

1.2.2 PCBs

The class of compounds known as PCBs has had many industrial uses, the most important being as dielectric oils in electrical transformers and capacitors including florescent light ballast. They were identified as environmental contaminants in 1966, corresponding to previously unknown peaks in chromatographic analyses of chlorinated pesticides. Their distribution in the marine environment is worldwide, presumably via atmospheric transport. Manufacture of PCBs began in the United States in the early 1930s (a decade before DDT) and ended in 1979. The disposal of existing PCB-containing equipment is regulated by the Environmental Protection Agency. Antifouling vessel paints may have been important local sources in the past, but not today (Young and Heeson, 1974). However, because equipment containing PCB oils is still in use, the potential for environmental contamination via spills and illegal disposal is great.

PCBs are now most likely to have major sources in areas of high population density and high use of electrical equipment. Such areas include the urbanized bays of the coast, e.g., Puget Sound, San Francisco Bay, and the Southern California Bight. PCB inputs to the Southern California Bight are also recorded in the layered sediments of the Santa Barbara Basin. Hom et al. (1974) suggest that PCB deposition in that area began in the 1940s: a decade prior to initiation of DDT deposition. Since 1970 a few studies have actually documented decreasing inputs of PCBs to the ocean from several sources, including ocean outfalls in southern California (e.g., Schafer, 1984). In the past, it has also been documented that significant inputs to the ocean have come from aerial fallout, river runoff (Hlavka, 1973) and from vessel related activities (Young and Heesen, 1974; Young et al., 1975).

1.2.3 Trends in fish and invertebrates

Given the regulatory actions that have occurred as well as the existing evidence of trends in inputs and sediment concentrations, one might suppose that there exist equivalent information about trends in DDT and PCB concentrations in coastal fish and invertebrates. To our knowledge, there are no assessments of large-scale or long-term trends for larger coastal areas that include both a spectrum of species and data both before and following the implementation of regulatory controls in the early- and mid-1970s.

1.3 Approach, Scope, and Limitations

Since it was clear that there did not exist a nationally consistent data base for examining long-term and large-scale trends, one had to be created from the potpourri of numerous local and regional synoptic surveys, site-specific long-term monitoring programs and scattered field experiments.

To acquire this data and conduct an assessment within existing resources and time constraints, we decided to limit a first effort to a pilot study for one coast. We chose the U.S. West Coast States of Washington, Oregon, and California. However, because contaminated organisms migrate without regard to political boundaries, we also decided to include data from adjacent areas of Mexico and Canada.

We further decided to limit the assessment to concentrations, or chemical residues, of DDT and PCBs in edible tissues of marine, estuarine, and anadromous fish and invertebrates. Edible tissues include muscle tissue of fin fish and large crustaceans (crabs, lobster, shrimp) as well as whole tissue and specific organs of mollusks (clams or snails) and other invertebrates.

The assessment was not limited to any particular time period but was guided only by the time period over which data are available, principally the past three decades for DDT and the past two decades for PCBs.

The principal objective of this study, to determine spatial and temporal trends in residues of DDT and PCBs in regional fish and shellfish, relies entirely on existing and historical data, some of which was not collected for this purpose. We therefore elected a two-pronged approach. First, we attempted to isolate from the mass of reports and data those surveys which were in fact designed as either long-term or large-scale (synoptic) surveys. Assuming this would be partially, but not completely informative, we then decided to attempt to fill in spatial and temporal gaps by compositing all of the data, perform manipulations to make small bits of data more comparable with the large surveys, and then reconstruct new geographical and time series plots.

We anticipated that the entire effort would be difficult because of limited use of indicator species, patchy sampling along the coast (with focus on polluted areas), and variable sampling intervals over time. To compensate for species differences, we decided to also evaluate data at a higher order of classification by combining species of similar habitat, feeding type, and trophic level. To compensate for patchy sampling in time and space, we decided to let the data help us isolate and compare data-rich time periods and data-rich coastal regions within which residue variations were minimal.

2. METHODS

Data used for this study were taken directly from numerous published and unpublished reports, entered into a computerized data base management system and sorted according to a specific set of criteria (described below) and, finally, examined for geographic comparisons and long-term trends.

2.1 Data Identification and Acquisition

Data were sought from several kinds of sources: papers in refereed journals and symposia proceedings; reports of federal, state, and local government agencies, and universities; and copies of unpublished, raw data sheets provided by willing investigators. Extensive searches of computerized bibliographic systems were conducted to generate additional references to data sets. These searches were especially helpful in the identification of older data. Additionally, numerous personal contacts were used to identify data sets of potential interest.

Hard copies of all reports were collected and catalogued at OAD's Pacific Office. Data was extracted directly from these reports as described below.

2.2 Data Extraction and Entry

Data on concentrations of DDT and PCBs from each report, or "Data Set," was extracted by hand and entered into a desktop computer data base management system tailored for this purpose. Information entered for each station included: a data set accession number, dates, locations, and species sampled. Information entered for each sample included: data on the size, weight, sex, habitat, feeding guild, trophic level of each organism; tissues sampled, lipid and water content, and the values of individual DDT isomers and PCB Arochlor mixtures or chlorination products. Each sample so described is here termed a "record."

Total DDT was here defined as the sum of concentrations of o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD, o,p'-DDT, and p,p'-DDT. When a data source provided levels for each of these isomers, they were summed to provide a total DDT level. Otherwise, only data presented by the researcher as total DDT were included in the report. Total PCBs were defined as the sum of all Arochlor mixtures or as the sum of multi-chlorinated biphenyl compounds. When a data source provided levels of multi-chlorinated biphenyl compounds, they were summed, otherwise, data given as total PCB levels were entered.

Whenever possible, raw individual data, as opposed to summaries or averages, were entered. However, if only mean levels were available, they were also entered.

2.3 Data Acceptance

We accepted all data encountered. The acceptance of all data encountered without comparison of each laboratory's methods as normalizers may lead to the introduction of errors into any apparent trends. Sampling and analytical methods vary among laboratories, and change over time. Inaccuracies can be introduced by the variations in the analytical methods chosen for the quantitation of DDT and PCBs. Two laboratories or two analysts could employ the same method on the same sample and produce very different results. Finally, many data sources did not report quality assurance programs involving interlaboratory comparisons and the use of standard reference materials, the comparability of results generated by different researchers was difficult to judge.

As described below, we decided to resolve some of the analytical uncertainties by first examining trends in data sets originating from the same laboratory programs and then determine the extent to which additional composited data agree or disagree with the trends based on single methodologies.

2.4 Data Manipulation and Compositing

Initially, we attempted to do as little data manipulation as possible. As a first step, data from individual surveys were examined in isolation to observe inherent trends. As reported below, these were informative but not sufficient to cover the entire coast over a long time period for a mix of species. Accordingly, data were composited and resorted by type of organism, geographic regions and time periods. The criteria used to composite and sort the data are described below.

2.4.1 Compositing species into functional groups

Species were combined into several functional groups or classes. Criteria used to classify species included habitat, feeding guild, and trophic level. Allen (1982) and others have provided a model for the functional structure of Pacific marine fish assemblages based on food habits and feeding guilds where fish can be classified by habitat (pelagic, bottom refuge, or bottom living), and by food source (purely pelagic, purely benthic, or mixed). Mearns (1982) and Yang (1981) further classified fish by trophic level based on actual food habits. Word (1979) conducted a similar analysis for infaunal invertebrates, emphasizing suspension vs. deposit feeding.

The three necessary factors (habitat, guild, and trophic level assignment) were determined for each species for which data was encountered utilizing existing food habits and behavioral information. First, the general biology of each species was reviewed to determine its general habitat type (pelagic, bottom-refuge, or bottom-living). Next, the literature was searched for food habits data for all species or their congeners. Where possible, the Index of Relative Importance (IRI-Pinkas et al., 1971) was computed for each dietary component. Then the food habits data were examined to determine the habitat types in which the target species derived the majority of its prey, and determined feeding guilds (pelagivore, mixed, benthivore). Finally, trophic level assignments (TLA) of target species were computed by weighing prey trophic level assignments against their relative importance determined from the IRIs (table 2.1). This computation resulted in fractional numbers on a scale of 1.0 (primary producers) to over 5.0 (tertiary carnivores) as described in Mearns (1982).

The three codings (habitat, feeding guild, and trophic level assignments) were used to combine the body burden data. Initial tests using these codings were conducted with residue data from fish muscle from the Southern California Bight region for 1975 and 1976. ANOVA and multiple, stepwise regression tests were run on this subset of data to determine significant factors in the analysis of mean body burden levels. The tests showed habitat and guild to be significant factors, but not trophic level assignments. An illustration of the effect of habitat, guild, and trophic level assignments on mean PCB levels is shown in table 2.2. It may be that trophic level is partially expressed through the combination of habitat preference and feeding guild. Therefore, species were combined only on the basis of feeding guild and habitat.

2.4.2 Compositing data by geographic location

In order to produce a meso-scale summary of pollutant trends, stations were composited into regions. Regions were initially defined using circulation, political and natural geographic boundaries as criteria (for example, Puget Sound, San Francisco Bay, the Southern California Bight). Mean levels of DDT and/or PCBs, and the standard deviations about them, were computed for these regions, and the areas were reduced in size to reduce standard deviations where possible. Overall, a total of 47 statistical regions were defined for the geographic comparisons.

2.4.3 Compositing data by sampling periods

It was assumed data was not equally distributed over time and that there were several data-rich periods. A frequency diagram revealed three such periods: (1969-71, 1975-76, and 1979-83). These three distinct, data-rich periods were separated by time spans when fewer samples from a variety of taxa were collected.

2.5 Data Presentation and Examination

Mean levels of DDT and PCBs in each area selected were plotted graphically together with the number of samples used to calculate mean levels, and the calculated standard deviation about the mean, and examined for the magnitude and direction of trends.

The primary statistical parameters used in this study were the mean (arithmetic average) and standard deviation of DDT and PCB concentrations. As noted above, some data were represented initially only by means or averages whereas other data were represented by individual values. In computing our means, we did not distinguish among these. Therefore, the number of samples used to calculate each mean level may be the number of organisms sampled (if one analysis per organism was reported), the number of composited samples for which data was reported, or a combination of both.

Ancillary data, such as lipid content, age, and size, were collected, but were not used to normalize the data since they were so rarely presented with data. All data are presented on a wet weight basis. Invertebrate data are usually for edible tissues only and most fish data are for flesh only. However, data for small fish, for example, anchovy, are for concentrations in whole fish.

2.6 Reaching Conclusions

We used a semi-quantitative "preponderance of evidence" approach to arrive at conclusions about trends and regional comparisons. Comparisons of regions was done as follows: for each species group, time period, and chemical we identified the region with the highest concentration. Regions were then ranked according to the number of times they were so classified. Regions with consistently higher body burdens relative to others on the list were determined to be "most contaminated."

Conclusions about long-term temporal trends in DDT and PCB levels were determined by tabulating the magnitude and direction of changes in levels over time for each species group resampled in an area. The magnitude and direction of all the changes (if any) were averaged, giving more weight to changes exceeding an order of magnitude in strength, and to more recent changes.

3. RESULTS

3.1 Overview of Available Data

The present database for observations of DDT and/or PCB residues along the West Coast contains over 4,800 records from 65 sources (data sets) of published and unpublished data (figure 3.1). The National Pesticide Monitoring Program (NPMP, now known as the National Contaminant Biomonitoring Program, or NCBP), originally active from 1965 through 1972, produced the largest volume of data of any one program. The Southern California Coastal Water Research Project (SCCWRP, conducting research since 1969) and the California State Mussel Watch Program (CMW, operative since 1977) have also been major data contributors. The appendix lists all data sources referenced in this report. Detailed descriptions of data sources are available from OAD's Seattle office. Table 3.1 describes data generated by previous synoptic surveys.

Over half of the data records are from 13 species of bivalves (figure 3.2). This is due to intensive monitoring of water quality through the analysis of tissues of mussels and oysters. Observations of residues in 103 species of bony fish from 38 families) and four species of sharks account for another 35% of the records. The remaining records are principally from crustaceans (11 species), but also include phytoplankton, zooplankton, salps, two species of echinoderms, four species of gastropods, and annelids.

The available data covers coastal and offshore waters of the Americas from about 4°S to 55°N, or about 6,000 km of coastline. The actual data summarized in this report are principally from the waters and shorelines of California (61.8% of the records), Oregon (2.7%), and Washington (28.4%), but data from adjacent areas of Mexico (4.4%) and Canada (2.7%) are also included (figure 3.3). The areas chosen for data presentation are displayed in figure 3.4, and area location codes are defined in table 3.2.

Although data were found for samples taken as long ago as 1949, very few samples for DDT/PCB residue analysis were taken until 1965 (figure 3.5) when large-scale (national) bivalve monitoring began. Large-scale fish sampling began in 1969, and three distinct, data-rich periods stand out as times when numerous measurements were made: 1969-71, 1975-76, and 1979-83. These data rich periods were used as base periods for most presentations of data.

3.2 Trend Results from Individual Surveys and Species

A few surveys (table 3.1) were encountered whose results can stand alone to provide some indications of geographic and temporal trends in residue levels. Results presented in this section provide the strongest evidence of trends because of the lack of error factors introduced by compositing different species, survey methods, and analytical techniques.

3.2.1 Geographic trends

3.2.1.1 DDT - Three projects produced results which stand alone to indicate geographic trends in total DDT levels (figure 3.6). The NPMP (Data Set 21), SCCWRP (Data Sets 48 and 51), and Burnett (Data Set 34) sampled bivalves or sand crabs along large sections of the coast from 1966 through 1971. There is no single area with consistently high levels of DDT among many types of organisms during this time period. Each species sampled shows a different location within California for the maximum body burden detected. Although sampled by only one of the three surveys (NPMP), areas of the outer coast of California north of San Francisco and the embayments of the Washington coast and Puget Sound produced bivalves with low mean levels of total DDT (less than 30 ppb) from 1966 through 1971.

3.2.1.2 PCBs - Total PCBs were sampled along the coast in several investigations from 1969 through 1976 (figure 3.7). SCCWRP (Data Sets 49, 51, 52, and 57) and the CMW (Data Set 13) analyzed Dover sole or mussels from California and Mowrer et al. (Data Set 59) sampled mussels in Puget Sound. Although no one area stands out with consistently highest levels of PCBs, Orange County, Palos Verdes, and Santa Monica Bay were the areas with the highest levels in Dover sole in 1975 and 1976. In contrast, Santa Catalina Island, the Santa Barbara coast, the northern Channel Islands, the central California coast, Bodega Bay, and all areas of Puget Sound (except Elliott Bay) produced mussels and/or sole with less than 60 ppb mean total PCBs from 1969 through 1976.

3.2.2 Temporal trends

3.2.2.1 DDT - Four studies provided results which stand alone to display temporal trends in DDT levels in California waters (figure 3.8). The NPMP (Data Set 21), Cox (Data Set 66), MacGregor (Data Set 37) and SCCWRP (Data Sets 32, 50, 51, and 68) sampled bivalves, phytoplankton, and fish, respectively between 1949 and 1981. The data from these individual surveys, examined together, are consistent in that they show DDT levels increasing until 1968-1970 (at Monterey Bay and the southern California coast), and decreasing since 1970 (at San Francisco Bay, Anaheim Bay, and the southern California coast). Data from individual surveys are inadequate to determine trends in DDT levels from Oregon and Washington over this time period.

3.2.2.2 PCBs - The CMW (Data Sets 13, 15, and 16) and SCCWRP (Data Sets 32, 35, 48, 49, 51, 57, and 68) sampled PCBs in mussels, sole, or white croaker in California waters beginning in 1971 (figure 3.9). Results show an overall decline in PCB concentrations since 1971 with small peaks in 1975, 1977, and 1979.

3.3 Trend Results from Composited Data

As anticipated, very few single surveys were encountered with analyses of a single taxon that could adequately depict recent geographic trends for the entire U.S. West Coast. Even by compositing data from different sources, a presentation that depicts trends for the whole coast could not be made for some taxonomic groups. However, such a picture can be partially resolved through individual snapshots for selected species during the data rich time intervals 1969-71, 1975-76, and 1979-83.

3.3.1 Geographic trends by taxa

3.3.1.1 Invertebrates Approximately 30 species of invertebrates have been analyzed for chlorinated hydrocarbons since 1965. Fifteen species of bivalves account for the major portion of samples taken, especially in the late 1960s and early 1970s due to the large sampling effort of the NPMP. Oysters and mussels were sampled from Baja California to British Columbia, making them the best single species indicators of geographic trends in chlorinated hydrocarbon levels. Lipid content and shell length were not available for enough samples to use them as data normalizers here.

Coastal mussels (Mytilus californianus) - Coastal mussels are common along the open coast of the western United States, Canada, and Baja California and are commercially harvested on a small scale. Spawning occurs year-round but breeding peaks in July and December in California. They are considered to be good indicators of water quality and have been used in at least two broad scale enviornmental quality monitoring programs: The California State Mussel Watch and the EPA Mussel Watch. Samples have been taken since 1967 along the California coast and transplanted mussels have been used to extend their range of usefulness as a monitoring tool.

DDT - Results of sampling efforts along the California coast since 1969 come from the NPMP (Data Set 21), SCCWRP (Data Sets 48 and 51), Risebrough et al. (Data Set 14), the California Mussel Watch (Data Sets 12, 15, and 16), and Gutierrez-Galindo et al. (Data Set 45). The geographic distribution of DDT levels (figure 3.10) shows that the Palos Verdes Peninsula was the area with the highest body burdens during all three time periods (3,240, 619, and 246 ppb). Between 1969 and 1971 the Orange County coast and Los Angeles Harbor also produced coastal mussels with high levels of total DDT (670 and 570 ppb respectively).

PCBs - The concentration of total PCBs in mussels along the coast shows no one area with levels significantly higher than any other (figure 3.11). Palos Verdes mussels were slightly more contaminated (397 ppb) than others from adjacent areas of southern California (200 ppb or less) during 1969, 1970, and 1971 only. After 1975 mussels from all areas sampled contained less than 100 ppb.

Bay mussels (Mytilus edulis) - Smaller than coastal mussels, bay mussels are commonly found in embayments and sheltered areas of the U.S. West Coast. They are sometimes found on outer coastal rocks and pilings within coastal mussel populations. Spawning occurs during the winter along the California coast. They are rarely eaten in this country, although they are widely utilized where they occur in Europe. Considered especially good indicators of trace metal contamination, they have been sampled well by the NPMP and CMW.

DDT - Results from sampling efforts for total DDT distributions along the coast come from the NPMP, Girvin et al. (Data Set 11), Risebrough et al. (Data Set 14), Cunningham (Data Set 7), CMW (Data Sets 12, 15, and 16), and McCleneghann (Data Set 60). The Santa Barbara coast produced bay mussels with the highest levels of DDT in 1969, 1970, and 1971 (667 ppb); Monterey Bay mussels had the highest levels in 1979-83 (447 ppb - figure 3.12). After 1979, bay mussels from the central California coast, Bodega Bay, and all areas sampled in Puget Sound contained mean levels of total DDT of less than 20 ppb.

PCBs - PCB levels were measured along the coast since 1975 by four investigators (figure 3.13). Results produced by Stout and Lewis (Data Set 5), Mowrer et al. (Data Set 59), Cunningham (Data Set 7) and CMW (Data Sets 15 and 16) indicate no region with excessively elevated levels of PCBs in bay mussels. Mussels from all areas contained less than 160 ppb.

Other invertebrate species - Other invertebrate species have been infrequently sampled along the coast and in very few areas. Therefore, geographic trends in DDT or PCB levels are not discernible. Major data sources for organisms from the lower trophic levels include the SCCWRP food web studies (Data Sets 51, 53, and 68), Malins (Data Set 24), and Munson (Data Set 36). Zooplankton, salps, squid, shrimp, crab, lobster, sea urchin, abalone, clams, mussels, scallops, and oysters were intermittently sampled for their DDT content at a few sites (table 3.3). Total PCBs were determined in these species and in sea cucumbers and worms (table 3.4). Sea urchins from the Palos Verdes Peninsula in 1979 contained the highest levels of DDT and PCBs encountered for these species, almost 4,500 and 1,200 ppb, respectively.

3.3.1.2 Fish - At least 100 species of fish (including sharks and rays) have been analyzed for PCBs or DDT. Data records extend back as early as 1949 for mesopelagic fish in southern California. And in total, the records available cover the entire 6,000 km coast from Alaska to Peru.

Below, geographic trends are reviewed based on the approach outlined in the methods section which groups species by habitat (benthic or pelagic) and feeding guild (benthic, pelagic, or mixed). Lipid content, weight, age, and length were not available for enough samples to invoke normalizing the data here.

Pelagic fish - Sixty species of pelagic free swimming fish have been sampled for total DDT or PCBs. The pelagic fish reported here include ocean run salmon, clupeid fish (e.g., herring and sardine), smelts, some of the pelagic rockfishes (Sebastes), gadids (cods), sablefish, the tuna and tuna-like fish, and the engraulids. For the complete list see tables 3.5 and 3.6.

Pelagic fish dominate U.S. and international commercial marine fish landings in the Eastern Pacific and Alaska. Pelagic fish are somewhat migratory, feeding and moving over large areas. As a consequence, it is presumed that their tissues integrate exposure to contaminants over large areas making them unsuitable as indicators of local contamination. However, pelagic fish may provide great insight into trends in the large-scale, oceanic, or even global distribution of DDT and PCBs, provided samples are available over equally large areas. Pelagic fish are thought to concentrate lipids and their associated pollutants in flesh rather than in the liver as benthic fish may, which would tend to increase their apparent pollutant body burden over that of benthic fish (MacGregor, 1974). Many data sources referenced in this report did not include flesh lipid content for fish samples, making MacGregor's hypothesis difficult to test on a large scale.

Fish group 1: pelagic living, pelagic feeding species - Data were found for chlorinated hydrocarbon residues in 37 species of pelagic living fish which feed exclusively in the water column including shark, tuna, swordfish, bonito, mackerel, salmon, hake, pollock, rockfish, and anchovy. The complete list of group 1 fish species for which data were found is given in table 3.5. Major data sources include Stout and Beezhold (Data Set 8), and the SCCWRP food web studies (Data Sets 53, 57, and 68).

DDT - Levels of total DDT in the early and mid-1970s were surprisingly high in pelagic fish from southern California (figure 3.14). Pelagic fish from Santa Monica Bay contained the highest DDT levels of all regions sampled in 1969, 1970, and 1971 (21,939 ppb), and again during 1979, 1980, and 1981 (353 ppb). Fish from the Santa Barbara coast and Los Angeles Harbor were also highly contaminated in 1969, 1970, and 1971 (containing 8,080 and 3,210 ppb respectively). Coastal areas of Oregon, and the embayments of the Washington coast and Puget Sound produced fish with low mean levels of total DDT (less than 200 ppb) during all three time periods.

PCBs - Levels of total PCBs in pelagic living, pelagic feeding fish show no obvious geographic peak (figure 3.15). Fish from all areas contained less than 250 ppb PCBs. However, fish from Santa Catalina Island and Elliott Bay in 1975 and 1976 and Vancouver, B.C. in 1979 contained highest levels of mean PCBs (between 200 and 250 ppb). After 1979, all areas of the coast sampled except Vancouver, B.C. showed pelagic fish to contain mean levels of total PCBs below 100 ppb.

Fish group 2: pelagic living, mixed feeding species - Pelagic living species which feed in the water column and on the bottom include dogfish, perch, cod, and white croaker. Data were found for chlorinated hydrocarbons in flesh of these and approximately 20 other species which inhabit the nearshore coastal waters and embayments of the West Coast. The complete species list is given in table 3.6. Large-scale data sets for these species include those of SCCWRP (Data Sets 32, 40, 40, 51, and 68), Malins (Data Set 25), and Gadbois and Maney (Data Set 65).

DDT - Total DDT levels in group 2 pelagic fish from the Palos Verdes Peninsula in 1975-76, 1979-81 were excessively high (36,344 and 42,988 ppb), making this area the hot-region of contamination along the coast for these species (figure 3.16). Other areas sampled produced fish with mean levels of total DDT of less than 200 ppb.

PCBs - Total PCB levels in fish from the Palos Verdes Peninsula have also been much higher than those from other areas of the coast (over 2,600 ppb as compared to less than 800 ppb - figure 3.17). Although much lower than the mean levels at Palos Verdes, fish from the northern California coast and northern San Francisco Bay contained relatively high levels of total PCBs (750 ppb and 477 ppb respectively) after 1979. Lowest mean levels were in fish from Puget Sound, Santa Catalina Island, and the southern California coast.

Benthic fish - Approximately 30 species of benthic fish have been sampled for chlorinated hydrocarbons along the West Coast. Some of the species reported here include sanddabs, sculpin, sole, flounder, and scorpionfish (see tables 3.7 and 3.8).

Benthic fish are generally not presumed to migrate far, and thus their proximity to the sediment reservoir of contaminants make them popular choices for the monitoring of chlorinated hydrocarbon residues. Some species support commercial fisheries which also contributes to their popularity among researchers. As with the pelagic fish data, corresponding lipid content for flesh samples were not found for most samples.

Fish group 3: benthic living, mixed feeding species - Benthic fish which feed in the water column and on the bottom include some sculpin, sole, sanddabs, and rockfish. A complete list of these species for which clorinated hydrocarbon data were found is given in table 3.7. Major data sources include SCCWRP (Data Sets 32, 51, 53, and 68), MacGregor (Data Sets 37 and 39), Shaw (Data Set 29), and Gadbois and Maney (Data Set 65).

DDT - Total DDT levels in benthic living, mixed feeding fish species were extremely high in Santa Monica Bay in 1969, 1970, and 1971 (56,000 ppb) and also high around the Palos Verdes Peninsula in 1975 and 1976 (5,433 ppb - figure 3.18). However, by 1979, levels of DDT in these fish from both areas had dropped dramatically to 540 and 350 ppb, respectively.

PCBs - Fish from both the Palos Verdes Peninsula and Elliott Bay in Puget Sound had comparable levels of PCBs in 1975 and 1976 (figure 3.19)-which were only slightly higher than those in other areas (487 and 458 ppb as compared to less than 350 ppb - figure 3.19). By 1979 mean levels in benthic fish had dropped to less than 250 ppb.

Fish group 4: benthic living, benthic feeding species - Five species of benthic living, benthic feeding fish have been sampled along the U.S. West Coast for chlorinated hydrocarbon levels in flesh. The species of sole and flounder are listed in table 3.8. Major data sources for these species include SCCWRP (Data Sets 48, 49, 51, 52, 57, and 68), Malins (Data Set 26), Stout (Data Sets 5 and 8), and MacGregor (Data Sets 37 and 39).

DDT - Total DDT contamination in these benthic species has been highest at the Palos Verdes Peninsula since 1969 (10,357, 17,316, and 5,994 - figure 3.20). Benthic living, benthic feeding fish species from Santa Monica Bay also contained elevated DDT levels in 1969, 1970, and 1971 (5,344 ppb).

PCBs - Total PCB levels show a less-distinct geographic trend than DDT (figure 3.21). Palos Verdes was the region most contaminated with PCBs in 1969, 1970, and 1971 (1,640 ppb). Santa Monica and Elliott Bay fish also contained elevated PCBs in 1975 and 1976 (1,767 and 1,705 ppb respectively), and Elliott Bay fish contained the highest levels of PCBs in 1979, 1980, and 1981 (1,635 ppb). Mean levels of total PCBs in benthic fish have been less than 65 ppb at Santa Catalina Island and the Santa Barbara coast from 1969 through 1976.

3.3.2 Temporal trends by taxa

Results of individual surveys can be combined and compared with those of later years to delineate temporal trends in chlorinated hydrocarbon residues. Such compositing of data sets adds weight to the evidence for temporal trends gathered by multi-year surveys whose results were presented in section 3.2.2. Results presented in section 3.3.1, where compositing by survey was conducted for the three data-rich time periods, can be analyzed for changes in residues with time. Areas where organisms were resampled between 1969 and 1983 include several embayments of Puget Sound and all of California's coastline. In addition to the organisms whose residue levels were composited by survey to produce geographic trends, two organisms were studied by several investigators in the same area over many years. Results of sampling for Japanese littleneck clams in San Francisco Bay and northern anchovy in the Southern California Bight are also presented as indicators of temporal trends in DDT and PCB levels.

3.3.2.1 Invertebrates - Changes in levels of DDT and PCBs with time in coastal mussels can be determined for many areas of the California coast (table 3.9). All areas show apparent declines in total DDT levels between 1969 and 1983, some by more than one order of magnitude. Levels of total PCBs in coastal mussels show declines for most areas of the California coast. Several areas, such as Santa Catalina Island and central California, show small increases, or no change in PCB levels. However, coastal mussels in these areas have also maintained very low PCB levels (below 60 ppb).

Bay mussels have been resampled in California bays and in Puget Sound (table 3.10). Trends in residues are variable. South of

Monterey, DDT and PCB levels have declined since 1969. However, DDT levels north of Monterey and PCB levels in Puget Sound appear to have increased in bay mussels since 1969 and 1975, respectively.

Although chlorinated hydrocarbon levels in oysters have not been determined in recent years from areas sampled in the late 1960s, trends in DDT levels from 1966 through the early 1970s area are apparent (table 3.11). Most areas show increases in DDT residues for this time period, though DDT levels in San Francisco Bay oysters declined. Total DDT levels in Japanese littleneck clams from San Francisco Bay have been determined between 1966 and 1981 (figure 3.22). Levels have declined dramatically according to a compilation of data from EPA (Data Set 38), Girvin et al. (Data Set 11), Kinney and Smith (Data Set 42), and McCleneghann (Data Set 60), since NPMP (Data Set 21) sampled clams from the Bay in 1966.

The results of the intermittent sampling of other invertebrate species showed declines in DDT and PCB levels between 1969 and 1981. Soft shelled clams from San Francisco Bay however, have shown slight increases in DDT levels, though concentrations remain low (less than 25 ppb).

3.3.2.2 Fish - Chlorinated hydrocarbon residues in northern anchovy have been determined from the Southern California Bight (between Pt. Conception and San Clemente) since 1965 (figure 3.23). Risebrough (Data Set 55) discovered high concentrations of DDT and PCBs in anchovy in the late 1960s (up to 14,000 ppb), Stout and Beezhold (Data Set 8) and SCCWRP (Data Sets 51 and 68) discovered much lower residues in later years (below 2,200 ppb).

DDT levels in white croaker from the southern California coast have been determined several times since 1969 (figure 3.24). SCCWRP (Data Sets 32, 40, and 50), Duke and Wilson (Data Set 18), Stout (Data Set 8), and MacGregor (Data Set 39) show DDT levels in white croaker to have declined from 627 ppb to 129 ppb since 1969.

Changes in DDT and PCB levels in pelagic living, pelagic feeding fish (species group 1) can be evaluated between 1969 and 1981 (table 3.13). All areas of the California coast which were resampled show declines in residue levels for this group of fish. The declines in DDT levels in fish from the Santa Barbara coast and Santa Monica Bay approach two orders of magnitude.

Pelagic living, mixed feeding fish (species group 2) have been resampled for their DDT and PCB concentrations only in the Southern California Bight (table 3.14). Total DDT concentrations declined in fish from two areas, while both DDT and PCB levels increased in fish from the Palos Verdes Peninsula.

From 1969 through 1981 benthic living, mixed feeding fish (species group 3) have been resampled for chlorinated hydrocarbon residues at Santa Catalina Island and the Palos Verdes Peninsula (table 3.15). DDT residues declined in both areas, PCBs declined at Palos Verdes and remained low and stable at Santa Catalina Island.

Chlorinated hydrocarbon levels in benthic feeding, benthic living fish (species group 4) were measured from 1969 through 1981 in the Southern California Bight and in Elliott Bay (table 3.16). Total DDT levels in these fish show declines for all areas where they were resampled. Total PCB levels have declined in some areas, and have remained the same or increased in others.

4. DISCUSSION

4.1 Geographic Trends

4.1.1 Concentration patterns

The results presented in section 3 were used to further quantify and identify which areas most frequently produced organisms with highest ranking levels of PCBs and DDT. Evidence for a geographic trend was considered to exist when one taxa (or species group) was sampled in more than two areas during one time period. The areas where highest levels of contaminants were reported were sorted by time period and decreasing frequency of highest values to produce a ranking of regions by relative degree of contamination.

Potential sources of DDT are from wastes produced in the manufacture of DDT which were dumped into the ocean off Los Angeles and discharged into the Los Angeles County sewer system which discharges off Palos Verdes Peninsula, and from the application of DDT to agricultural and forest lands. These sources would make the Southern California Bight, especially the Palos Verdes Peninsula, central California, Monterey Bay, San Francisco Bay, the Columbia River Estuary, and the Skagit River Delta areas where elevated DDT levels might be found in marine organisms.

As expected, the areas with highest levels of DDT in marine organisms are centered around the Palos Verdes Peninsula (Tables 4.1, 4.2, and 4.5). The samples with the highest levels of total DDT (up to 200,000 ppb in a spiny dogfish in 1981) came from the waters of the Palos Verdes Peninsula. This is the area which most often has produced fish and shellfish with maximum levels of total DDT. Santa Monica Bay ranked second as an area with high levels of DDT in fish (up to 76,300 ppb in a rockfish in 1970). Other areas of the Southern California Bight: Orange County, Los Angeles Harbor, southern California, and Santa Barbara, have produced fish with elevated levels of DDT (up to 31,000 ppb in a Dover sole from southern California in 1974). The only exception to this dominance by southern California of the maximum DDT levels is Monterey Bay, which was the area with the highest mean level of DDT in bay mussels: 447 ppb in recent years.

Regions where mean DDT levels do not fit the expected relationship with agricultural use include central California, San Francisco Bay, the Columbia River Estuary, the Skagit River Delta, and the Fraser River Estuary, where DDT levels have been relatively low.

Potential sources of PCBs are in areas of high population density where there is heavy use of electrical equipment. Such areas include the urbanized bays of the coast, Puget Sound, San Francisco, and the Southern California Bight.

As expected, areas where highest levels of PCBs occur in marine organisms are urbanized (Tables 4.3, 4.4 and 4.5). Highest concentrations of PCBs have occurred at the Palos Verdes Peninsula (up to 14,800 ppb in a spiny dogfish in 1981). Especially since 1979, fish and shellfish from Elliott Bay have also contained high levels of PCBs (up to 5,900 ppb in an English sole in 1976).

Fish from Vancouver, B.C. have ranked second in terms of their frequency of highest total PCB levels since 1979, although mean levels have not exceeded 250 ppb.

Fish and shellfish from Santa Monica Bay and the Orange County coast have also contained high levels of PCBs (up to 6,420 ppb in a striped mullet from Orange County in 1978). Fish from Commencement Bay have also contained relatively high levels of PCBs (up to 714 ppb in an English sole in 1980).

Regions which are exceptions to the expected relationship between urbanization and mean PCB levels include San Francisco Bay and San Diego Harbor which are highly urbanized, but where total PCB levels were not discovered to be among the highest relative to other areas.

4.1.2 Seafood action limits and wildlife protection criteria

Levels of DDT and PCBs measured in previous surveys and presented in this report were compared to FDA action limits and wildlife protection criteria established for these compounds. The U.S. FDA has set action limits for DDT and PCB compounds at 5,000 and 2,000 ppb respectively. Action levels are temporary until formal safety limits are determined (Hui, 1979). The EPA has suggested food limits of 200 ppb DDT (Konasewich et al., 1982) and 500 ppb PCB (EPA, 1976).

Samples of edible tissues which exceeded the FDA seafood limits for DDT and PCBs have been uncommon in most areas (Tables 4.6 and 4.7). Two sand crab samples from Orange County in 1970 or 1971 contained more than 5,000 ppb total DDT (7,248 in 1970 and 5,640 in 1971), and two yellow crab samples from Santa Monica Bay in 1972 contained more than 2,000 ppb total PCBs (2,100 and 2,900 ppb). Although the maximum concentrations of DDT and PCBs measured in fish flesh have been high (200,000 ppb total DDT and 14,800 ppb total PCBs in spiny dogfish from Palos Verdes in 1981), the number of fish samples found which have exceeded FDA limits is 46 for PCBs and 120 for DDT, out of approximately 1,000 flesh samples available for this analysis.

Mean levels of total DDT in composited fish groups have exceeded the FDA limit in three areas of southern California. In 1969, 1970, and 1971 DDT levels in pelagic (group 1) and/or benthic fish (group 4) from the Santa Barbara coast, Santa Monica Bay, and the Palos Verdes Peninsula exceeded 5,000 ppb. In 1975 and 1976, DDT levels in pelagic fish (group 2) and both groups of benthic fish from Santa Monica Bay and/or the Palos Verdes Peninsula exceeded 5,000 ppb. By 1979, mean levels of DDT in these same groups of fish (2, 3, and 4) were exceeding the FDA limit only at the Palos Verdes Peninsula.

Samples of edible tissues which exceeded the FDA limit by mean levels in composited fish groups for PCBs have been much less common than for DDT. Only at the Palos Verdes Peninsula, and only in pelagic fish (group 2) has the limit of 2,000 ppb been exceeded by composited samples. This occurred between 1974 and 1982.

Several local public health agencies have disputed that FDA action limits are low enough to protect frequent consumers of seafood against cancer. Warnings against heavy consumption of locally-caught seafood, based in part on estimates of cancer risk due to DDT and PCB levels have been issued for four Puget Sound embayments, Santa Monica Bay, Palos Verdes, Los Angeles Harbor, and the mouth of the Tijuana River. While no agency has recommended specific concentrations below which there is an acceptable risk, some investigators have suggested seafood levels above which the risk of cancer would exceed 1 in 100,000 (10^{-5}). For the average per capita U.S. seafood consumption rate of 9.3 gm/day of domestic estuarine and marine fish, the limits for this cancer risk would be 18 ppb for PCBs and 320 ppb for DDT (computed by D. Brown, personal communication).

Inspection of all the graphs and tables presented here indicates that mean levels of total DDT have exceeded the limit for a cancer risk of 10^{-5} (320 ppb) in fish and shellfish in as many as ten areas of California (from Monterey to the Mexican border) since 1969. Fish and shellfish which have been sampled north of Monterey Bay have contained less than 320 ppb total DDT.

Mean levels of total PCBs have exceeded the limit (18 ppb) for a cancer risk of 10^{-5} in fish and shellfish in nearly all areas sampled. The coast and embayments of Washington, Oregon, and California have all produced fish or shellfish with PCB concentrations in excess of 18 ppb at some time since 1969. Bodega Bay, California, Hood Canal, Washington, and the Rogue River, Oregon are three exceptions to this.

Several groups have recommended upper limits for levels of PCBs and DDT in fish to protect the birds, mammals, and marine life which consume fish. The International Joint Commission (IJC, 1977), the U.S. National Academy of Sciences, and the Academy of Engineering (U.S. NAS, 1973) have recommended limits of 1,000 ppb DDT in fish based on levels which have caused problems in bird reproduction. A limit of 500 ppb total PCBs (U.S. NAS, 1973) has been recommended by the latter groups. The American Fisheries Society (1979) has recommended a PCB limit of 100 ppb because of the cessation of reproduction in ranch mink fed a beef diet containing 640 ppb of Aroclor-1254.

The limits which have been recommended to protect wildlife populations have been commonly exceeded in edible tissues of organisms along the coast. Monterey Bay, Santa Monica Bay, the Palos Verdes Peninsula, and Los Angeles Harbor have produced sea urchins, mussels, crabs, oysters, or fish with mean levels of DDT exceeding 1,000 ppb. Because the most conservative recommendation for a wildlife protection limit for PCBs is low (100 ppb), there are few areas where edible tissues of invertebrates or fish have not exceeded this limit. These areas include Baja California, the outer California coast between Pt. Conception and Bodega Head, the outer Washington coast, and northern

Puget Sound. However, these are also among the least frequently sampled areas, especially for PCB levels in fish flesh.

4.2 Temporal Trends

4.2.1 Concentration patterns

Temporal trends were evaluated by compiling the magnitude and direction of changes in contaminant levels for each area resampled since 1959. The changes were averaged, giving more weight to magnitudes of change greater than 10 and to more recent changes, and are summarized in figure 4.2.

The effect of regulating DDT and PCB manufacture and use was examined using the data presented in section 3. In 1970 the discharge of pesticide waste into the Los Angeles County sewage system was discontinued (MacGregor, 1974), in 1972 the use of DDT was banned in the United States, and in 1982 production of DDT for foreign export was discontinued by the sole U.S. manufacturer. In 1979 the production of PCBs was discontinued in the United States and the EPA began regulating the use and disposal of PCBs.

DDT levels have declined sharply since regulation of its use and ocean disposal in 1970. Schafer (1984) clearly documented decreasing inputs from sewage over this time period as a consequence of industrial source control. The response of marine organisms to these declining inputs, since 1970, are clearly illustrated in figures 3.8, 3.22, and 3.23a and table 4.8, and is especially strong around the major input area (Palos Verdes). Decreases in PCB levels since its regulation and source control are apparent but are not as strong as for DDT. Declines appear to have been sharpest around 1974 (before regulation) and are illustrated in figures 3.9, 3.23b, and table 4.9.

The entire Southern California Bight and the central California coast show strongly decreasing levels (up to 100 times less) of total DDT in nearly all groups of fish and shellfish since 1969 (table 4.8). Smaller decreases in oysters or mussels are noted along the northern Baja California coast, the San Diego coast, and the outer coast between San Francisco and Bodega Head since 1969. In contrast, Monterey Bay, San Francisco Bay, and the northern California coast show small increases in levels of DDT in shellfish since 1969. Levels of DDT in pelagic fish from Elliott Bay have decreased slightly since 1969.

PCB levels in fish and shellfish appear to be decreasing dramatically in the northern Channel Islands, along Palos Verdes Peninsula, and the southern California coast and decreasing slightly in fish and shellfish from Elliott Bay, Bodega Bay, central California coast, and along the Orange County and San Diego coasts (table 4.9). PCB levels in mussels from Commencement Bay show no change since 1975 while PCB levels in Dover sole from Santa Monica Bay have increased slightly since 1969.

4.2.2 Contamination levels exceeding current seafood action limits since 1969

The frequency of levels of contamination exceeding FDA limits by fish samples is lessening with time. Only 12 (out of 318 total) samples of fish flesh were discovered which exceeded 5,000 ppb of total DDT between 1977 and 1981, compared to 108 (out of 318 total) samples which exceeded the limit before 1977 (table 4.6). The FDA limit for PCBs was exceeded by only 6 (out of 292 total) samples of fish flesh between 1977 and 1981, in fish from Puget Sound, Palos Verdes, and Orange County (table 4.7). Before 1977, 40 (out of 369 total) flesh samples were found from California and Puget Sound waters where PCB levels exceeded the limit.

The level of total DDT required to produce a cancer risk 10^{-5} (320 ppb) has been exceeded in fewer places since 1979 than in 1969, 1970, and 1971. In 1969, 1970, and 1971 the mean level of total DDT in fish and shellfish exceeded 320 ppb in nine California areas between Monterey Bay and Mexico. Between 1979 and 1983 only Monterey Bay, Santa Monica, Palos Verdes, Los Angeles, and Orange County produced fish (or shellfish) with total DDT levels above 320 ppb.

A similar trend can be seen for PCB levels. The level of total PCBs required to produce a cancer risk of 10^{-5} (18 ppb) has been exceeded by fish and shellfish in many areas along the coast, from all three states. These high levels of contamination continued to occur, but between 1969 and 1976 only two areas produced shellfish with levels of PCBs below 18 ppb, whereas, since 1979, fish and shellfish from 13 areas have contained less than 18 ppb total PCBs.

4.3 Data Gaps

4.3.1 Gaps in geographic trend data

The status of contamination of organisms with DDT and PCBs is uncertain for some areas of the U.S. West Coast. Many areas appear to be relatively clean but also have not been well sampled. Organisms from Baja California, the outer California coast between Pt. Conception and Bodega Head, the Washington coast, and northern Puget Sound appear to be relatively uncontaminated with PCBs based on results for mussels, pelagic fish (group 1), and benthic fish (group 4). Mussels and fish (groups 2 and 4) from San Diego Bay and San Francisco Bay are cleaner than expected given the size of the adjacent human population and level of industrialization. However, all these areas need to be sampled to confirm that they are relatively clean and that levels are not increasing.

4.3.2 Gaps in temporal trend data

Long-term temporal trends in DDT and PCB levels cannot be evaluated for much of the U.S. West Coast because of inadequate sampling over the last 20 years. Long-term trends in DDT levels with time cannot be evaluated between California and Elliott Bay. This is primarily due to a rarity of historical sampling for DDT in Washington and Oregon.

Trends in PCB levels with time cannot be evaluated for Baja California, Los Angeles Harbor, California bays and coast north of Monterey, Oregon's estuaries, and for the outer coast of Washington.

Temporal trends identified on the basis of limited sampling results also indicate areas with data gaps. Trends in DDT levels in Monterey Bay, San Francisco Bay, northern California, and Elliott Bay are based upon too little data to assure accuracy. PCB trends in organisms of Santa Catalina Island, Santa Monica Bay, the Santa Barbara coast, southern Puget Sound, and Commencement Bay are relatively uncertain due to the limited sampling there over time.

4.3.3 Gaps in data among species

Many species have been so rarely sampled that any trends in their DDT or PCB levels cannot be discerned.

The only fish species sampled well enough over space and time to enable large-scale single species trend analysis is Dover sole from southern California. All other fish species, from sharks down to anchovy, have been sampled too infrequently and over too small an area to obtain large-scale spatial and temporal trends. The crustaceans provide limited trend data, and only for commercially utilized species, especially shrimp and crab. Other crustaceans which contribute heavily to the diets of benthic fish, juvenile fish of pelagic species, and shore birds, have been undersampled. Among the mollusks, the bivalves have been sampled well and continue to be (except for oysters). The largest sampling gap among the mollusks is of squid, which supports a relatively large recreational and commercial fishery. There is a clear need to resample commercial fisheries stocks on a large scale.

Other obvious gaps include echinoderms and annelids. Chief among these are the pollution sensitive brittle star and the pollution tolerant sea urchin. The latter has become a major nuisance at several waste disposal sites. Selected taxa of polychaetes, which dominate the infauna and food chains of contaminated ecosystems, are also seriously undersampled.

5. SUMMARY AND CONCLUSIONS BY REGIONS

This section repeats much of the information presented above, but reviews it explicitly from the viewpoint of each region. Regional summaries are presented in order of decreasing severity of contamination by DDT or PCBs. Because this report evaluates large-scale, long-term trends in DDT and PCB levels, any conclusions which are made are only valid over these large scales. It is recognized that local conditions may result in sites where trends are not the same as those apparent from a regional evaluation effort such as this one.

Areas were ranked according to their frequency of highest levels of DDT or PCBs found in fish and shellfish. Areas considered to be the most contaminated were those where the highest levels were found most frequently. Less contaminated areas were those with a lower incidence of highest levels. The least contaminated level included areas where levels were often in the top three but rarely highest.

1. Palos Verdes has and continues to be the area with the highest frequency of maximum DDT levels in fish and shellfish. Prior to 1979 it was also the area where highest levels of PCBs were most often discovered. In more recent years it has ranked third in its frequency of highest levels of PCBs in fish and shellfish. Levels of DDT and PCBs have declined since 1969 in fish and shellfish (by up to 17 times). As the site of a major outfall which has discharged pesticide manufacturing waste, and the site of ocean dumping of such waste, it was not surprising that organisms from this area reflect such inputs. The Palos Verdes Peninsula has been well sampled since the late 1960s, and evidence for declining levels of DDT and PCBs in marine life of this area is plentiful. The Palos Verdes Peninsula is also the area where samples of fish flesh have most often exceeded FDA limits for DDT and PCBs.

2. Since 1979, Elliott Bay has been the area with the highest frequency of maximum levels of PCBs in fish and shellfish. From 1969 through 1976 it ranked second in frequency of highest PCB levels. DDT levels have been low (less than 50 ppb) in fish and shellfish from Elliott Bay, and have declined slightly in pelagic fish since 1969. PCB levels in caridean shrimp and English sole from the Bay have also slightly declined since 1975. Elliott Bay, which is here considered to include the Duwamish River, is adjacent to a highly industrialized and populated area with many sources of PCBs. Levels of PCBs in the flesh of English sole from the Bay have exceeded the FDA limit for PCBs in 1976 and 1980.

3. Santa Monica Bay has and continues to be the area with the second highest frequency of maximum levels of DDT in fish and shellfish. Prior to 1979 it ranked third in frequency of highest levels of PCBs in fish and shellfish. Levels of DDT in pelagic fish in the Bay have declined up to 100 times since 1969, while PCB levels in Dover sole increased slightly between 1969 and 1976 (from 946 to 1,767 ppb). Sole from Santa Monica Bay should be sampled for their PCB levels to confirm this apparent trend. DDT in sole and sablefish from Santa Monica Bay exceeded FDA limits in 1970 and 1971, but not in more recent years.

Levels of PCBs in Dover Sole from Santa Monica Bay exceeded the FDA criteria in 1972 and 1975.

4. The waters of Burnaby Inlet and the Fraser River Estuary (Vancouver, B.C.) have been ranked second in their frequency of highest levels of PCB contamination since 1979. This is the result of relatively high levels in fish (group 1 and group 3), which although less than 250 ppb, still exceeded those of other areas sampled. Data to provide temporal trends in PCBs in these fish are lacking, as well as information on total DDT levels in organisms from this area.

5. Since 1979 Monterey Bay has been ranked third in its frequency of highest levels of DDT in fish and shellfish. PCB levels in Monterey Bay shellfish and fish have been less than 25 ppb in mussels and 250 ppb in fish, but infrequently determined. DDT levels in oysters, phytoplankton, and bay mussels have increased since 1959. Levels of DDT in bay mussels have increased four times to almost 450 ppb between 1974 and 1984. Further sampling should be conducted to validate this apparent trend. As a major agricultural center, shellfish around Monterey Bay might be expected to contain high pesticide levels.

6. The marine waters of Orange County and Los Angeles Harbor have in the past and continue to be ranked third, along with Monterey Bay, for their frequency of high levels of DDT in fish and shellfish. With the exception of Dover sole, levels of PCBs in fish and shellfish from these areas have generally been low. Levels of DDT in mussels and fish have declined since 1969 by up to 20 times. PCB levels have declined in mussels from Orange County since 1969 and increased in benthic fish between 1969 and 1976. Data to determine temporal trends in PCB levels from Los Angeles Harbor was not encountered. Fish from Orange County have occasionally exceeded the FDA limit for DDT and PCBs (in 1974, 1975 and 1978). Orange County and the area around Los Angeles Harbor are highly developed, with many potential sources of PCBs.

7. Prior to 1979, the southern California coast (as defined in figure 3.4) and the Santa Barbara coast were ranked third in their frequency of high levels of DDT in fish and shellfish, along with Orange County and Los Angeles Harbor. DDT levels have declined since 1969 in fish and shellfish (by up to 20 times). PCB levels have declined by up to 167 times in southern California fish or shellfish since 1969. Temporal trend information for PCBs in organisms from the Santa Barbara coast is scarce, but levels in Dover sole remained the same from 1969 through 1976 (60 ppb). Further sampling should be conducted to validate this apparent trend. Pacific bonito from the Santa Barbara Channel (in 1971) and Dover sole or mackerel from the southern California coast in 1970 and 1974 have exceeded the FDA limit for DDT. Dover sole from the southern California coast exceeded the FDA limit for PCBs in 1974.

8. Since 1979, Commencement Bay (now an EPA Superfund Site) has been the ranked third for its frequency of high levels of PCBs in fish and shellfish, along with the Palos Verdes Peninsula. Levels of DDT in fish and shellfish from the Bay are low, less than 15 ppb. Data to determine temporal trends in PCBs from the Bay are scarce, though levels of PCBs in bay mussels have remained unchanged between 1974 and 1984 (55 ppb).

Further sampling should be conducted to validate this apparent lack of a trend. No fish samples have been discovered which have exceeded the FDA limit for PCBs.

9. From Baja California to Monterey, DDT levels have decreased since 1969 by magnitudes of up to 100 times. The regulation of DDT has had greatest effect here, with abundant evidence of decreases in fish and shellfish.

10. From San Francisco to the Oregon Border, DDT levels in shellfish have increased in some places and decreased in others since 1966, but, with the exception of levels in bay mussels from northern San Francisco Bay (which increased to 78 ppb), levels remain below 40 ppb.

11. Although data exist on levels of DDT and PCBs in fish and shellfish between the Oregon-California border and Puget Sound, they were insufficient to determine geographic or temporal trends. Levels of DDT and PCBs appear to be low.

12. PCB levels in organisms along the coast have declined in most areas where they were resampled since 1969 (eight out of 13 areas). Strongest declines have occurred in organisms from the southern California coast, the Palos Verdes Peninsula, the northern Channel Islands, and Bodega Bay.

13. PCB levels have increased in bay mussels from southern Puget Sound (from 22 to 90 ppb since 1975) and remain uncertain off Santa Catalina Island, where levels have increased in some organisms, and decreased in others.

14. Because many areas of the coast have not been heavily sampled, large-scale, long-term trends either cannot be discerned or need further validation. Tables 5.1 and 5.2 review sampling needs to fill gaps in apparent trends or to validate them. Future sampling should emphasize commercially utilized species in areas which appear to be relatively uncontaminated by DDT and PCBs. Most of the large urbanized embayments of the coast have been adequately sampled to determine large-scale, long-term trends in DDT and PCB contamination of their fish and shellfish populations.

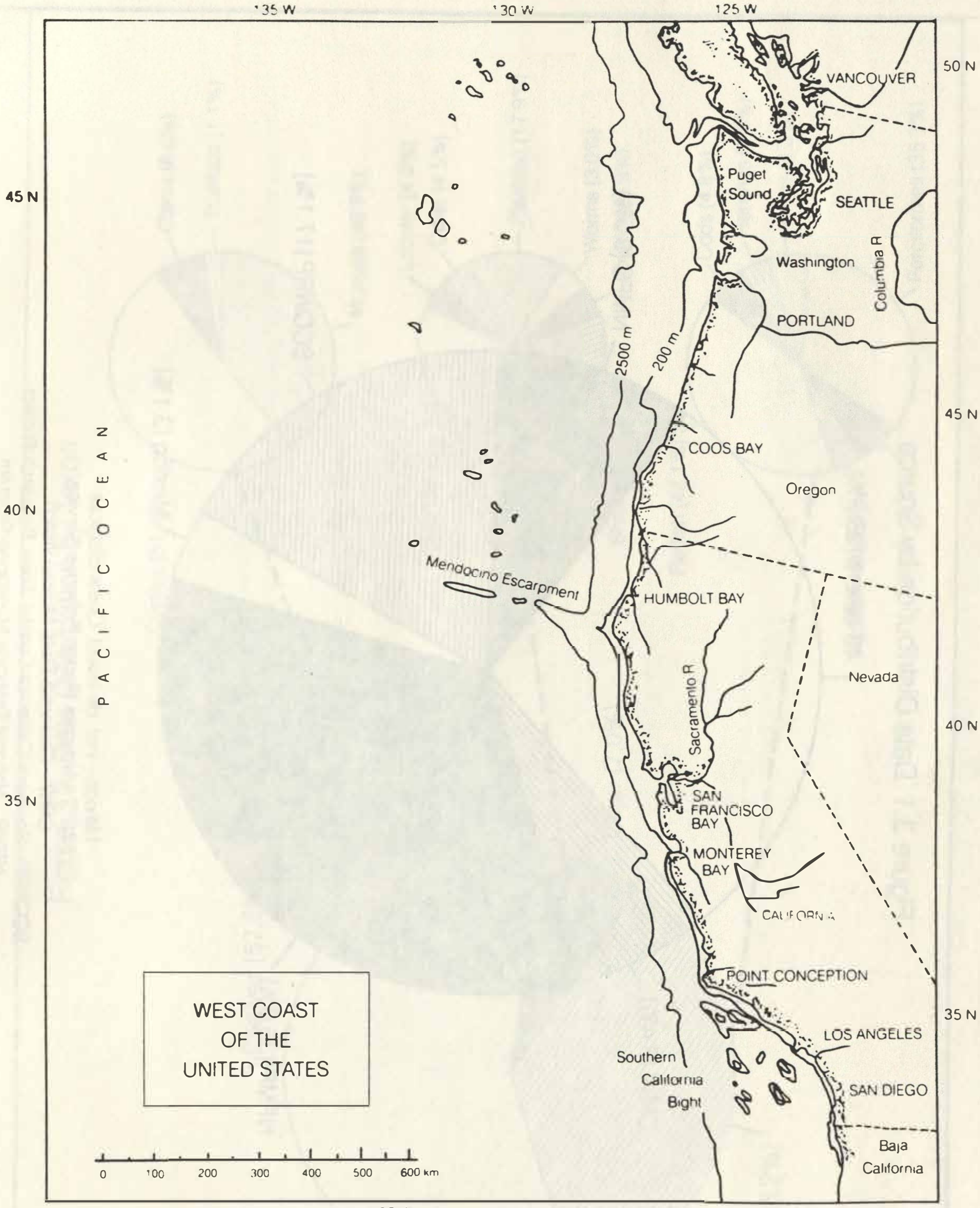
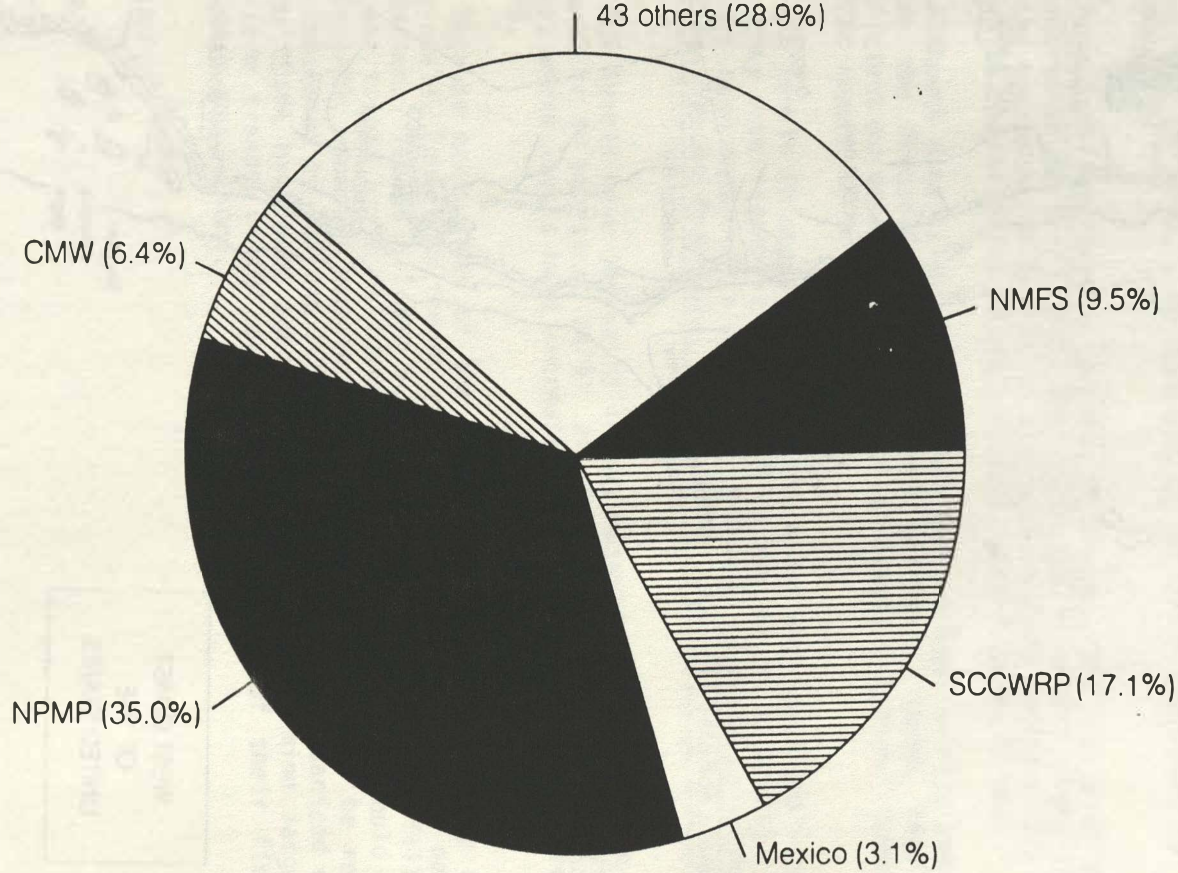


Figure 1.1 West Coast of the United States.

Figure 3.1 Data Distribution by Source



Mexico—Inst. de Invest. Oceanologicas
NMFS—National Marine Fisheries Service
CMW—California State Mussel Watch
SCCWRP–Southern California Coastal Water Research Project
NPMP—National Pesticide Monitoring Program

Figure 3.2 Data Distribution by Taxon

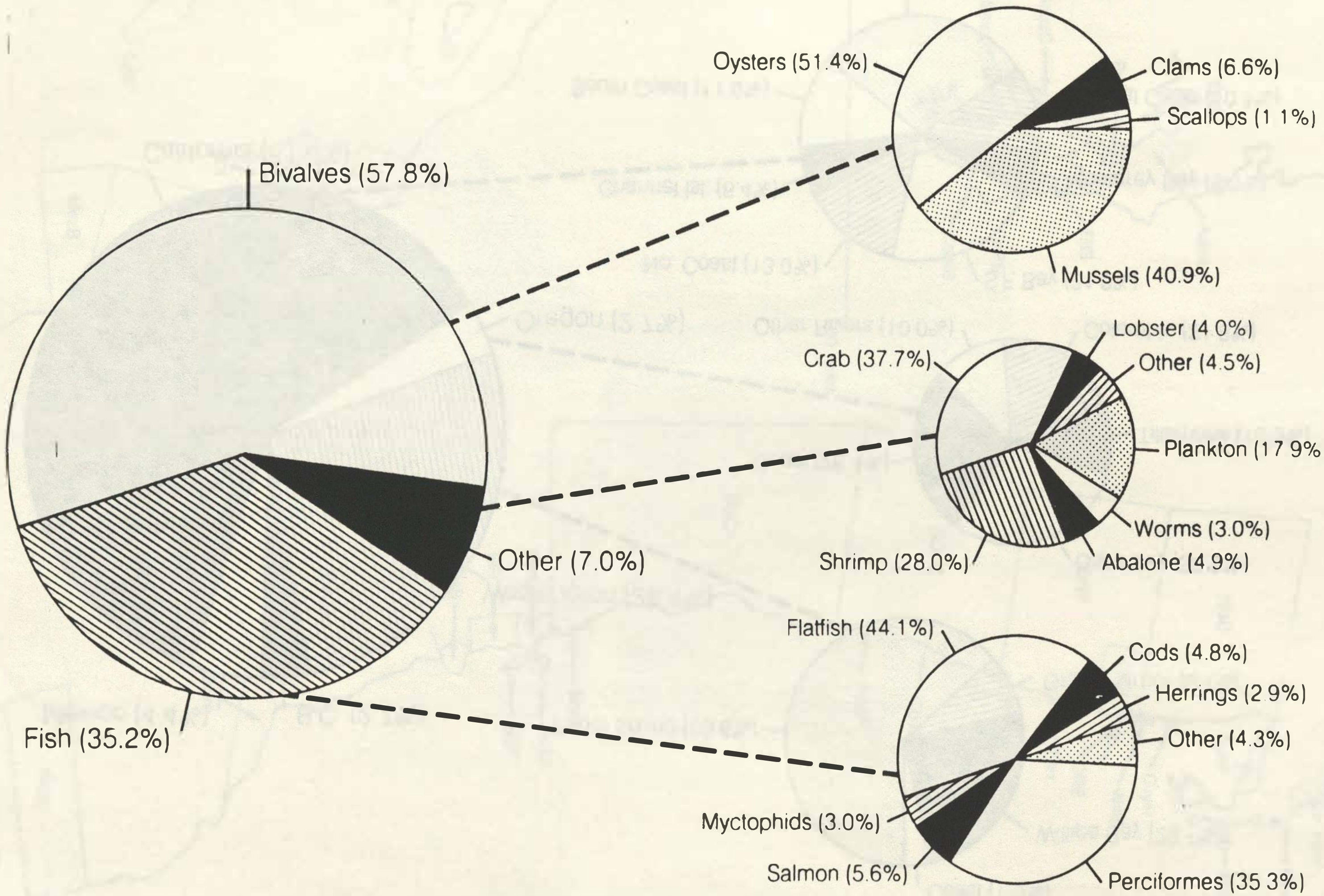


Figure 3.3 Data Distribution by State and Area

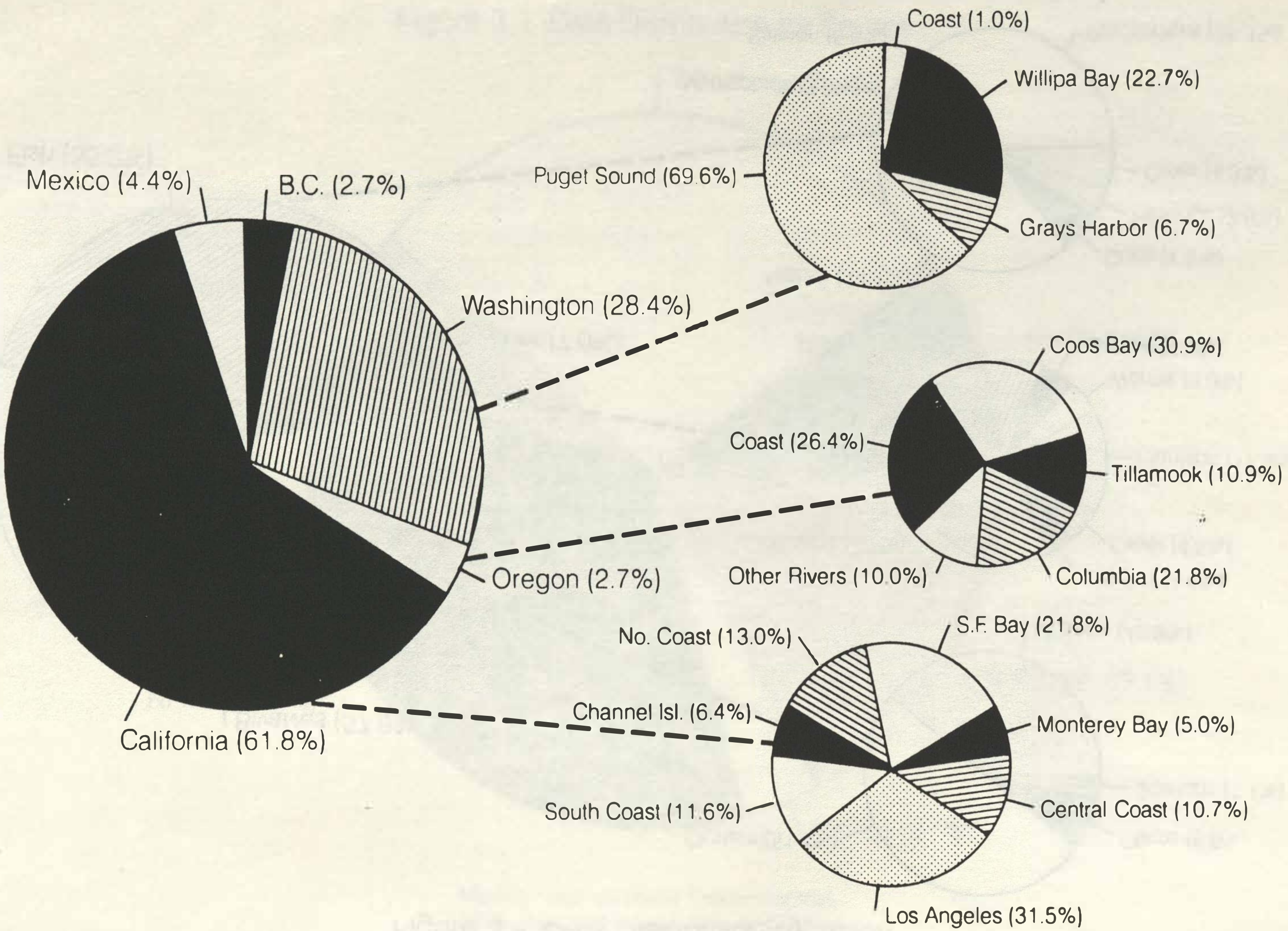


Figure 3.4 Area Locations and Boundaries

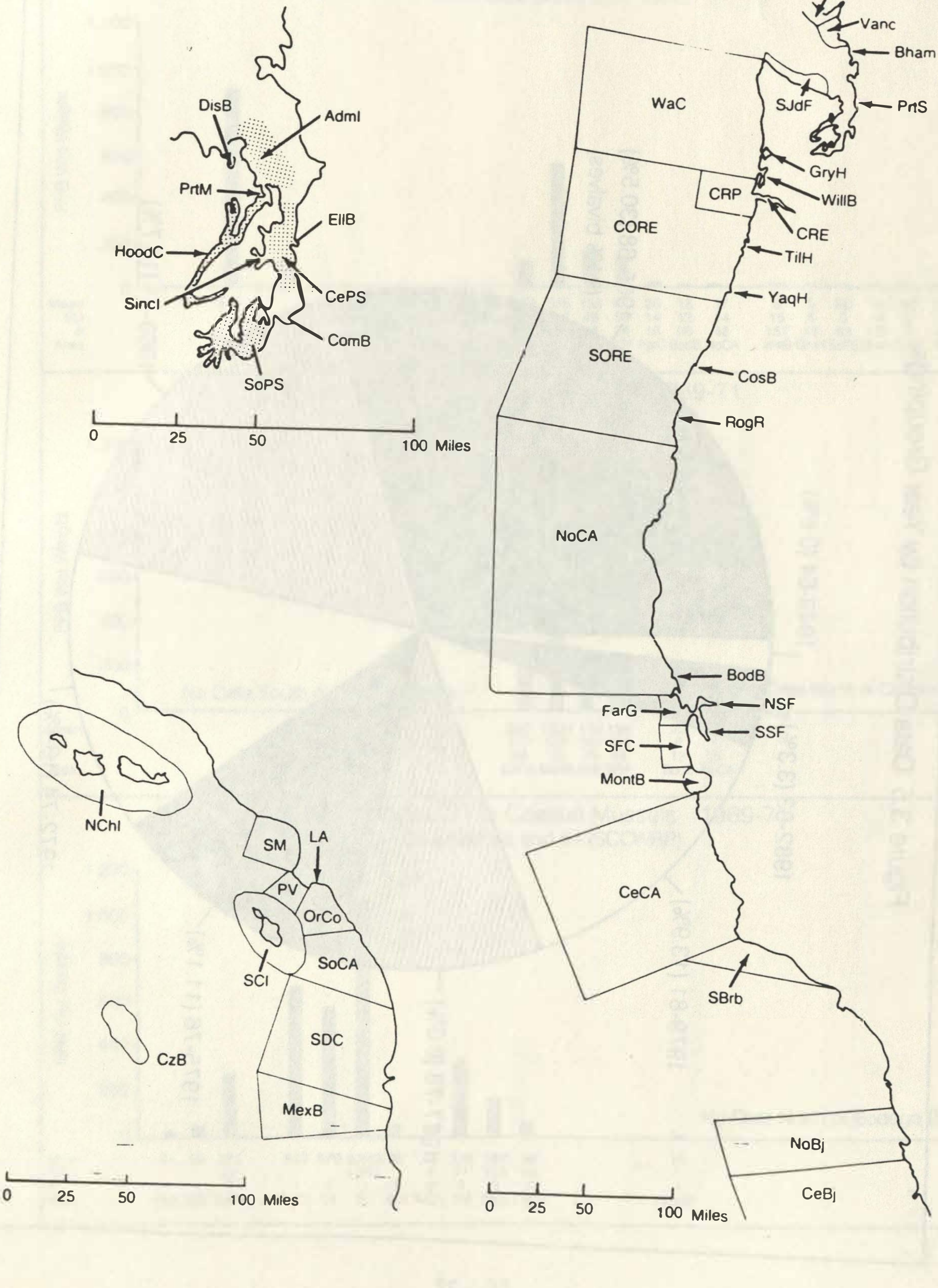


Figure 3.5 Data Distribution by Year Groupings

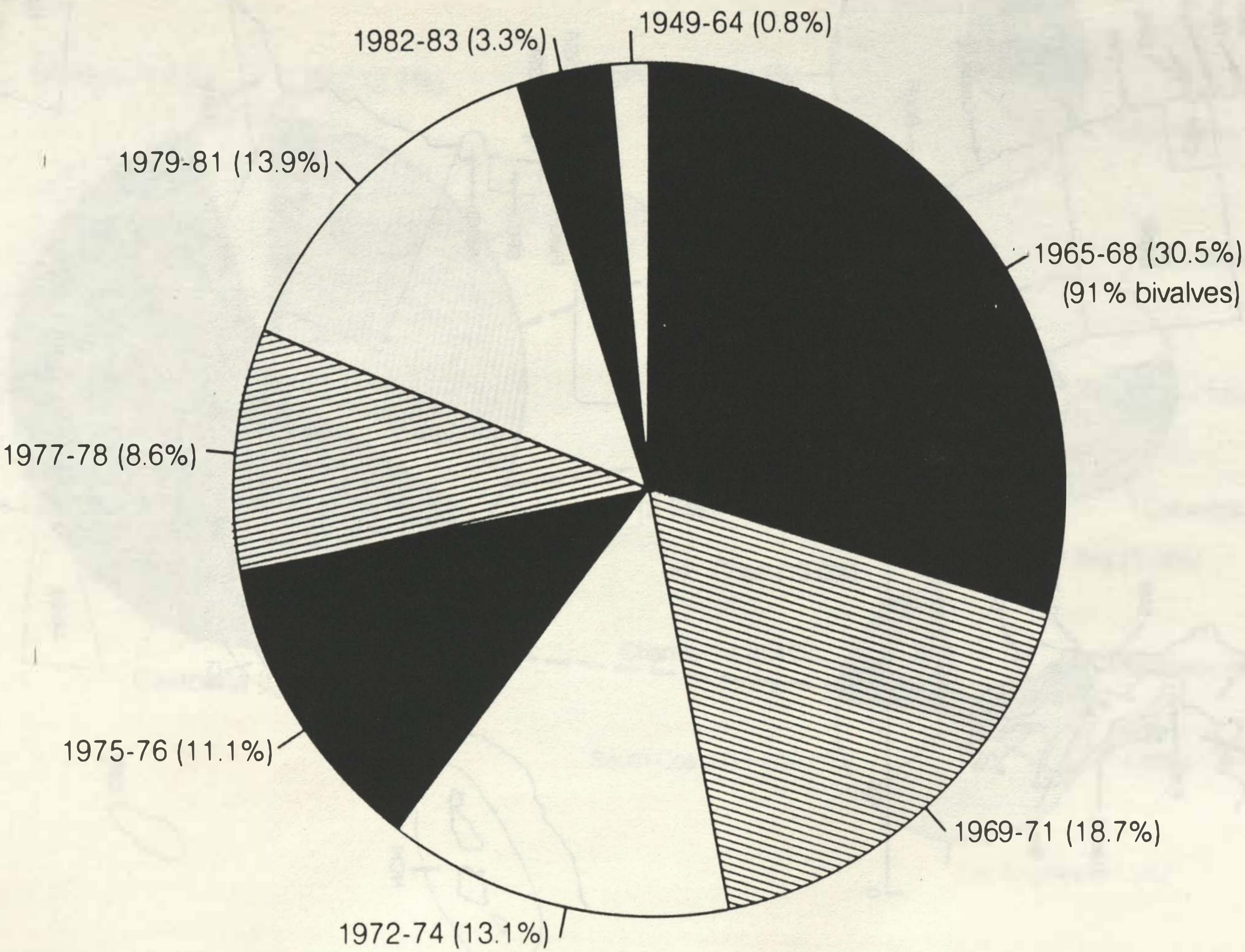


Figure 3.6a Total DDT in Oysters 1966-67
From Data Set 21

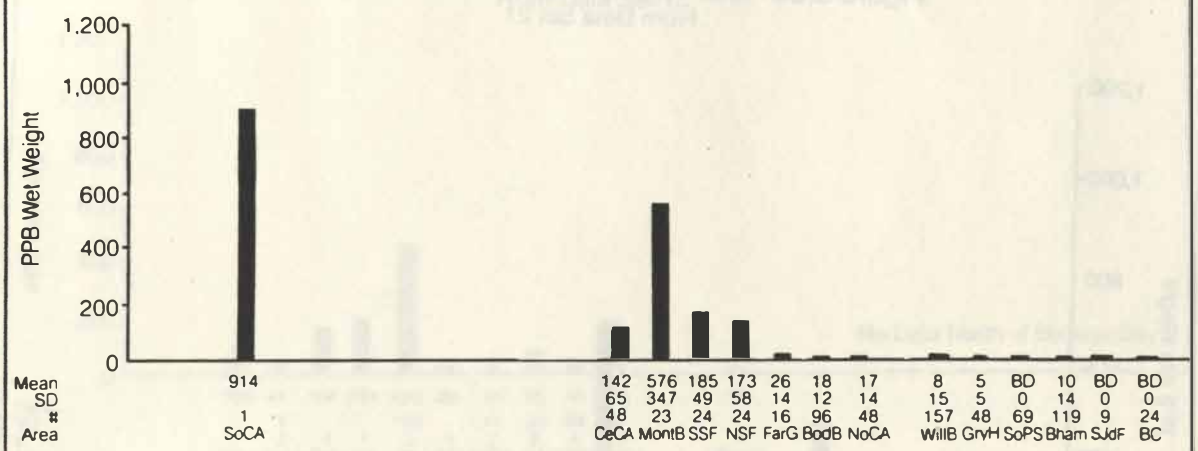


Figure 3.6b Total DDT in Oysters 1969-71
From Data Set 21

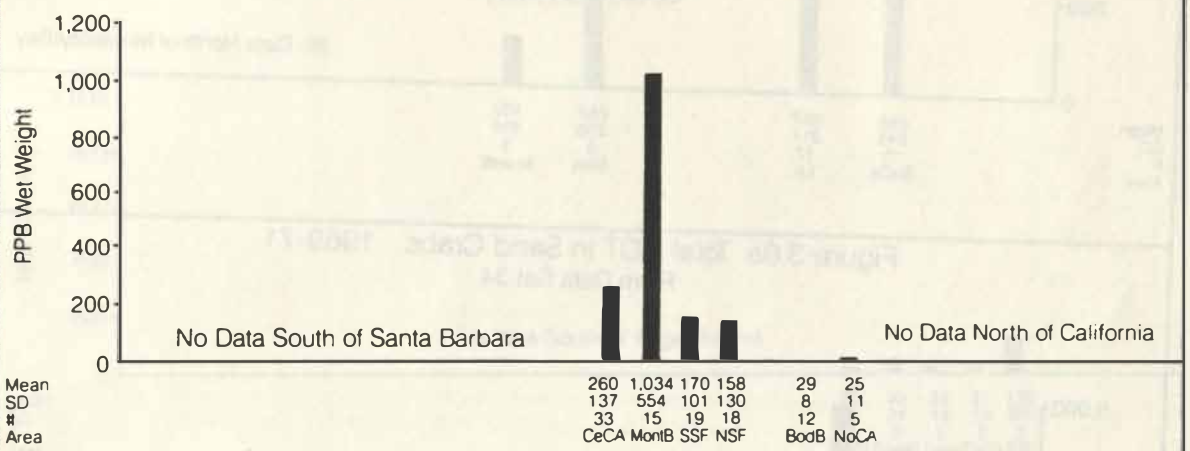


Figure 3.6c Total DDT in Coastal Mussels 1969-71
From Data Sets 48 and 51 (SCCWRP)

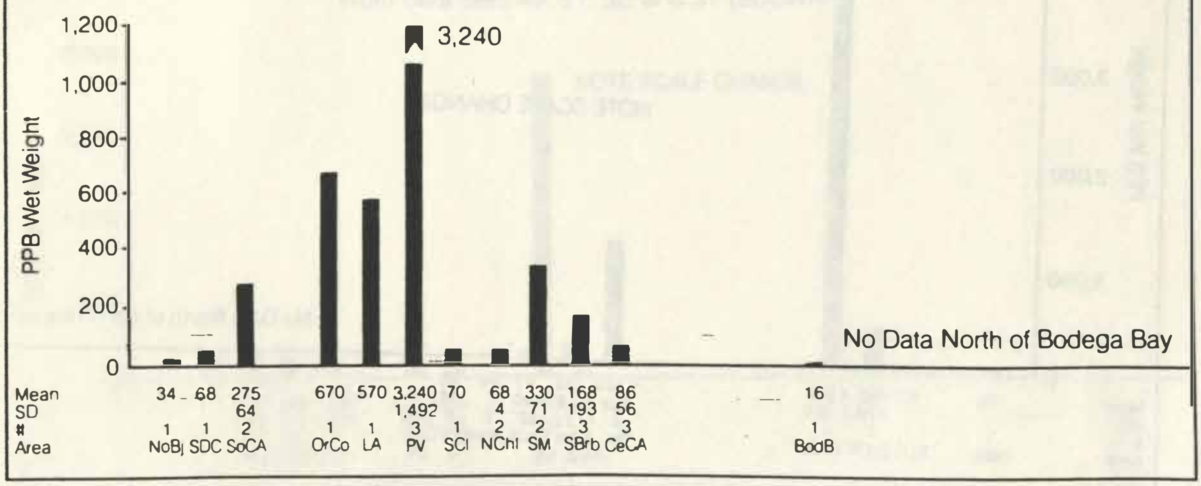


Figure 3.6d Total DDT in Bay Mussels 1969-71
From Data Set 21

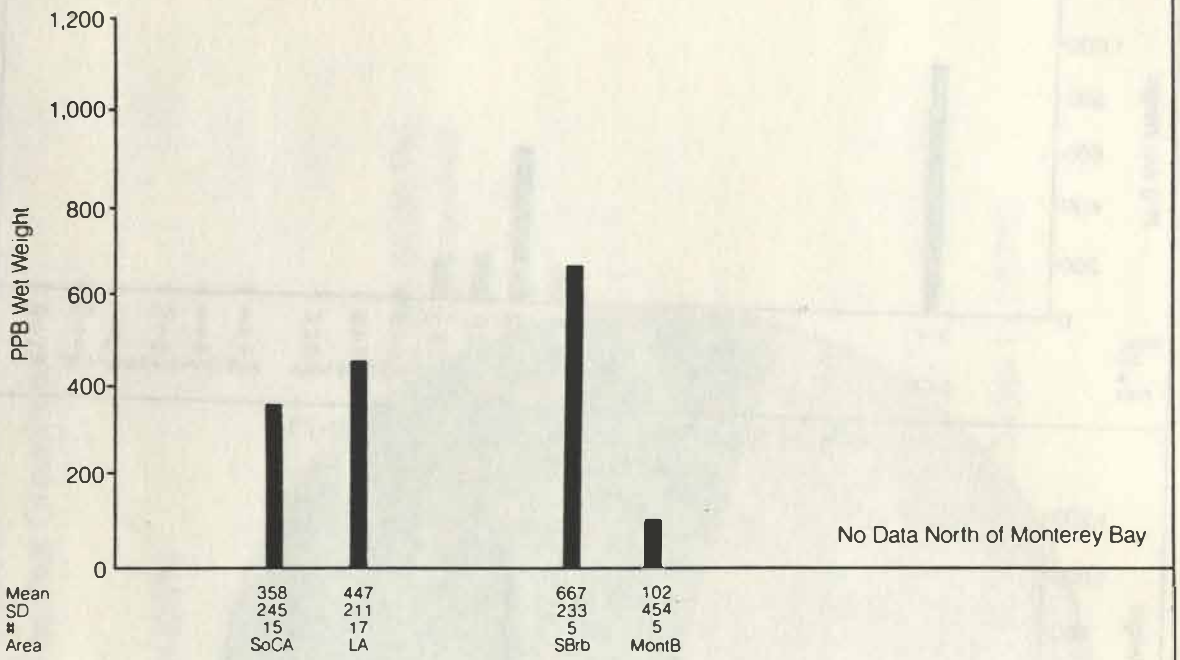


Figure 3.6e Total DDT in Sand Crabs 1969-71
From Data Set 34

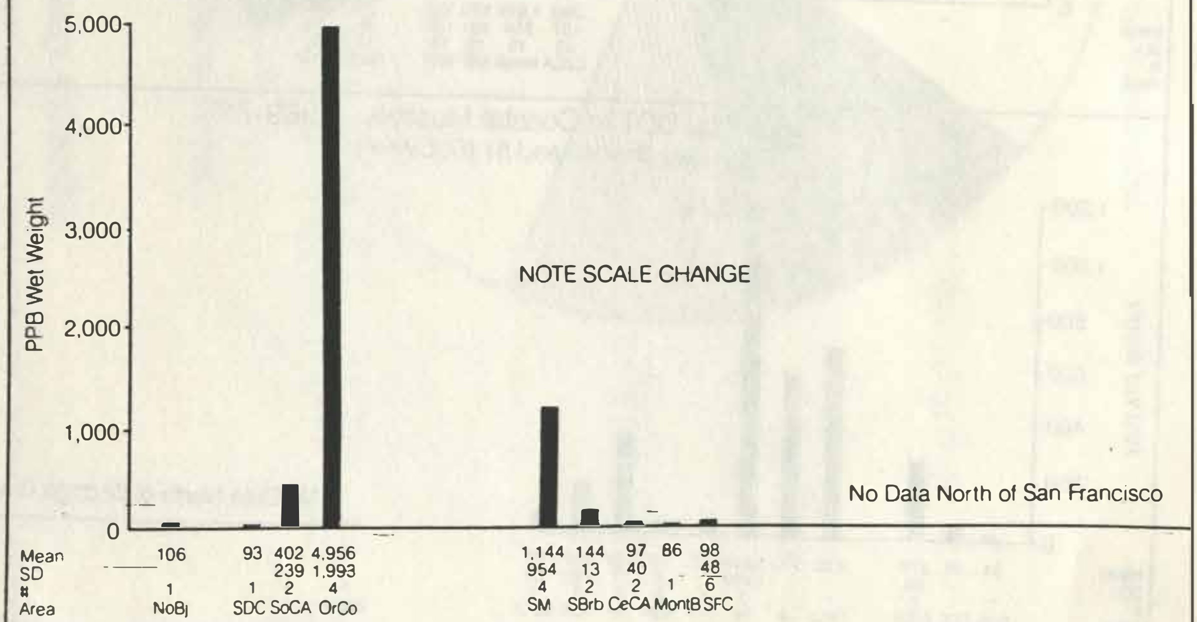


Figure 3.7a Total PCBs in Coastal Mussels 1969-71
From Data Set 13

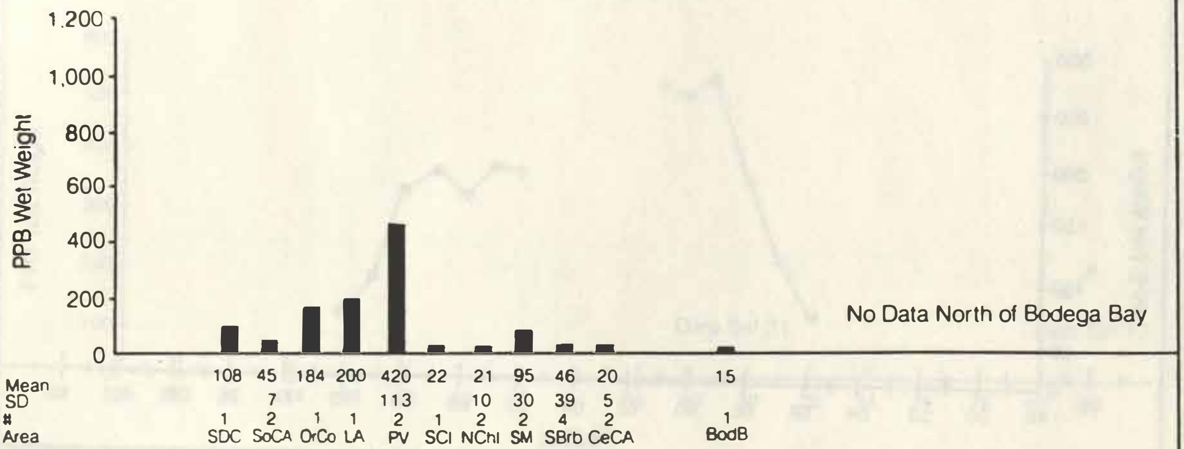


Figure 3.7b Total PCBs in Bay Mussels 1975-76
From Data Set 59

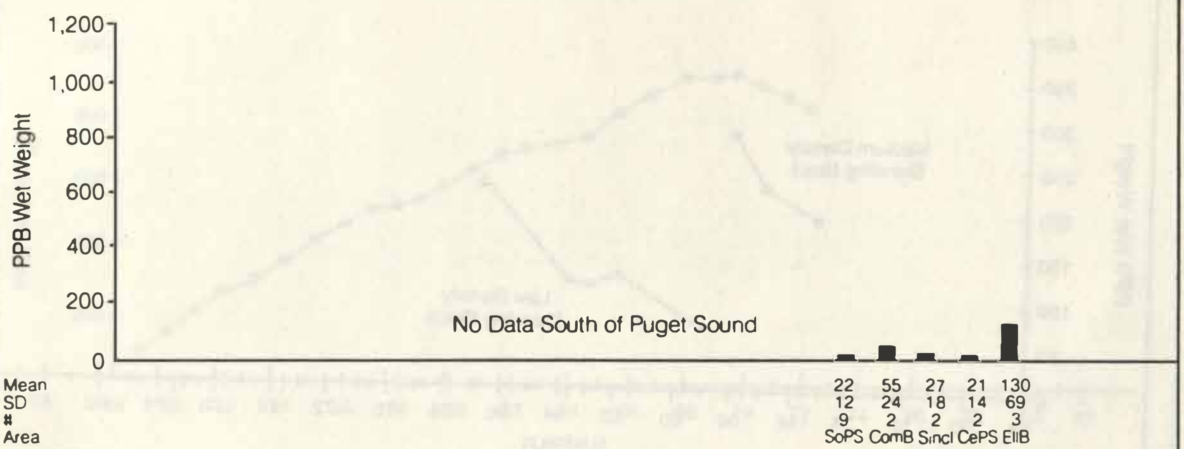


Figure 3.7c Total PCBs in Dover Sole 1975-76
From Data Sets 49, 51, 52, and 57 (SCCWRP)

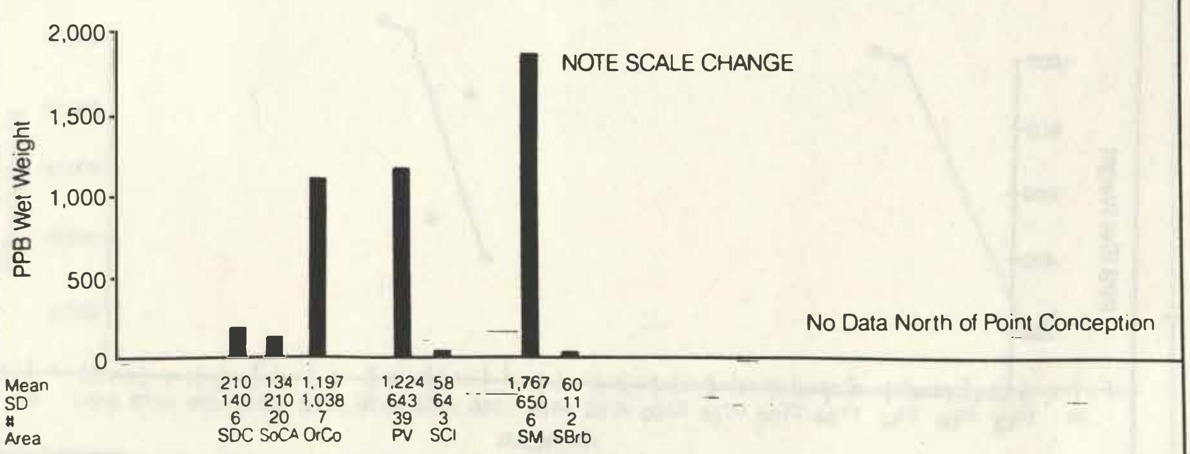


Figure 3.8a Total DDT in Oysters San Francisco Bay
From Data Set 21

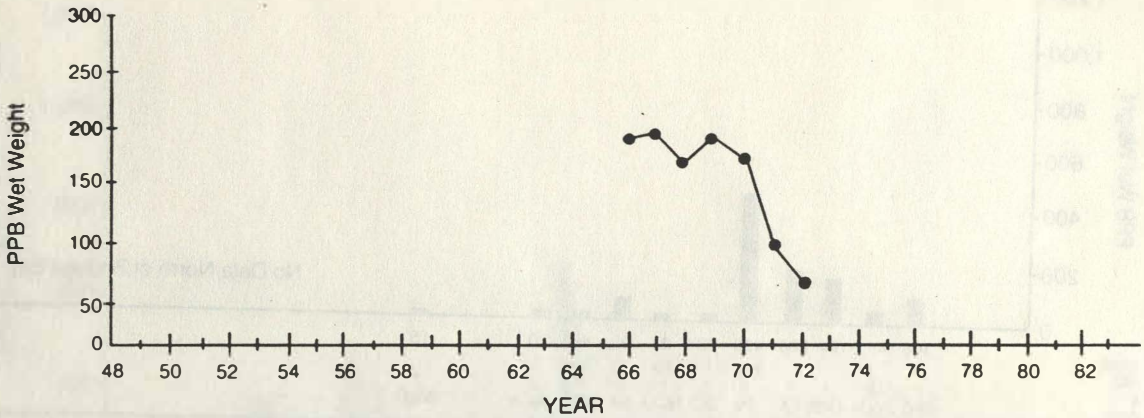


Figure 3.8b Total DDT in Phytoplankton Monterey Bay
From Data Set 66

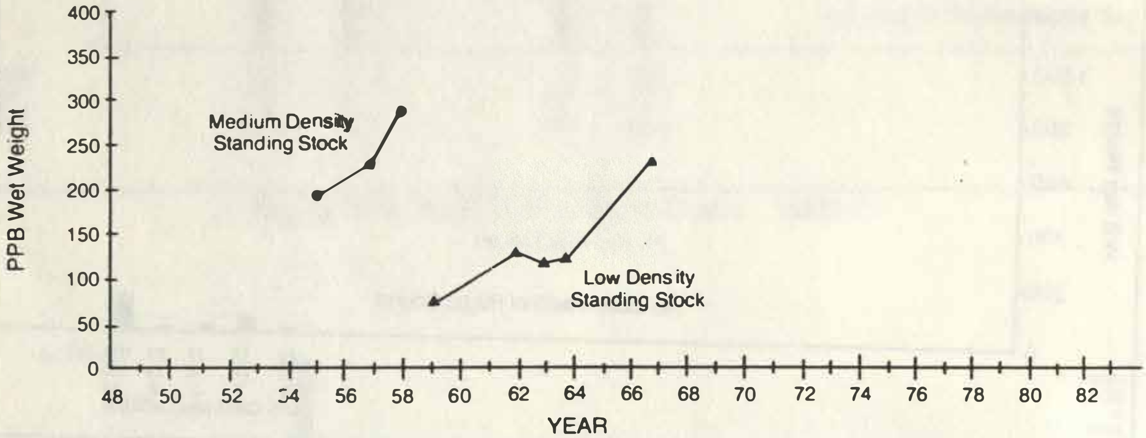


Figure 3.8c Total DDT in Oysters Monterey Bay
From Data Set 21

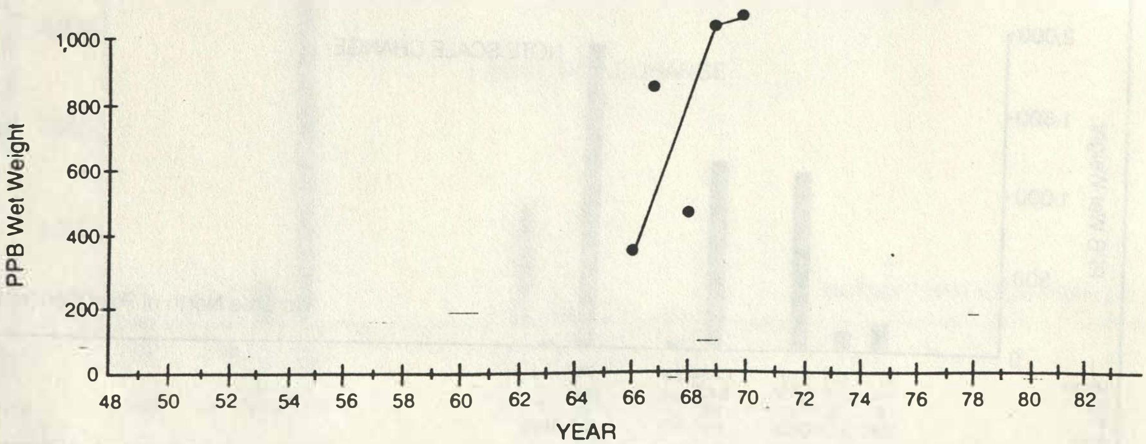


Figure 3.8d Total DDT in Bay Mussels Anaheim Bay

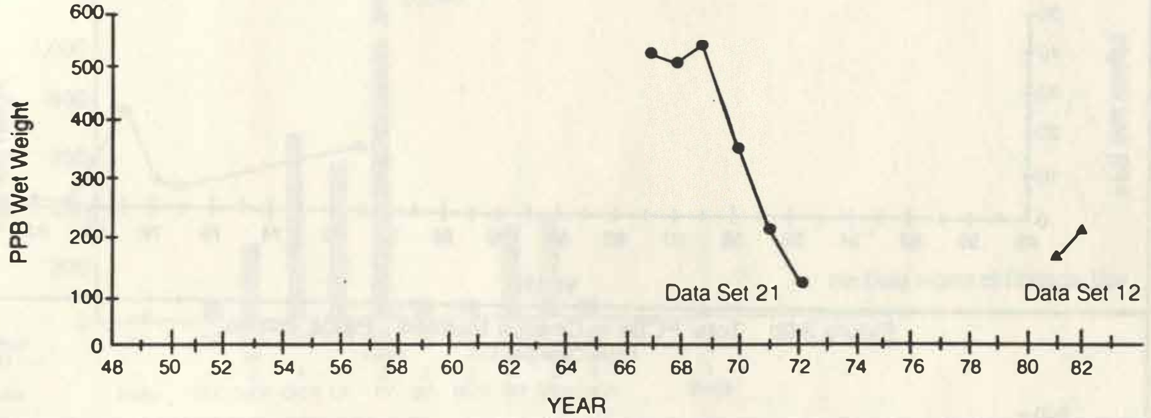


Figure 3.8e Total DDT in Midwater Myctophids Southern California
From Data Set 37

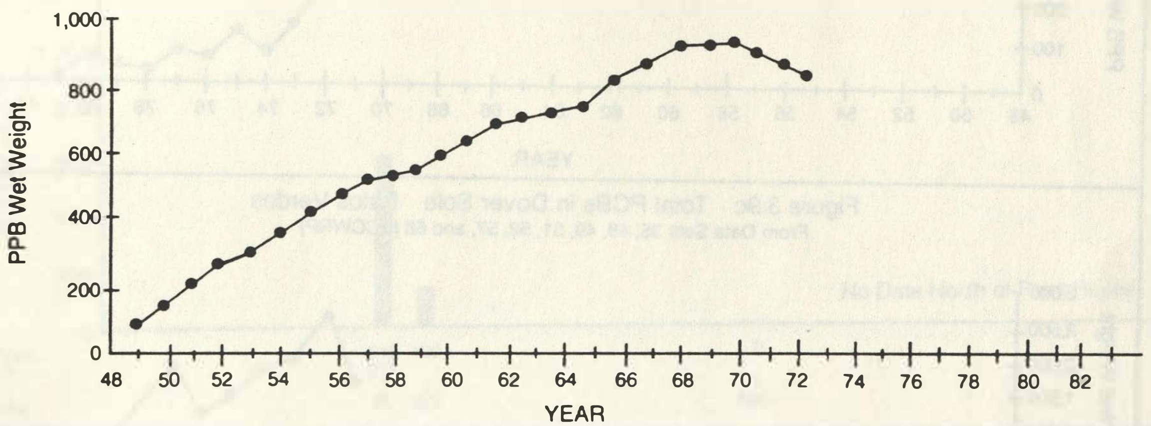


Figure 3.8f Total DDT in White Croaker Palos Verdes
SCCWRP

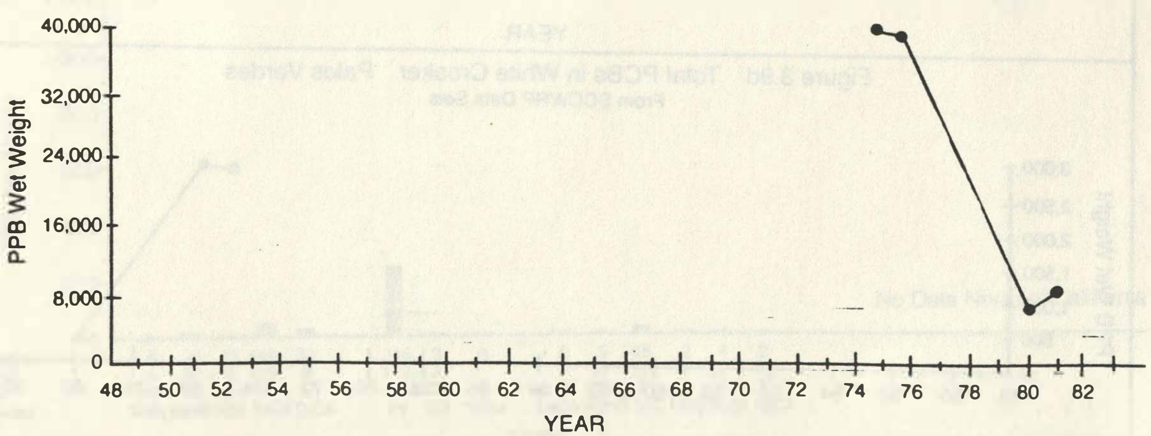


Figure 3.9a Total PCBs in Coastal Mussels Bogeda Bay
From Data Sets 13, 15, and 16

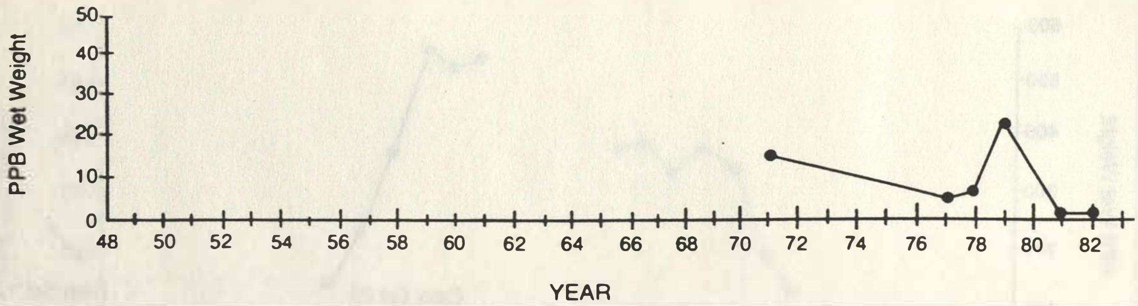


Figure 3.9b Total PCBs in Coastal Mussels Palos Verdes
From Data Set 51

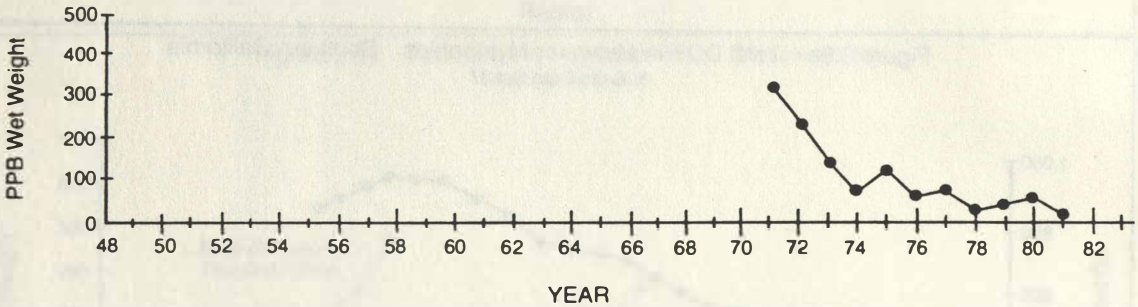


Figure 3.9c Total PCBs in Dover Sole Palos Verdes
From Data Sets 35, 48, 49, 51, 52, 57, and 68 (SCCWRP)

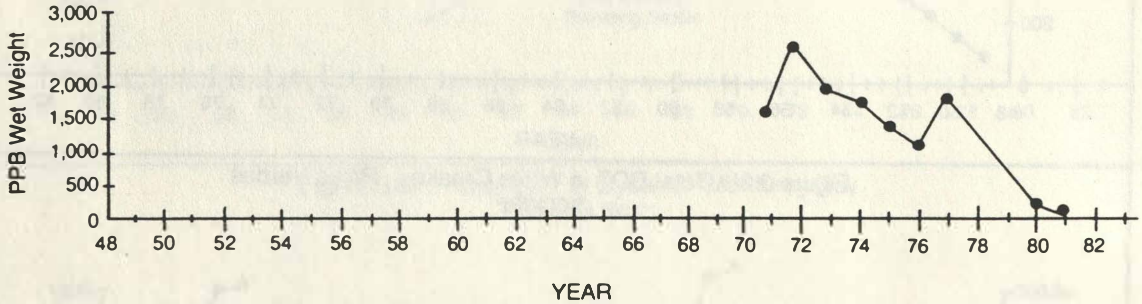


Figure 3.9d Total PCBs in White Croaker Palos Verdes
From SCCWRP Data Sets

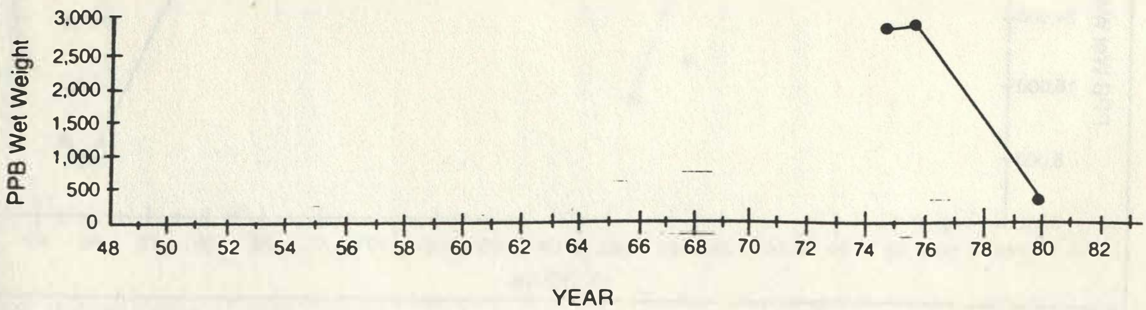
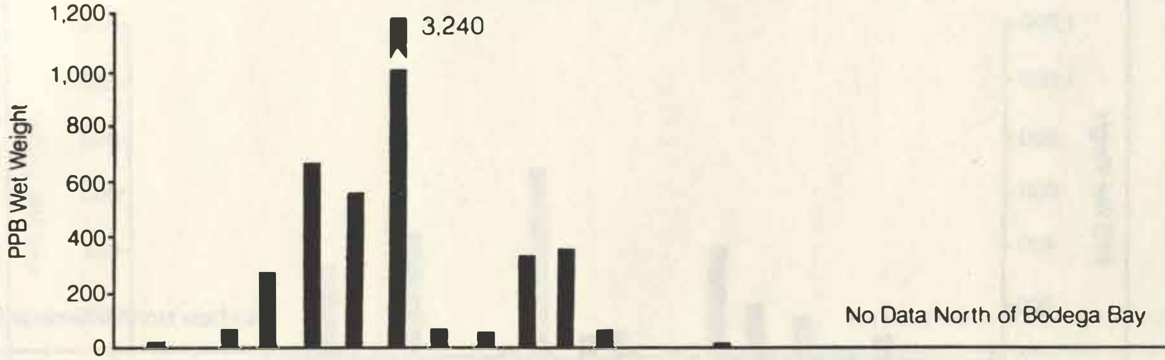
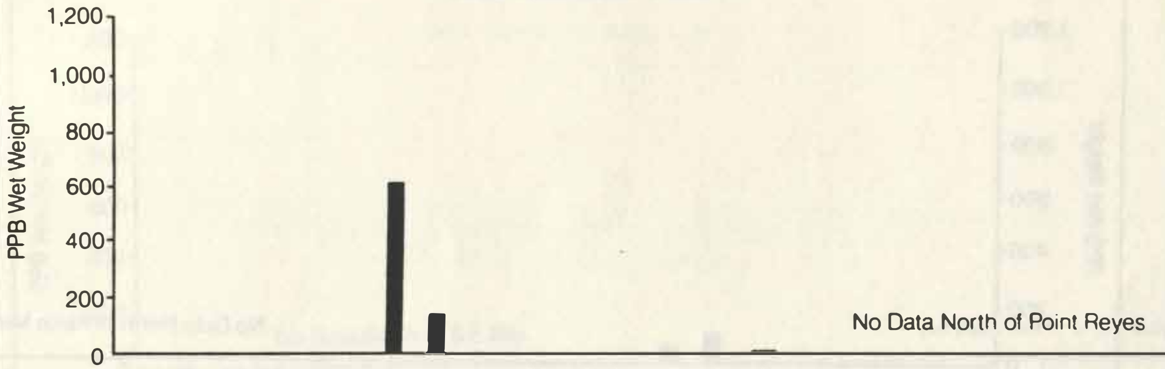


Figure 3.10a Total DDT in Coastal Mussels 1969-71
From Data Sets 21, 48, and 51



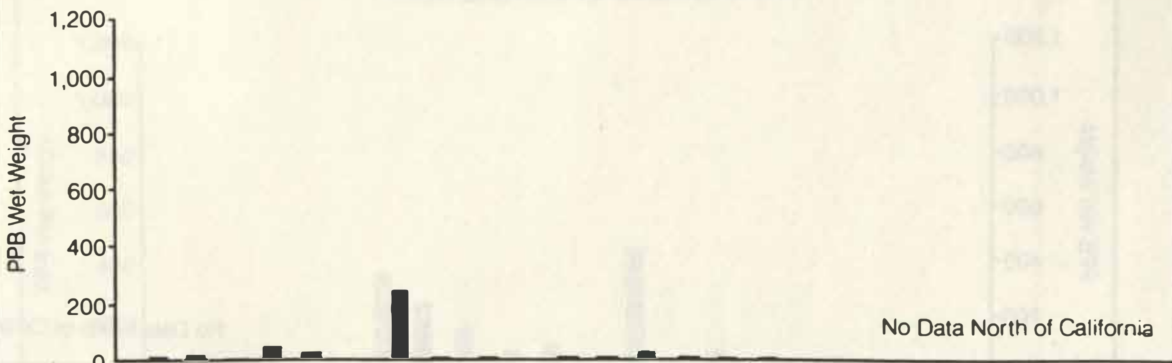
Area	NoBj	SDC	SoCA	OrCo	LA	PV	SCI	NChI	SM	SBrb	CeCA	BodB
Mean	34	66	275	670	570	3,240	70	68	330	370	86	16
SD			64			1,492		4	71	433	56	
#	1	1	2	1	1	3	1	2	2	12	3	1

Figure 3.10b Total DDT in Coastal Mussels 1975-76
From Data Sets 14 and 51



Area	PV	SCI	FarG
Mean	619	120	7
SD	217		
#	3	1	1

Figure 3.10c Total DDT in Coastal Mussels 1979-83
From Data Sets 12, 15, 16, 45, and 51



Area	NoBj	MexB	SDC	SoCA	OrCo	PV	SCI	NChI	CeCA	MontB	SFC	FarG	BodB	NoCA
Mean	6	25	11	48	33	246	3	3	5	9	45	2	4	2
SD	6	20	8	29	9	112	3		2	5	58	1	2	2
#	48	16	3	4	2	11	2	1	9	10	2	4	7	9

Figure 3.11a Total PCBs in Coastal Mussels 1969-71
From Data Sets 13 and 51

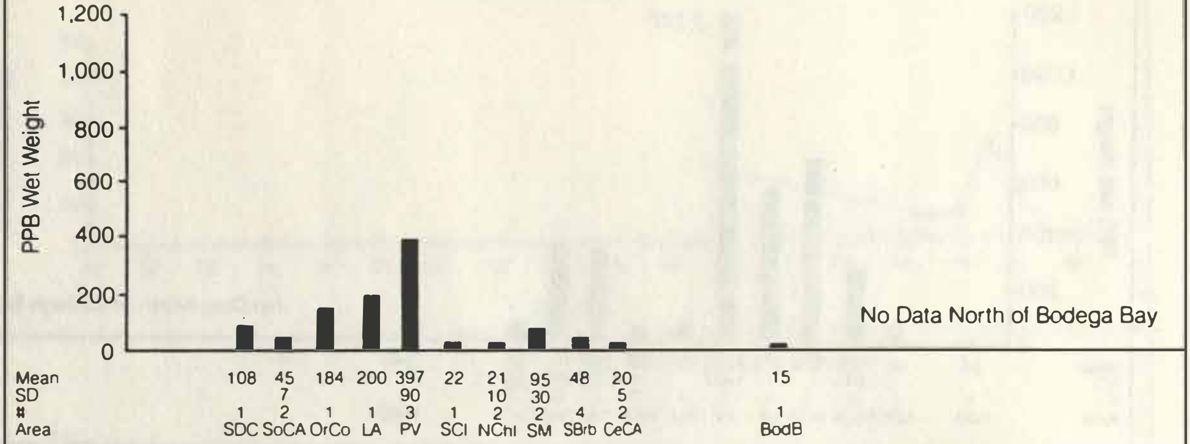


Figure 3.11b Total PCBs in Coastal Mussels 1975-76
From Data Set 51

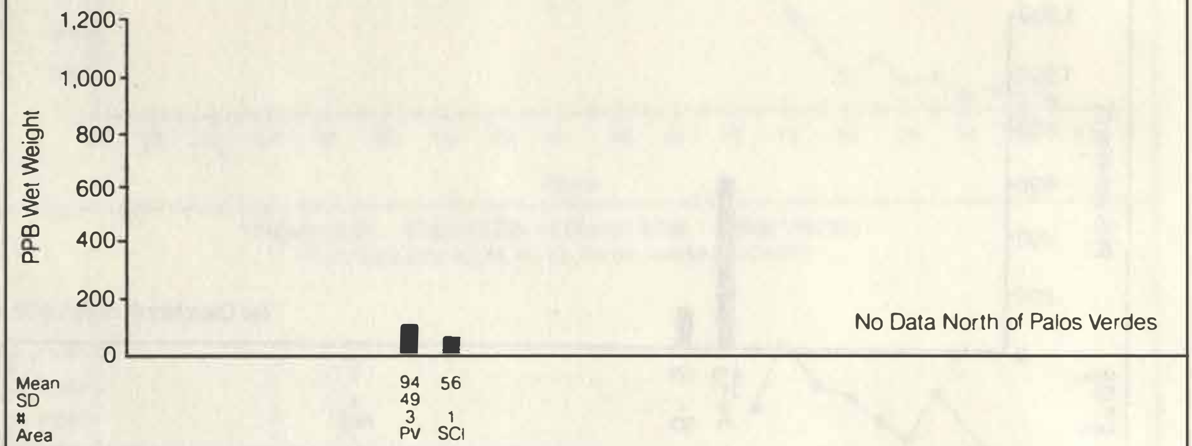


Figure 3.11c Total PCBs in Coastal Mussels 1979-83
From Data Sets 15, 16, and 51

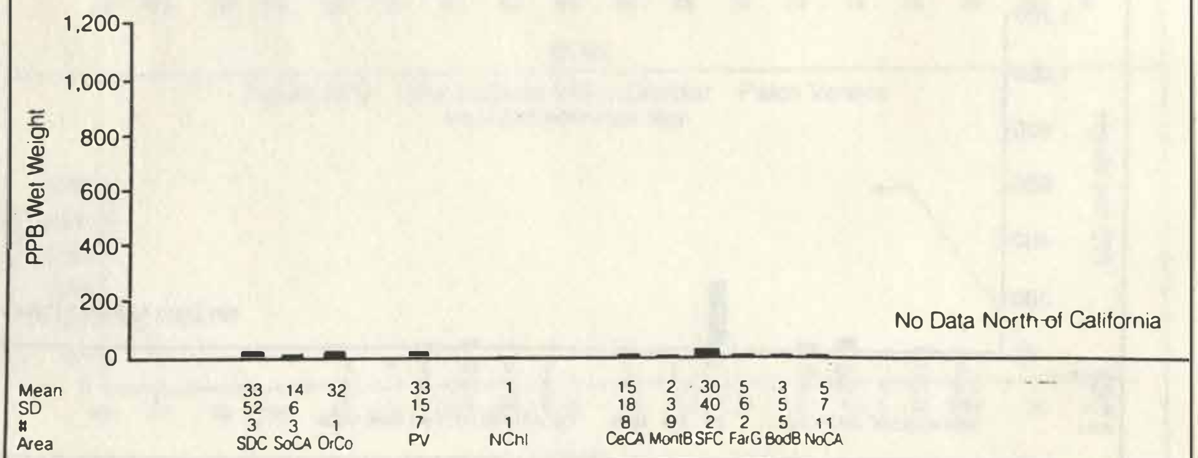


Figure 3.12a Total DDT in Bay Mussels 1969-71
From Data Set 21

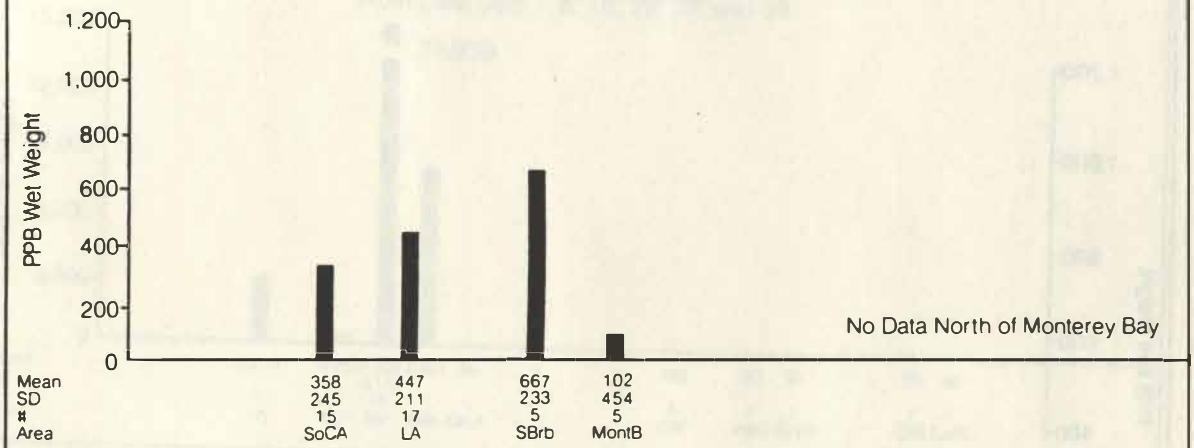


Figure 3.12b Total DDT in Bay Mussels 1975-76
From Data Sets 11 and 14

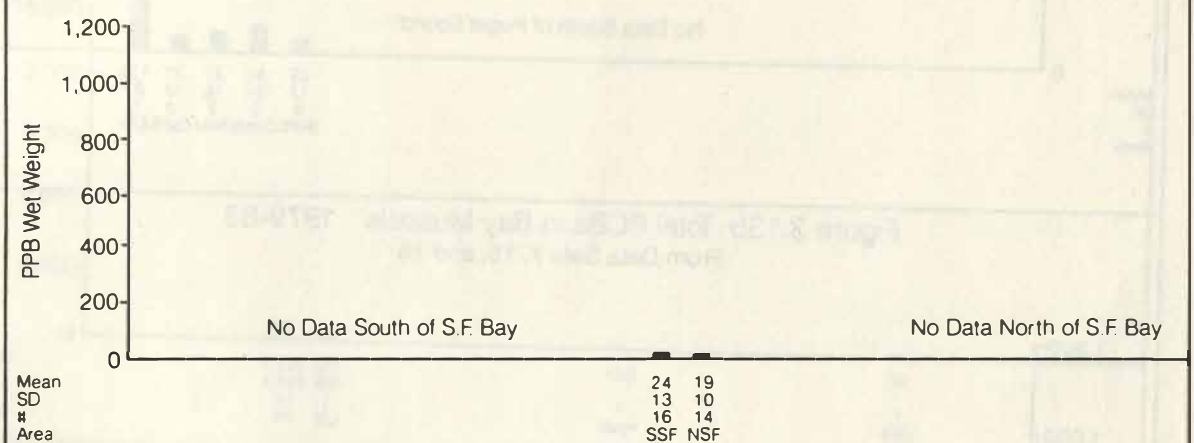


Figure 3.12c Total DDT in Bay Mussels 1979-83
From Data Sets 7, 12, 15, 16, and 60

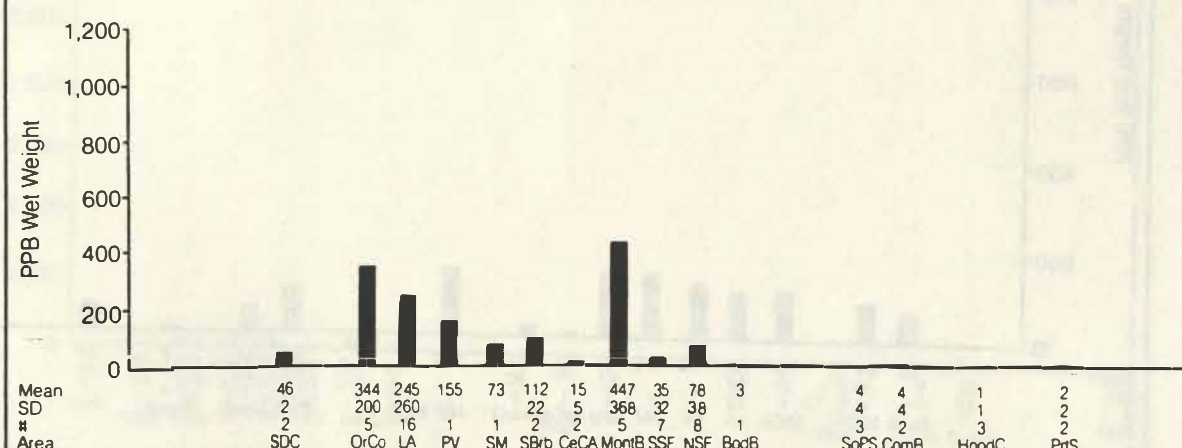


Figure 3.13a Total PCBs in Bay Mussels 1975-76
From Data Sets 5 and 59

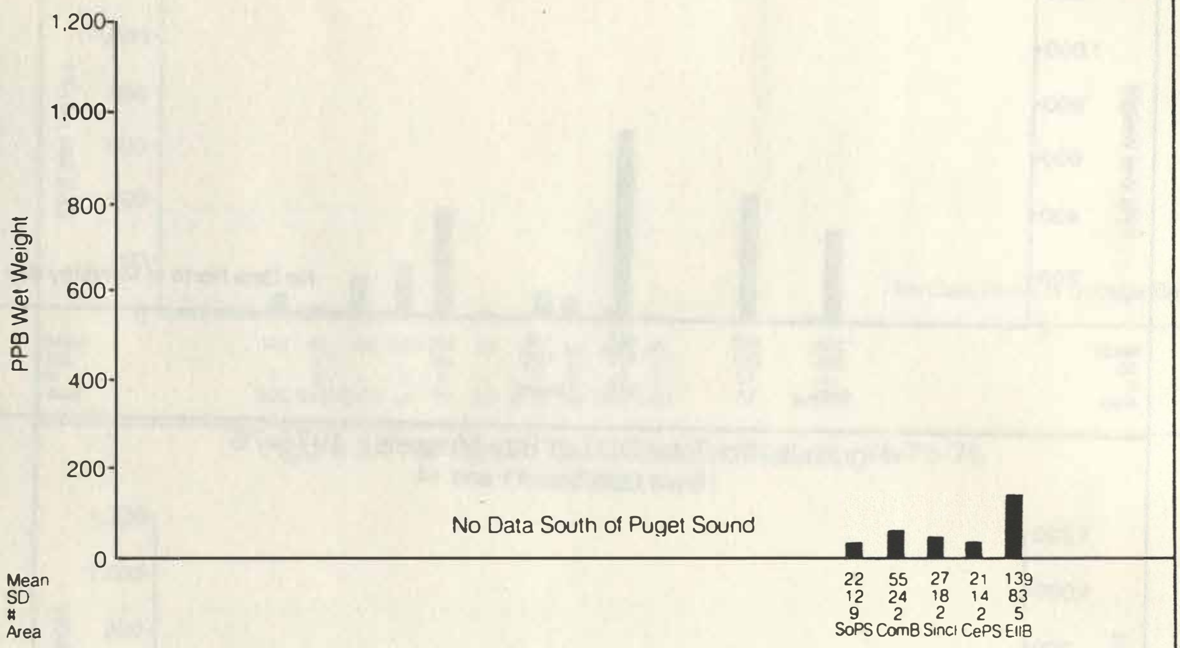


Figure 3.13b Total PCBs in Bay Mussels 1979-83
From Data Sets 7, 15, and 16

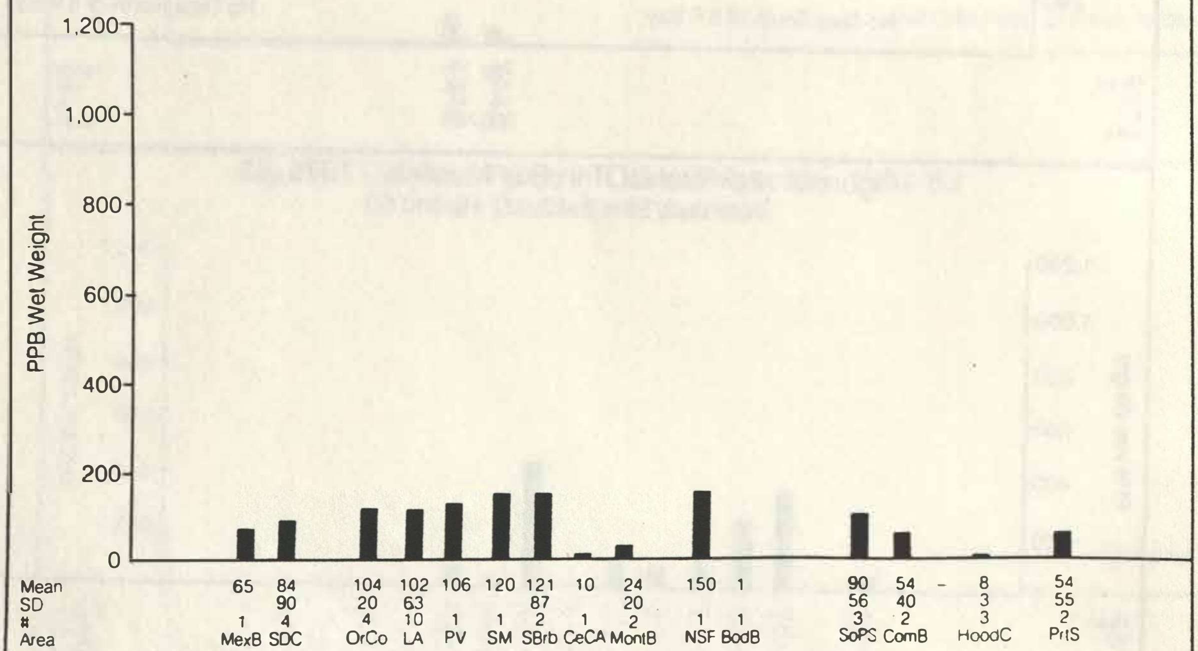


Figure 3.14a Total DDT in Group 1 Fish 1969-71
(Pelagic Living—Pelagic Feeding)
From Data Sets 1, 8, 18, 29, 37, and 39

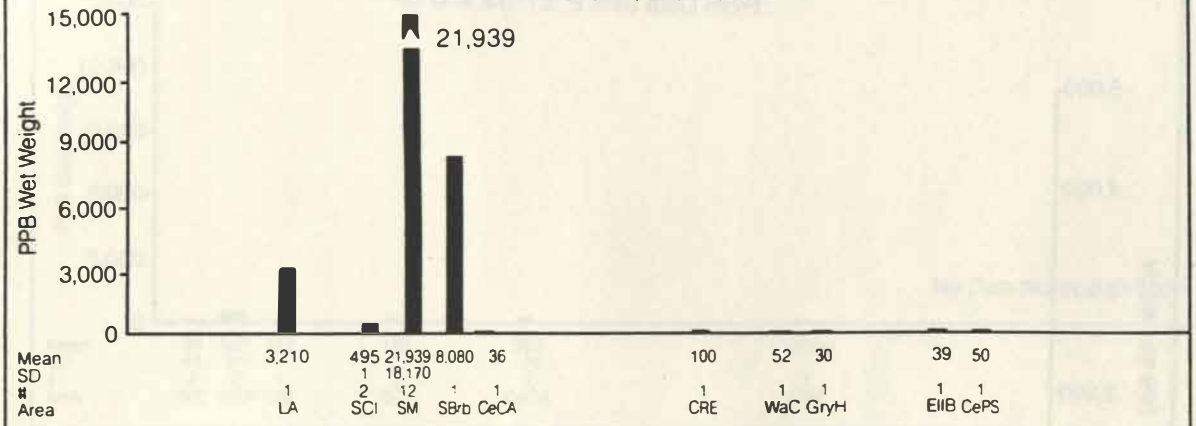


Figure 3.14b Total DDT in Group 1 Fish 1975-76
From Data Sets 8, 51, 53, and 68

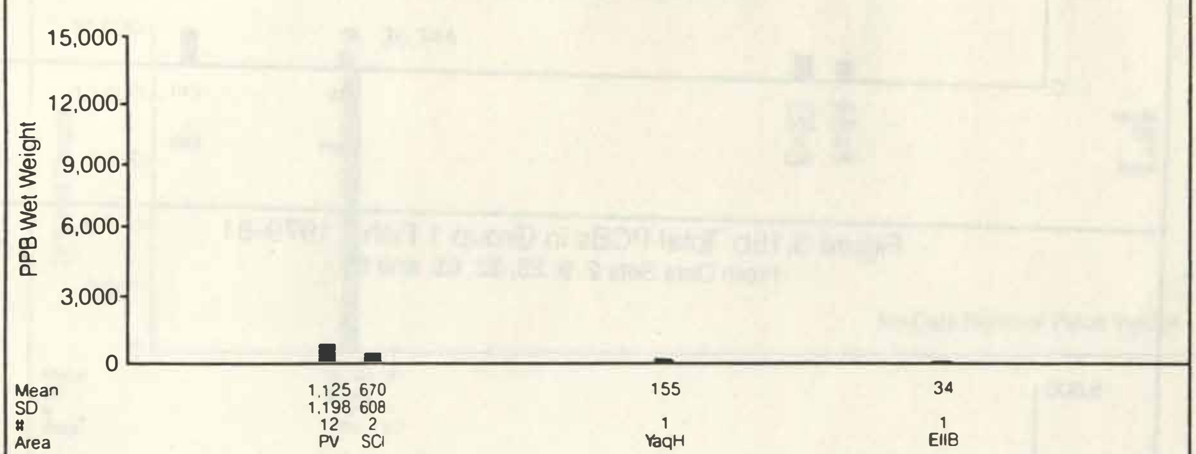


Figure 3.14c Total DDT in Group 1 Fish 1979-81
From Data Sets 2, 22, 25, 32, and 68

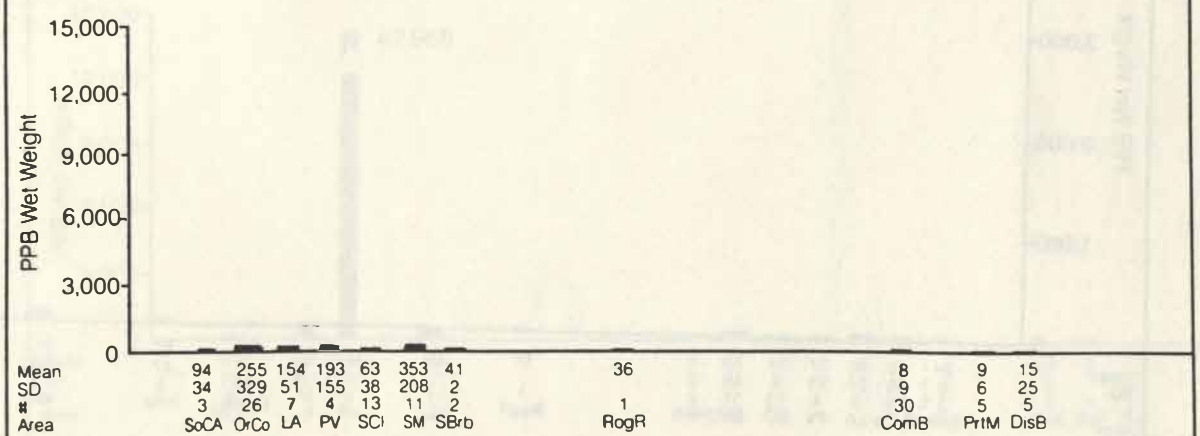


Figure 3.15a Total PCBs in Group 1 Fish 1975-76
(Pelagic Living—Pelagic Feeding)
From Data Sets 8, 51, 53, and 68

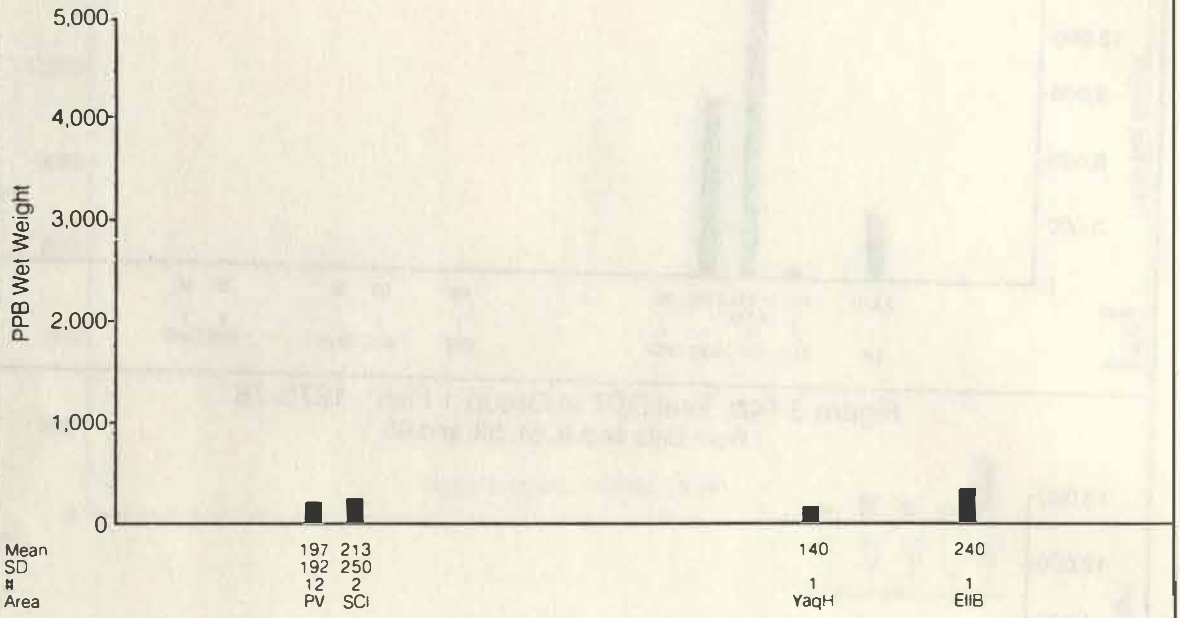


Figure 3.15b Total PCBs in Group 1 Fish 1979-81
From Data Sets 2, 9, 25, 32, 65, and 68

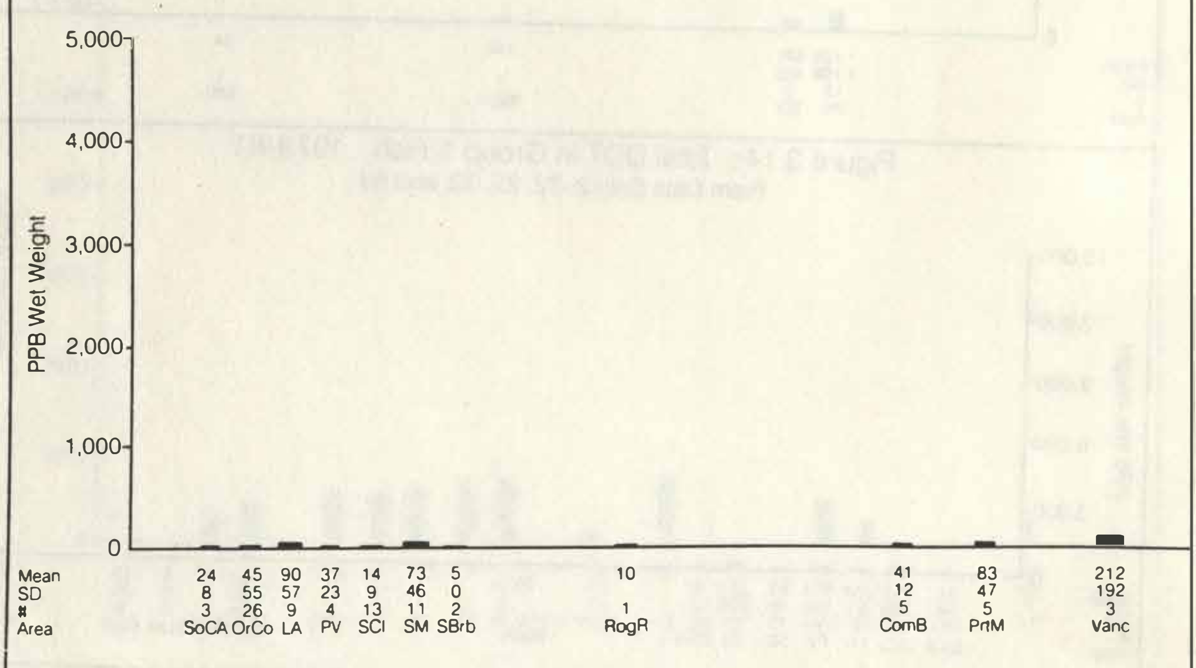


Figure 3.16a Total DDT in Group 2 Fish 1969-71
(Pelagic Living—Mixed Feeding)
From Data Sets 8, 29, 36, and 39

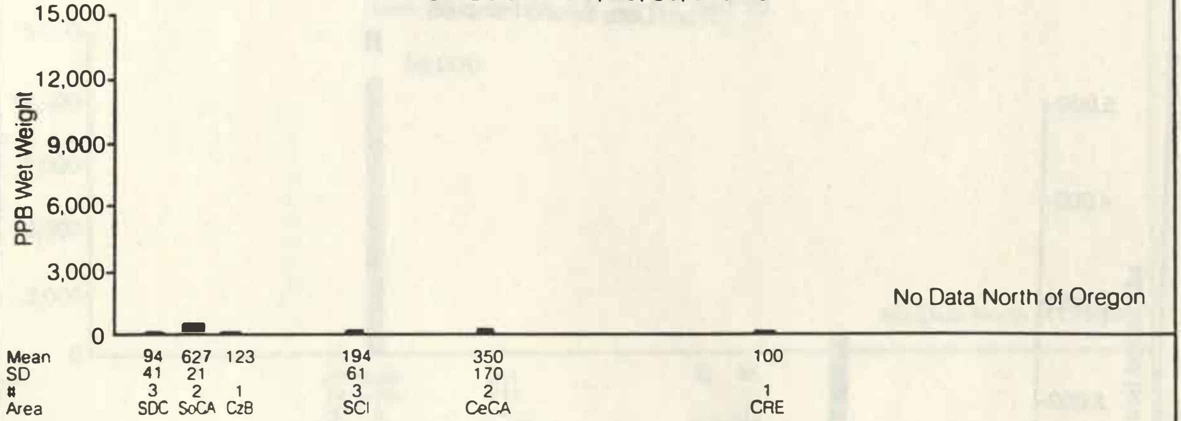


Figure 3.16b Total DDT in Group 2 Fish 1975-76
From Data Sets 51 and 68

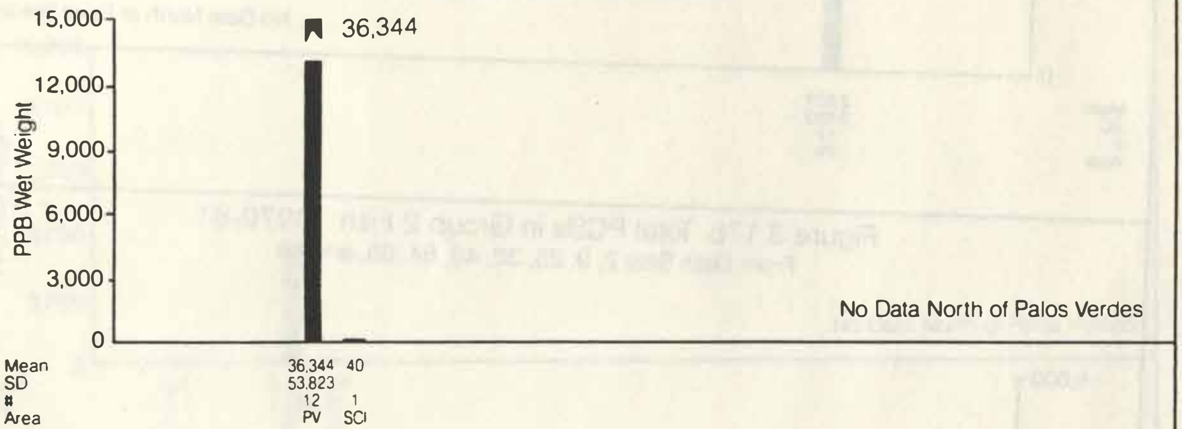


Figure 3.16c Total DDT in Group 2 Fish 1979-81
From Data Sets 2, 22, 25, 32, 40, 50, and 68

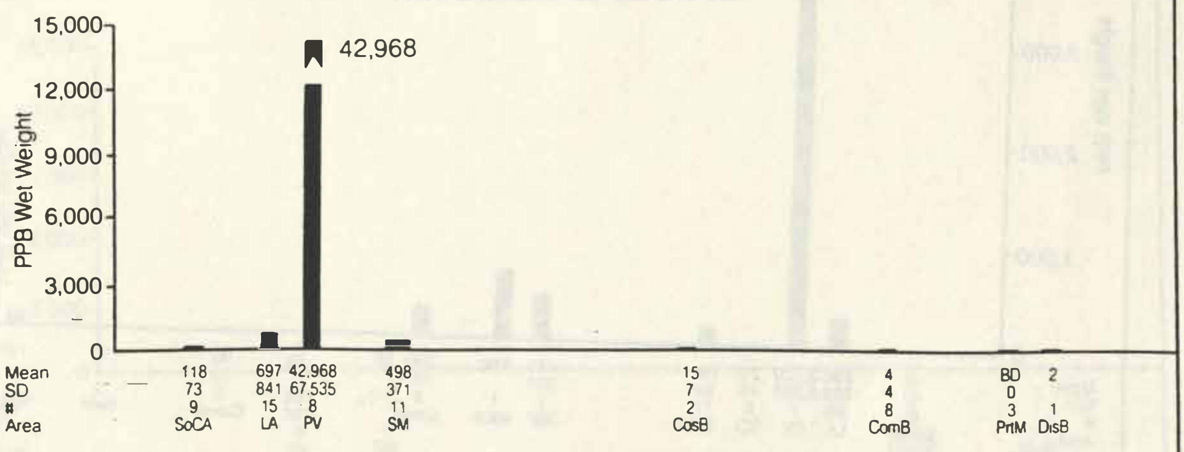


Figure 3.17a Total PCBs in Group 2 Fish 1975-76
(Pelagic Living—Mixed Feeding)
From Data Sets 51 and 68

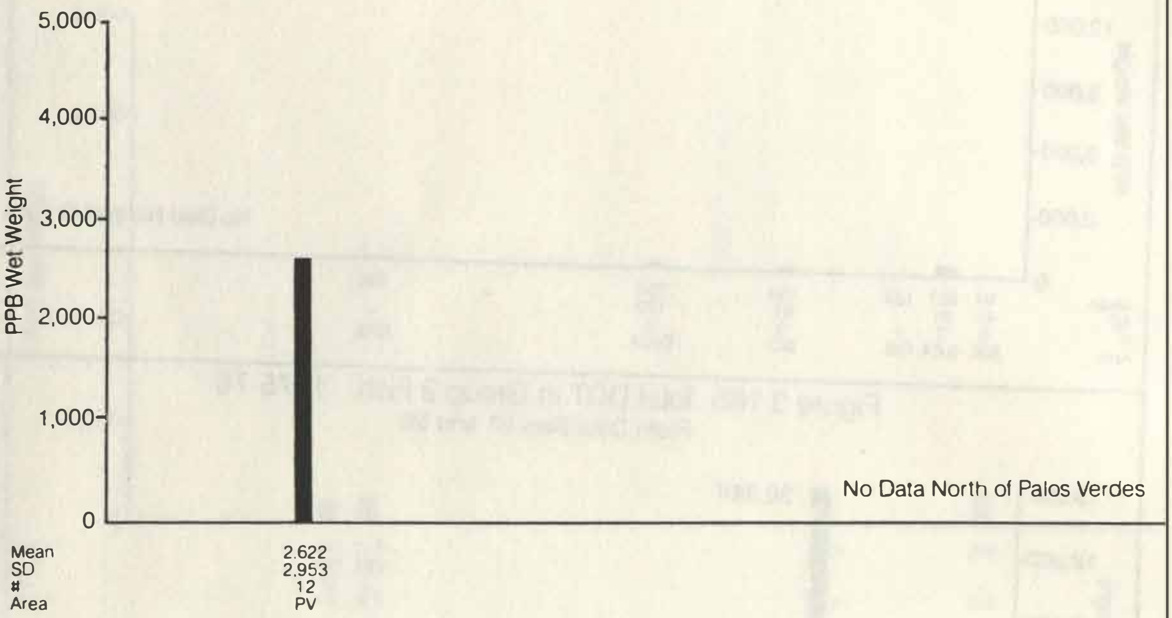


Figure 3.17b Total PCBs in Group 2 Fish 1979-81
From Data Sets 2, 9, 25, 32, 40, 64, 65, and 68

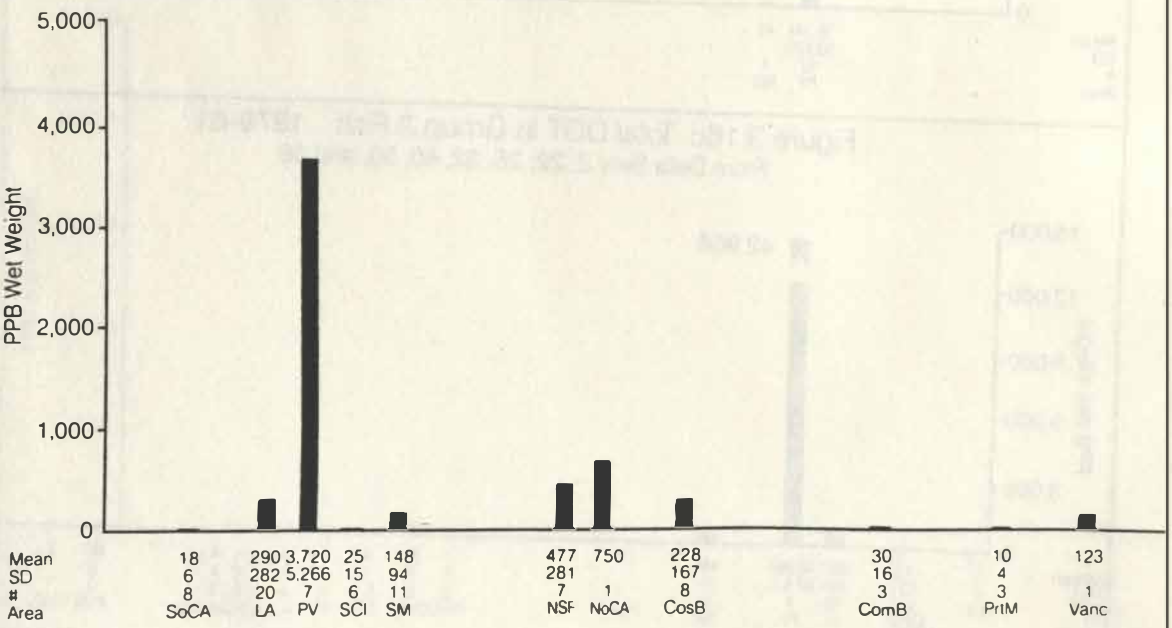


Figure 3.18a Total DDT in Group 3 Fish 1969-71
(Benthic Living—Mixed Feeding)
From Data Sets 8, 18, 29, 37, and 39

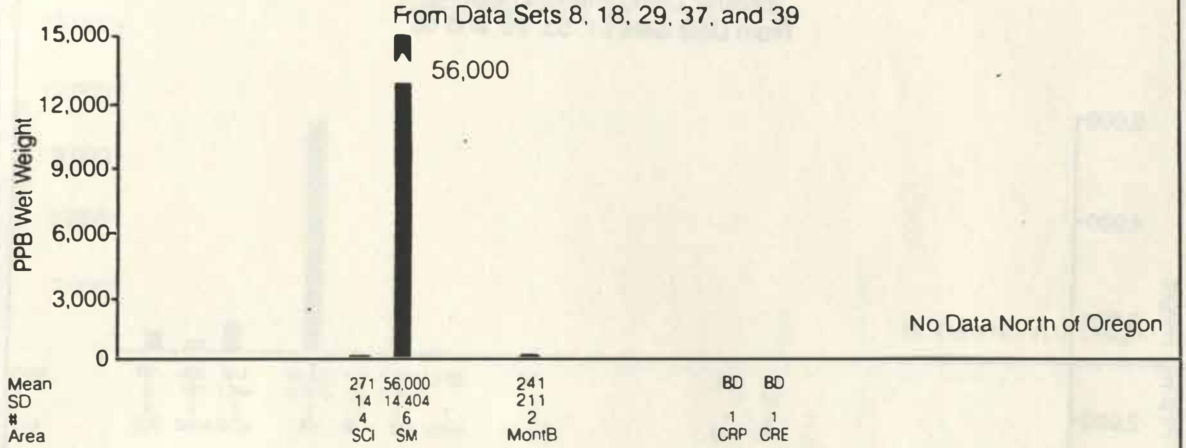


Figure 3.18b Total DDT in Group 3 Fish 1975-76
From Data Sets 51, 53, and 68

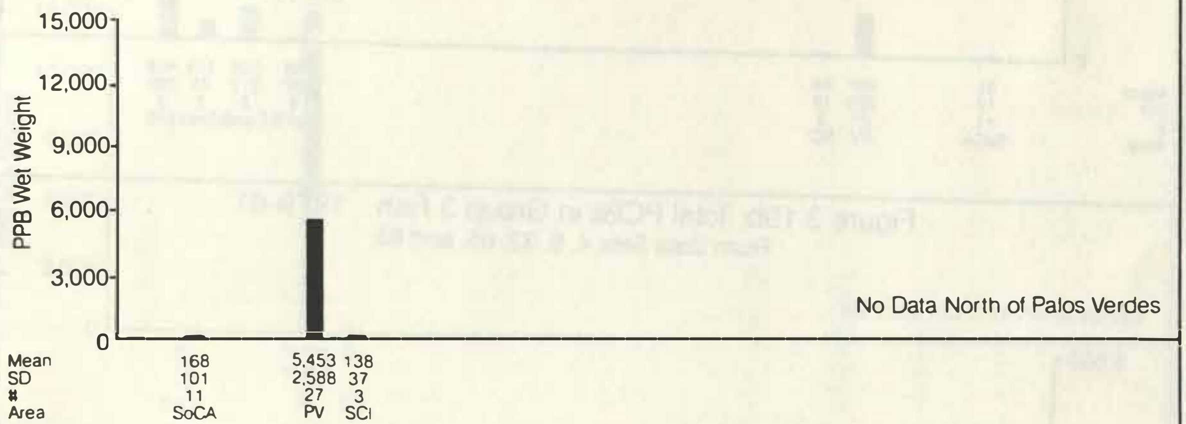


Figure 3.18c Total DDT in Group 3 Fish 1979-81
From Data Sets 22, 32, and 68

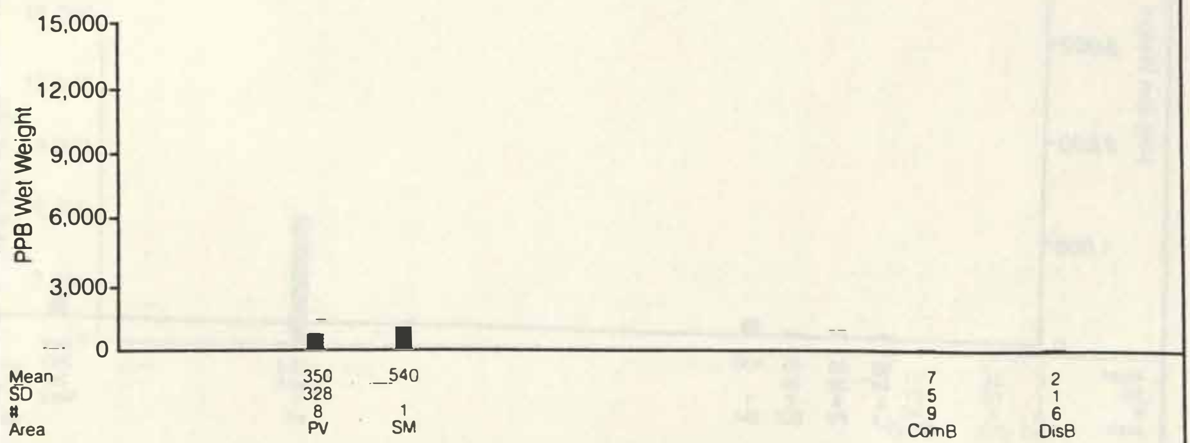


Figure 3.19a Total PCBs in Group 3 Fish 1975-76
(Benthic Living—Mixed Feeding)
From Data Sets 51, 53, 59, and 68

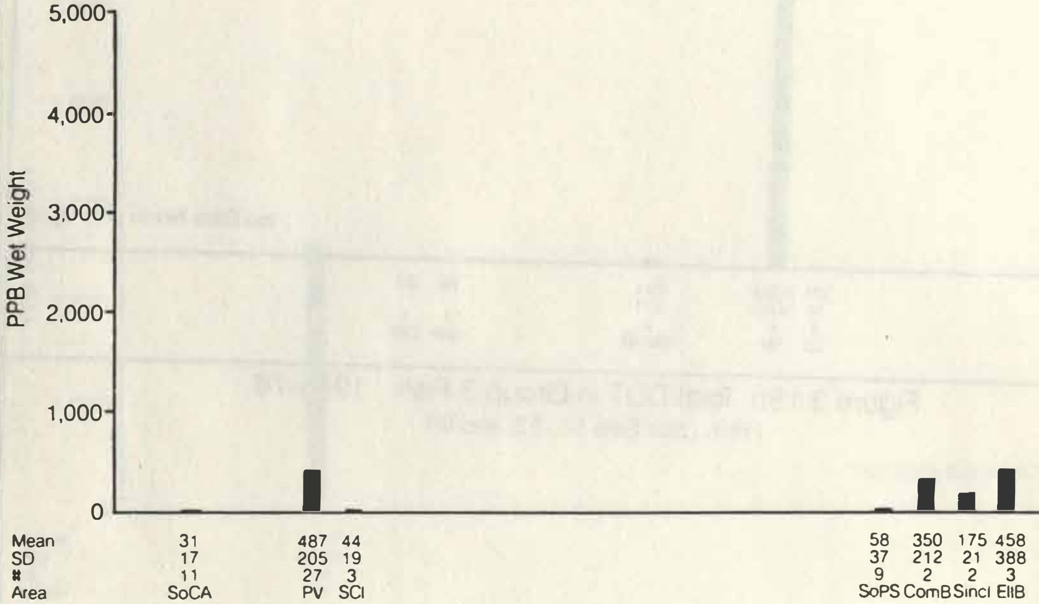


Figure 3.19b Total PCBs in Group 3 Fish 1979-81
From Data Sets 4, 9, 32, 65, and 68

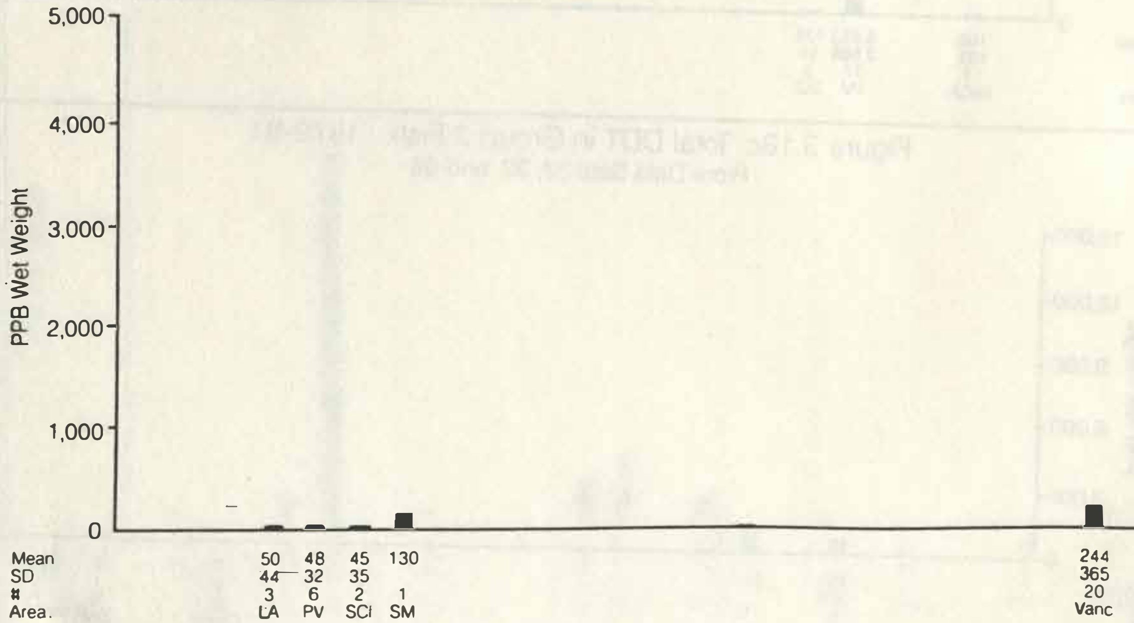


Figure 3.20a Total DDT in Group 4 Fish 1969-71
(Benthic Living—Benthic Feeding)
From Data Sets 8, 29, 37, 39 and 48

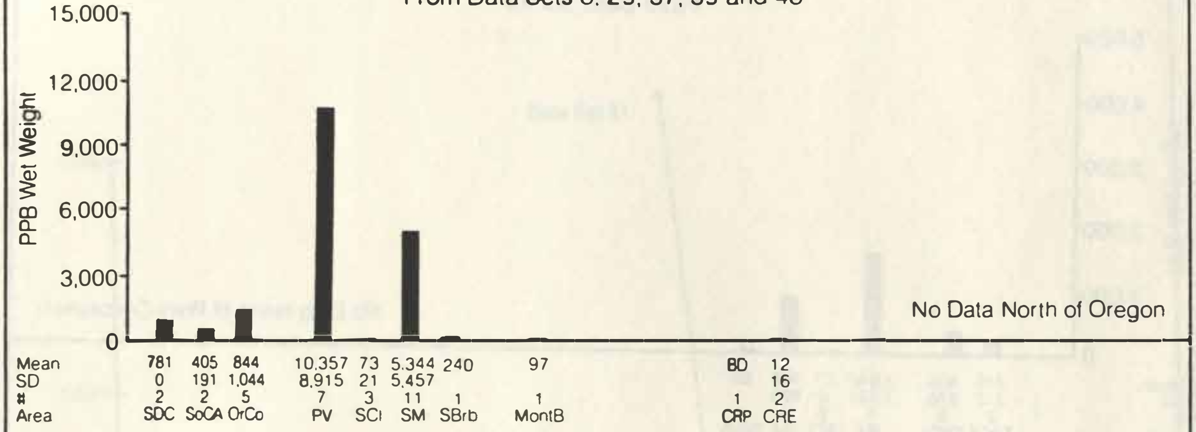


Figure 3.20b Total DDT in Group 4 Fish 1975-76
From Data Sets 52 and 57

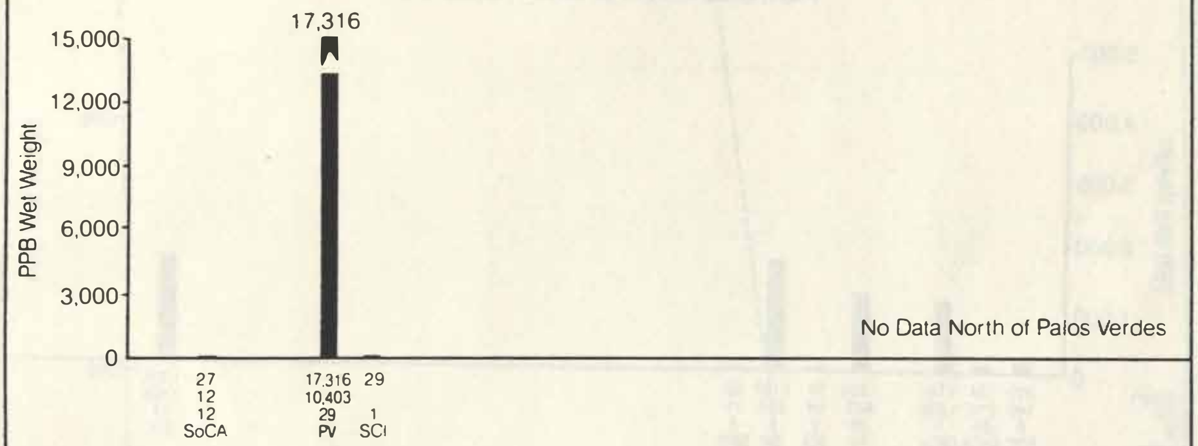


Figure 3.20c Total DDT in Group 4 Fish 1979-81
From Data Sets 22, 26, 51, and 68

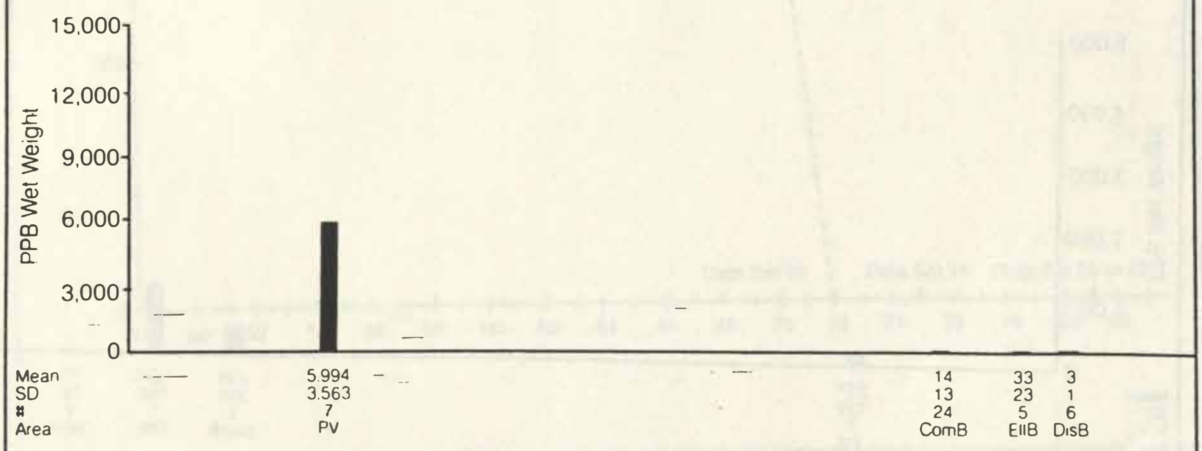


Figure 3.21a Total PCBs in Group 4 Fish 1969-71
(Benthic Living—Benthic Feeding)
From Data Set 48

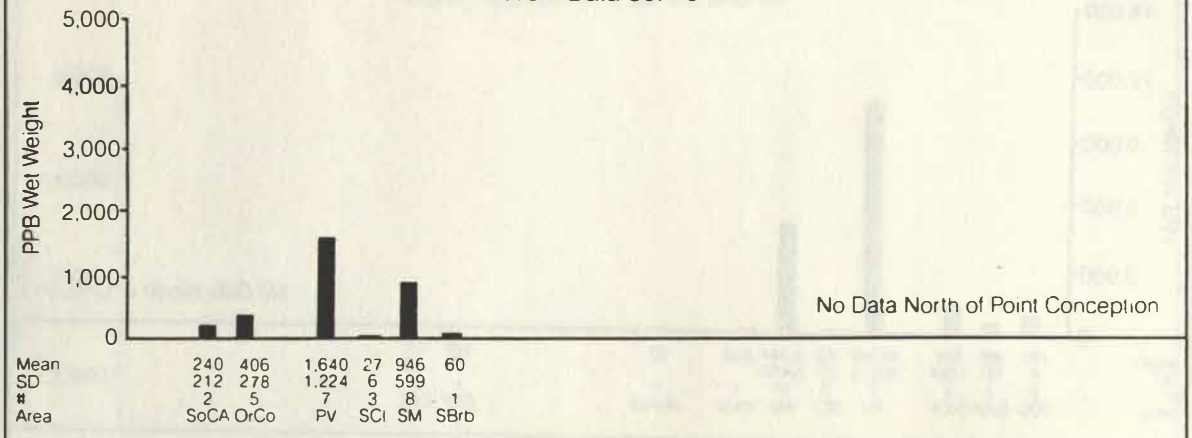


Figure 3.21b Total PCBs in Group 4 Fish 1975-76
From Data Sets 5, 8, 49, 51, 52, and 57

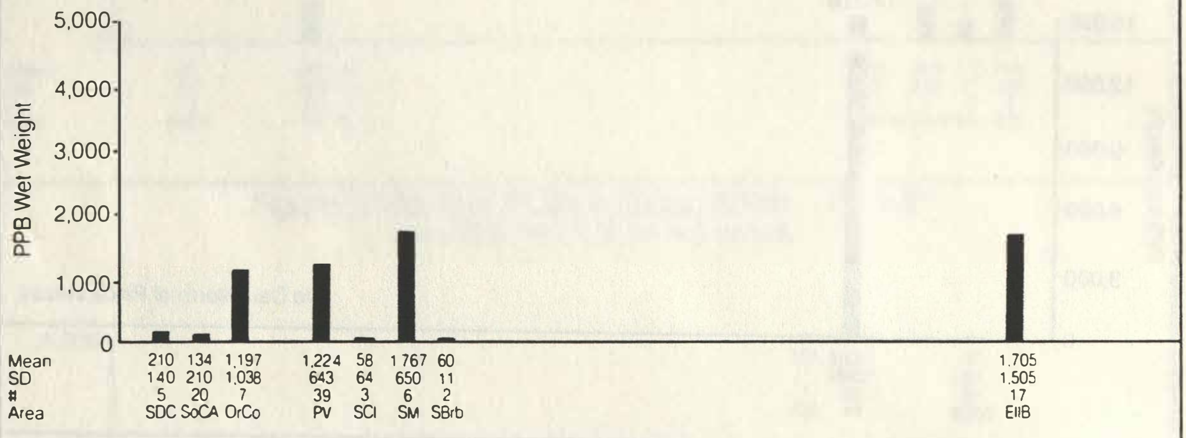


Figure 3.21c Total PCBs in Group 4 Fish 1979-81
From Data Sets 9, 26, 51, and 68

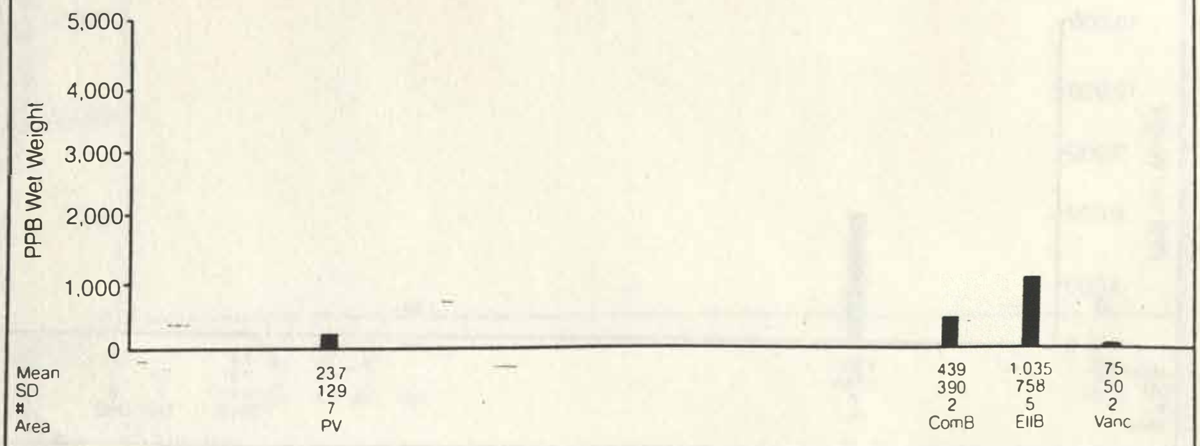


Figure 3.22 Total DDT in Littleneck Clams San Francisco Bay

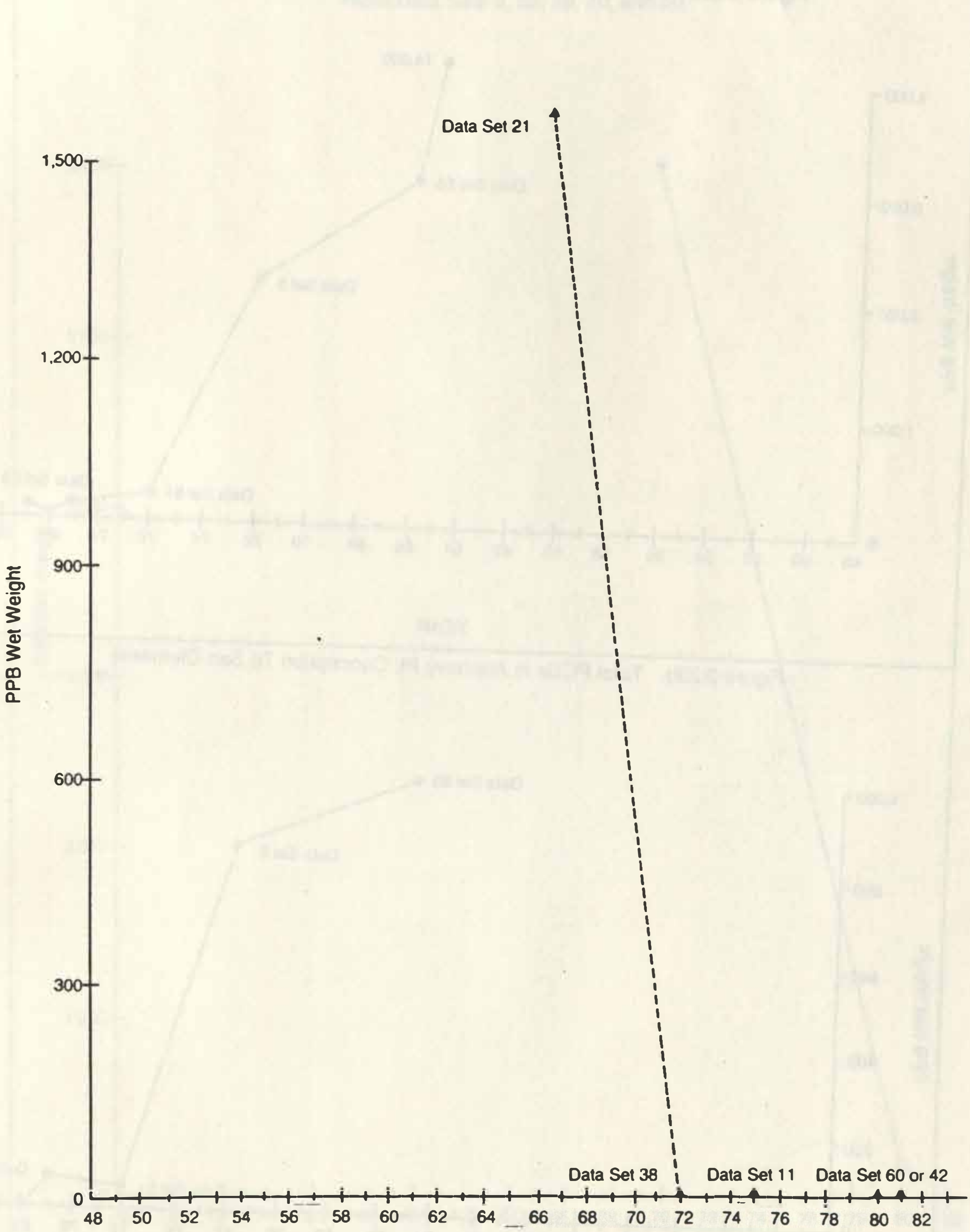


Figure 3.23a Total DDT in Anchovy Pt. Conception To San Clemente

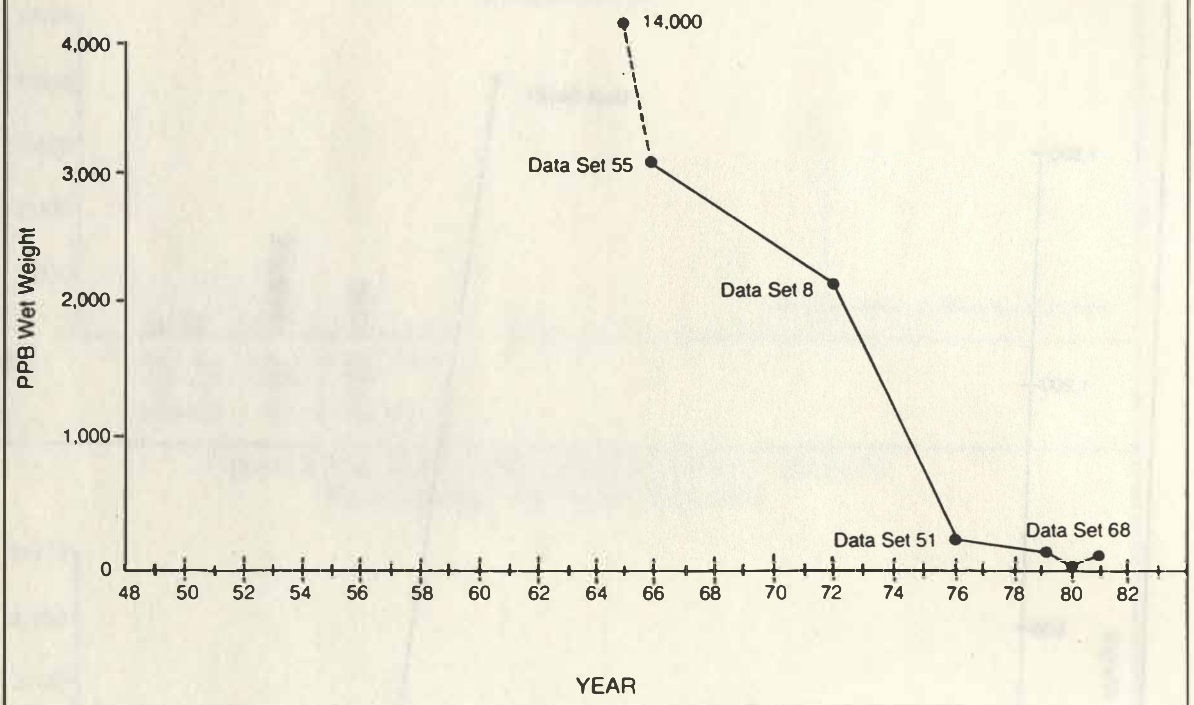
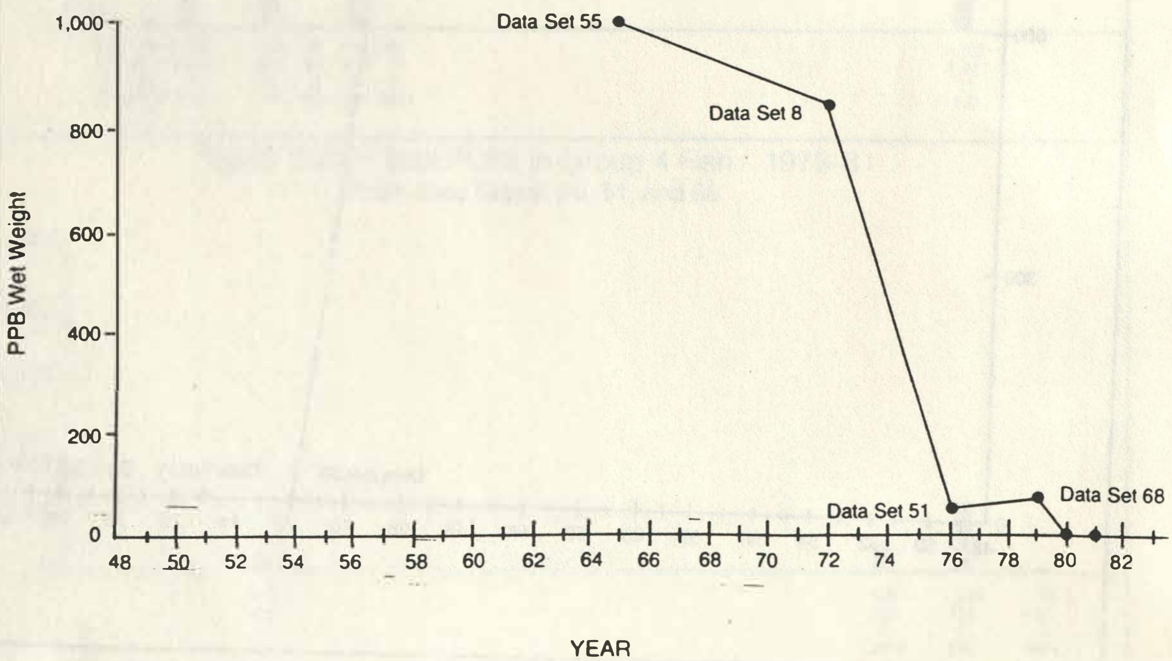


Figure 3.23b Total PCBs in Anchovy Pt. Conception To San Clemente



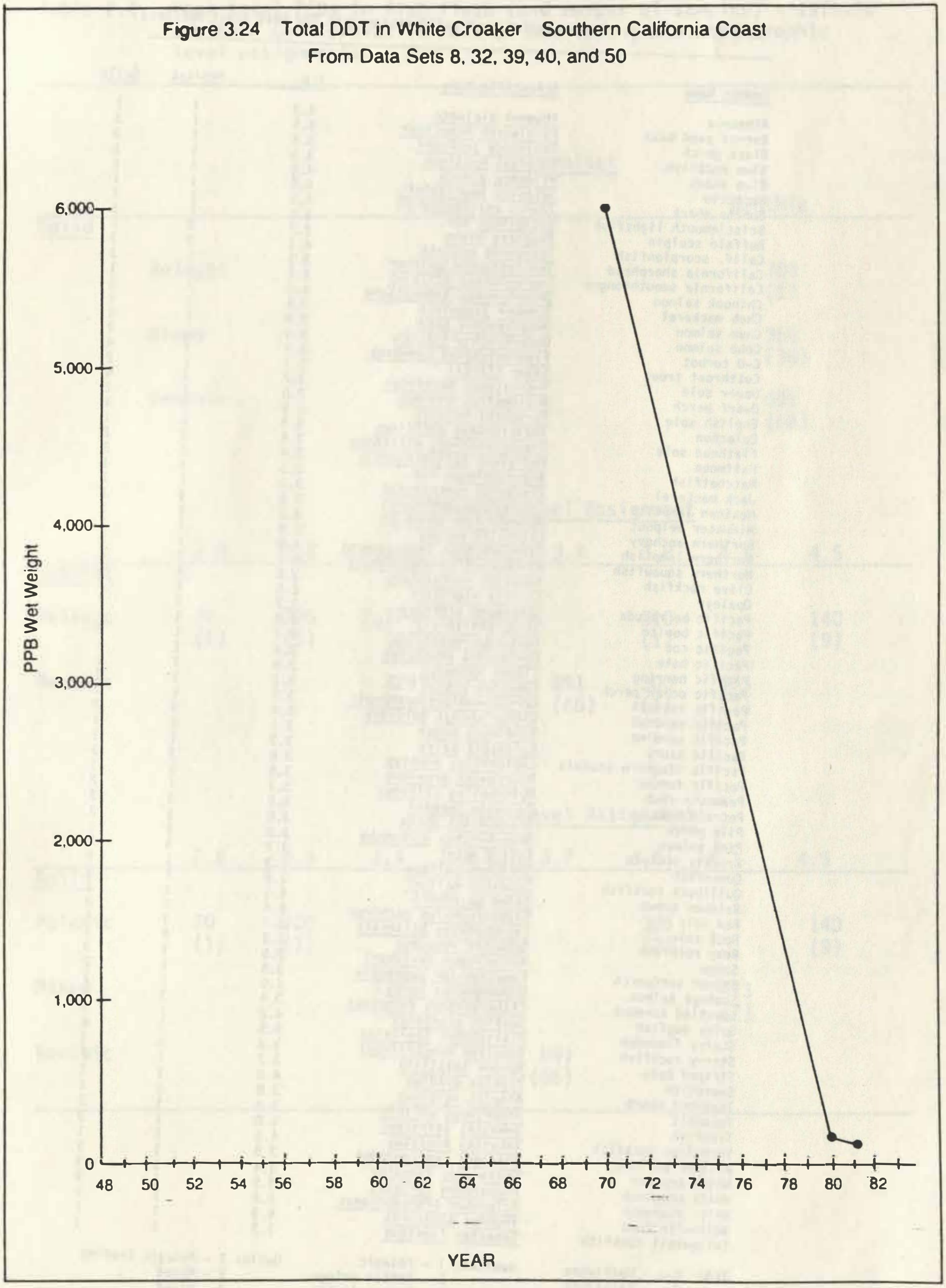


Figure 3.24 Total DDT in White Croaker Southern California Coast
From Data Sets 8, 32, 39, 40, and 50
PPB Wet Weight
6,000
5,000
4,000
3,000
2,000
1,000
0
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
YEAR

Table 2.1. Trophic level, habitat, and guild assignments for West Coast Species.

Common Name	Scientific Name	TLA	Habitat	Guild
Albacore	Thunnus alaluega	4.3	1	1
Barred sand bass	Paralabrax nebulifer	4.5	1	3
Black perch	Embiotoca jacksoni	3.5s	1	3
Blue rockfish	Sebastes mystinus	3.5	1	1
Blue shark	Prionace glauca	4.0	1	1
Bocaccio	Sebastes paucispinis	4.5	1	1
Bonito shark	Isurus oxyrinchus	4.4	1	1
Bristlemouth lightfishs	Cyclothone spp.	3.5	1	1
Buffalo sculpin	Enophrys bison	2.7	3	3
Calif. scorpionfish	Scorpaena guttata	4.1	3	3
California sheephead	Semicossyphus pulcher	3.5	1	3s
California smoothtongue	Leuroglossus stilbies	3.1	1	1
Chinook salmon	Oncorhynchus tshawytscha	4.0	1	1
Chub mackerel	Scomber japonicus	3.6	1	1
Chum salmon	Oncorhynchus keta	3.9	1	1
Coho salmon	Oncorhynchus kisutch	3.9	1	1
C-O turbot	Pleuronichthys coenosus	3.7	3	4s
Cutthroat trout	Salmo clarkii	3.7	1	2
Dover sole	Microstomus pacificus	3.7	3	4
Dwarf perch	Micrometrus minimus	3.0s	1	2
English sole	Parophrys vetulus	3.9	3	4
Eulachon	Thaleichthys pacificus	3.3	1	1
Flathead sole	Hippoglossoides elassodons	3.4	3	2
Halfmoon	Medialuna californiensis	2.4	1	3
Hatchetfish	Argyropelecus spp.	3.5	1	1
Jack mackerel	Trachurus symmetricus	3.0	1	1
Mexican lampfishs	Triphoturus mexicanuss	3.6	1	1
Midwater eelpout	Melanostigma pammelas	3.2	1	1
Northern anchovy	Engraulis mordax	2.8	1	1
Northern lampfish	Stenobrachius leucopsaurus	3.8	1	1
Northern squawfish	Ptychocheilus oregonensis	4.1	1	2
Olive rockfish	Sebastes serranoides	3.8	1	1
Opaleye	Girella nigricans	2.5	1	2
Pacific barracuda	Sphyraena argentea	3.7	1	1
Pacific bonito	Sarda chiliensis	3.8s	1	1
Pacific cod	Gadus macrocephalus	4.1	1	3
Pacific hake	Merluccius productus	3.1	1	1
Pacific herring	Clupea harengus	3.2	1	1
Pacific ocean perchs	Sebastes alutus	3.1	1	1
Pacific rattail	Coryphaenoides acrolepis	3.7	1	3s
Pacific sanddab	Citharichthys sordidus	3.4	3	2s
Pacific sardine	Sardinops sagax	3.1	1	1
Pacific saury	Cololabis saira	3.3	1	1
Pacific staghorn sculpins	Leptocottus armatus	3.8	3	3
Pacific tomcod	Microgadus proximus	3.5	1	3
Peamouth chub	Mylocheilus cairunuss	3.7	1	2
Petrale sole	Eopsetta jordani	3.9	3	2
Pile perch	Rhacochilus vacca	3.0	1	3
Pink salmon	Oncorhynchus gorbuscha	3.6	1	1
Prickly sculpin	Cottus asper	3.7	3	3
Queenfish	Seriphus politus	3.3	1	1
Quillback rockfish	Sebastes maliger	3.8s	1	3
Rainbow trout	Salmo gairdneri	4.1	1	1
Rex sole	Glyptocephalus zachiruss	4.4	3	3
Rock sole	Lepidopsetta bilineata s	3.7	3	4
Rosy rockfish	Sebastes rosaceus	3.3	2	1
Sargo	Anisotremus davidsoni	3.5	1	3s
Shiner surfperchs	Cymatogaster aggregata	3.5	1	2
Sockeye salmon	Oncorhynchus nerka	4.0	1	1
Speckled sanddabs	Citharichthys stigmaeus	3.4	3	2
Spiny dogfish	Squalus acanthias	4.2	1	2
Starry flounders	Platichthys stellatus	3.5	3	4
Starry rockfishs	Sebastes constellatus	3.8	3	3
Striped bass	Morone saxatilis	3.7	1	2
Swordfish	Xiphias gladius	4.0	1	1
Thresher sharks	Alopias vulpinus	3.8	1	1
Topsmelt	Atherinops affiniss	3.4	1	2
Treefish	Sebastes serriceps	4.0	1	3
Vermilion rockfishs	Sebastes miniatus	4.5	1	1
Walleye pollock	Theragra chalcogramma	3.8	1	1
White croaker	Genyonemus lineatus	3.4	1	3
White seaperch	Phanerodon furcatus	3.5s	1	3
White sturgeon	Acipenser transmontanuss	3.8	1	3
Yellowfin tuna	Thunnus albacores	4.3	1	1
Yellowtail rockfish	Sebastes flavidus	3.3	1	1

TLA: 2-3 - Herbivores
3+ - Carnivore

Habitat: 1 - Pelagic
2 - Bottom refuges
3 - Bottom livings
4 - Benthic

Guild: 1 - Pelagic feeding
2 - Mixed
3 - Mixed
4 - Benthic
5 - Suspension feeder
6 - Surface deposit feeder

Table 2.2. Mean total PCBs in fish flesh (and number of samples) - 1975-76 southern California. Effect of habitat, guild, and trophic level assignments.

Guild	Habitat: Pelagic	Habitat: Benthic
Pelagic	197 (12)	300 (1)
Mixed	2,622 (12)	355 (38)
Benthic		891 (66)

Habitat	Trophic Level Assignment: 2.8	3.3	3.4	3.5	3.7	3.8	4.1	4.5
Pelagic	70 (1)	720 (1)	2,779 (11)	890 (1)		310 (1)		140 (9)
Benthic			329 (31)		891 (66)	300 (1)	473 (7)	

Guild	Trophic Level Assignment: 2.8	3.3	3.4	3.5	3.7	3.8	4.1	4.5
Pelagic	70 (1)	720 (1)				305 (2)		140 (9)
Mixed			971 (42)	890 (1)			473 (7)	
Benthic					891 (66)			

Table 3.1. Previous synoptic surveys for which large scale geographic and temporal trends can be plotted.

Data Set (#)	Years Sampled	Regions Sampled	Fish Species	Invertebrate Species	Other Species	Data Points
Cox (66)	1955-69	California	0	0	phyto-plankton	23
California Mussel Watch (12,13,15,16)	1971-83	California	0	bay mussels, coastal mussels	0	231
EPA Mussel Watch (3)	1977-78	entire coast	0	bay mussels, coastal mussels	0	49
NPMP (21)	1965-72	entire coast	0	oysters, 6 other bivalves	0	1,412
SCCWRP (48,49, 51,57)	1971-81	Southern California	starry flounder, Dover sole	yellow crab, coastal mussels, bay mussels	0	400
MacGregor (37,39)	1949-73	Southern California and Baja	mycto-phids, 38 other species	mysids, shrimp, euphausids	0	105
Stout and Beezhold (8)	1967-76	entire coast	28 spp.	8 spp.	0	64
Duke and Wilson (18)	1969-70	entire coast	26 spp.	0	0	44

Table 3.2. Area Code Definitions

Code	Area
AdmI	Admiralty Inlet, Puget Sound
Bham	Bellingham Bay, Washington
BC	British Columbia, Canada
BodB	Bodega Bay, California
CeBj	Central Baja California (Punta San Jose to Punta Eugenia)
CeCA	Central California Coast (Monterey to Point Conception)
ComB	Commencement Bay, Puget Sound
CORE	Central Oregon Coast (Seaside to Newport, Oregon)
CosB	Coos Bay, Oregon
CePS	Central Puget Sound
CRE	Columbia River Estuary
CRP	Columbia River Plume
CzB	Cortez Bank, California
DisB	Discovery Bay, Puget Sound
EllB	Elliott Bay, Puget Sound (including lower Duwamish River)
FarG	Gulf of Farallones, California (Pt. Reyes to Halfmoon Bay)
GryH	Grays Harbor, Washington
HoodC	Hood Canal, Washington
LA	Los Angeles-Long Beach Harbor, Calif
MexB	Mexico-California Border (Tijuana River mouth to Rosarito)
MontB	Monterey Bay, California
NChI	Northern Channel Islands, California (San Miguel, Santa Rosa, Santa Cruz, Anacapa Islands)
NoBj	Northern Baja California (Rosarito to Punta San Jose)
NoCA	Northern California Coast (Oregon border to Pt. Reyes)
NSF	Northern San Francisco Bay, California (North of Treasure Island)
OrCo	Orange County Coast, California (Seal Beach to Corona del Mar)
PrtM	Port Madison, Puget Sound
PrtS	Port Susan, Puget Sound
PV	Palos Verdes Peninsula, California
RogR	Rogue River, Oregon
SBrb	Santa Barbara Coast, California (Pt. Conception to Pt. Dume)
SCI	Santa Catalina Island, California
SDC	San Diego Coast, California (Oceanside to Tijuana River mouth)
SFC	San Francisco Coast, California (Half Moon Bay to Monterey Bay)
SJdF	Straits of Juan de Fuca, Washington
SM	Santa Monica Bay, California
SincI	Sinclair Inlet, Puget Sound
SoBj	Southern Baja California (Punta Eugenia to Cabo de San Lucas)
SoCA	Southern California Coast (Corona del Mar to Oceanside)
SoPS	Southern Puget Sound
SORE	Southern Oregon Coast (Newport, Oregon to California border)
SSF	Southern San Francisco Bay, California (south of Treasure Island)
TilH	Tillamook Head, Oregon
Vanc	Vancouver, British Columbia (Fraser River Estuary and Burrard Inlet)
WAC	Washington Coast (Cape Flattery to Columbia River mouth)
WillB	Willapa Bay, Washington
YaqH	Yaquina Head, Oregon

Table 3.3a. 1969-71 Total DDT levels in other invertebrates: mean, standard deviation (SD), number of samples (N), and data set (values in ppb wet weight).

	Southern California			San Francisco Bay		Oregon		Washington	
Region/Species	San Diego	Coast	Palos Verdes Peninsula	South	North	Yaquina Head	Tillamook Head	Columbia River Plume	Coast
Sea urchin									
Mean (SD)	72 (-)	65 (11)							
N	1	2							
Data set	36	36							
Abalone									
Mean (SD)	2 (-)	6 (-)							
N	1	1							
Data set	36	36							
Scallops									
Mean (SD)		32 (-)							
N		1							
Data set		36							
Asiatic fresh-water clam									
Mean (SD)					298 (176)				
N					13				
Data set					21				
Horse mussels									
Mean (SD)				85 (-)	56 (50)				
N				29	34				
Data set				21	21				
Salps									
Mean (SD)						0 (-)			
N						1			
Data set						1			
Zooplankton									
Mean (SD)			387 (148)			4 (2)	14 (-)	2 (1)	
N			3			5	2	5	
Data set			37			1	1	1	
Penaeid shrimp									
Mean (SD)			4,485 (149)						
N			2						
Data set			37						
Caridean shrimp									
Mean (SD)						4 (1)	2 (-)	2 (1)	3 (1
N						2	1	3	7
Data set						1	1	1	1
Dungeness crab									
Mean (SD)					49 (36)				
N					14				
Data set					56				
Lobster									
Mean (SD)		37 (-)							
N		1							
Data set		36							

Table 3.3b. 1975-76 Total DDT levels in other invertebrates: mean (values in ppb wet weight), standard deviation (SD), number of samples (N), and data set.

Region/Species	Southern Calif.Coast	Santa Catalina Is.	Palos Verdes Peninsula	Santa Monica Bay	Southern San Francisco Bay	Northern San Francisco Bay
Abalone						
Mean (SD)		1 (-)	1(-)			
N		4	7			
Data set		51,53,68	51			
Scallops						
Mean (SD)	4 (1)	89 (73)				
N	3	24				
Data set	68	51,53,68				
Oysters						
Mean (SD)					25 (11)	
N					2	
Data set					6	
Soft-shell clam						
Mean (SD)					10 (-)	13 (-)
N					1	1
Data set					11	11
Penaeid shrimp						
Mean (SD)		7 (2)	150 (-)	188 (121)		
N		3	1	5		
Data set		68	53	68		
Lobster						
Mean (SD)	4 (-)	3 (-)	562 (526)			
N	1	1	6			
Data set	51	51	51,68			
Yellow Crab						
Mean (SD)	5 (3)		1,496 (333)			
N	4		7			
Data set	51,68		51,53,68			

Table 3.3c. 1979-81 Total DDT levels in other invertebrates: mean, standard deviation (SD), number of samples (N), and data set (values in ppb wet weight).

Region/ Species	Santa Catalina Island	Palos Verdes Peninsula	Santa Monica Bay	South San Francisco Bay	North San Francisco Bay	Coos Bay	Puget Sound: South Puget Sound	Puget Sound: Commence-ment Bay	Puget Sound: Discovery Bay	Puget Sound: Sinclair Inlet	Puget Sound: Elliott Bay	Puget Sound: Port Madis
Annelids												
Mean (SD)								9(9)		4(-)	5(-)	1(
N								3		1	3	1
Data set								24		24	24	24
Sea Urchins												
Mean (SD)		4,500(-)										
N		1										
Data set		51										
Oysters												
Mean (SD)						10(-)						
N						5						
Data set						2						
Horse clam												
Mean (SD)	36(5)					10(-)						
N	5					1						
Data set	68					2						
Soft-shell clam												
Mean (SD)				13(16)	24(17)							
N				5	3							
Data set				60	60							
Squid												
Mean (SD)	12(11)											
N	5											
Data set	68											
Zooplankton												
Mean (SD)			9(1)									
N			4									
Data set			68									
Caridean shrimp												
Mean		335(137)					1(-)	8(11)		6(4)	3(1)	1
N		6					1	3		3	2	1
Data set		68					24	24		24	24	24
Yellow crab												
Mean (SD)		327(77)										
N		5										
Data set		68										
Dungeness crab												
Mean (SD)							1(-)		1(-)			
N							4		2			
Data set							22		22			

Table 3.4a. 1969-71 Total PCB levels in other invertebrates: mean, standard deviation (SD), number of samples (N), and data set (values in ppb wet weight).

Region/Species	San Diego Coast	Southern California Coast	Yaquina Head
Sea urchins			
Mean (SD)	210 (-)	140 (28)	
N	1	2	
Data set	36	36	
Abalone			
Mean (SD)	47 (-)	8 (-)	
N	1	1	
Data set	36	36	
Scallops			
Mean (SD)		500 (-)	
N		1	
Data set		36	
Salps			
Mean (SD)			20 (-)
N			1
Data set			1
Lobster			
Mean (SD)		160 (-)	
N		1	
Data set		36	

Table 3.4b. 1975-76 Total PCB levels in other invertebrates: mean, standard deviation (SD), number of samples (N), data set (values in ppb wet weight).

Region/Species	Southern California	Santa Catalina Island	Palos Verdes Peninsula	Santa Monica Bay	San Francisco Coast	Gulf of Farallones	Northern California	Elliott Bay
Sea cucumbers								
Mean (SD)								65 (7)
N								2
Data set								5
Abalone								
Mean (SD)		24 (15)	28 ([illegible])					
N		4	7					
Data set		51,53,58	51					
Oysters								
Mean (SD)					25 (6)			
N					2			
Data set					11			
Scallops								
Mean (SD)	3 (2)	10 (6)						
N	3	24						
Data set	68	51,53,68						
Penaeid shrimp								
Mean (SD)		16 (5)	58 (-)	1[illegible]0 (84)				
N		3	1	[illegible]				
Data set		68	53	68				
Caridean shrimp								
Mean (SD)								430(182)
N								35
Data set								5
Dungeness crab								
Mean (SD)						32 (-)	13 (-)	
N						1	1	
Data set						41	41	
Yellow crab								
Mean (SD)	32 (9)		359 (31[illegible])					
N	4		6					
Data set	51,68		51,53,68					

Table 3.4c. 1979-81 Total PCB levels in other invertebrates: mean, standard deviation (SD), number of samples (N), and data set (ppb wet weight).

Region/ Species	Santa Cataline Island	Palos Verdes Peninsula	Santa Monica Bay	Coos Bay	South Puget Sound	Puget Sound: Commencement Bay	Puget Sound: Sinclair Inlet	Puget Sound: Elliott Bay	Puget Sound: Port Madison
Annelids									
Mean (SD)						136 (104)	165 (-)	184 (63)	44 (-)
N						3	1	3	1
Data set						24	24	24	24
Sea Urchins									
Mean (SD)		1,200 (-)							
N		1							
Data set		51							
Oysters									
Mean (SD)				0(-)					
N				5					
Data set				2					
Horse clam									
Mean (SD)	20 (13)			0 (-)					
N	5			1					
Data set	68			2					
Squid									
Mean (SD)	13(7)								
N	5								
Data set	68								
Zooplankton									
Mean (SD)	4 (-)		3 (1)						
N	1		4						
Data set	68		68						
Caridean shrimp									
Mean		32 (13)			2 (-)	239 (344)	119 (66)	292 (255)	55 (-)
N		6			1	3	3	2	1
Data set		68			24	24	24	24	24
Yellow crab									
Mean (SD)		61 (25)							
N		5							
Data set		68							

Table 3.5. Species list of group 1 fish (pelagic living, pelagic feeding) sampled for DDT or PCBs on the U.S. West Coast

Common Name	Scientific Name	Data Sources
Blue shark	Prionace glauca	68
Bonito shark	Isurus oxyrinchus	68
Bristlemouth lightfish	Cyclothone spp.	37
California smoothtongue	Leuroglossus stilbius	37
Chub mackerel	Scomber japonicus	18,32,39,65,68
Eulachon	Thaleichthys pacificus	9
Hatchetfish	Argyropelecus spp.	37
Jack mackerel	Trachurus symmetricus	8,18,29,32,39,55,68
Mexican lampfish	Triphoturus mexicanus	33
Midwater eelpout	Melanostigma pammelas	37
Northern anchovy	Engraulis mordax	8,27,51,55,68
Northern lampfish	Stenobrachius leucopsaurus	37
Pacific barracuda	Sphyraena argentea	32,68
Pacific bonito	Sarda chiliensis	8,18,32,39,51,68
Pacific hake	Merluccius productus	8,18,22,27,39,55,68
Pacific herring	Clupea harengus	1,8
Pacific sardine	Sardinops sagax	18,39,68
Pacific saury	Cololabis saira	8
Queenfish	Seriphus politus	32,51
Rainbow trout	Salmo gairdneri	2,9,28
Rockfish	Sebastes spp.	8,18,27,32,36,37, 39,51,53,65,68
Salmon	Oncorhynchus spp.	8,18,25,28
Swordfish	Xiphias gladius	68
Thresher shark	Alopias vulpinus	68
Tuna	Thunnus spp.	8,18,39
Walleye pollock	Theragra chalcogramma	22

Table 3.6. Species list of group 2 fish (pelagic living, mixed feeding) sampled for DDT or PCBs on the U.S. West Coast

Common Name	Scientific Name	Data Sources
Barred sand bass	Paralabrax nebulifer	18,32,36,39,65
Black perch	Embiotoca jacksoni	1,32,51
California sheephead	Semicossyphus pulcher	36
Cutthroat trout	Salmo clarkii	9,28
Dwarf perch	Micrometrus minimus	56
Halfmoon	Medialuna californiensis	65
Northern squawfish	Ptychocheilus oregonensis	28
Opaleye	Girella nigricans	65
Pacific cod	Gadus macrocephalus	8,22,25
Pacific rattail	Coryphaenoides acrolepis	29
Pacific tomcod	Microgadus proximus	1,22
Peamouth chub	Mylocheilus cairunus	1,28
Pile perch	Rhacochilus vacca	56
Rockfish	Sebastes spp.	8,18,24,32,36,39
Sargo	Anisotremus davidsoni	36
Shiner surfperch	Cymatogaster aggregata	55,56
Spiny dogfish	Squalus acanthias	18,39,68
Striped bass	Morone saxatilis	2,8,53,64,65,68
Topsmelt	Atherinops affinis	53,68
White croaker	Genyonemus lineatus	8,18,29,32,39, 40,50,51,65,68
White seaperch	Phanerodon furcatus	32,56,65
White sturgeon	Acipenser transmontanus	28

Table 3.7. Species list of group 3 fish (benthic living, mixed feeding) sampled for DDT or PCBs on the U.S. West Coast.

Common Name	Scientific Name	Data Source
Buffalo sculpin	Enophrys bison	22
Calif. scorpionfish	Scorpaena guttata	8,18,32,51,53,65,68
Flathead sole	Hippoglossoides elassodon	22
Pacific sanddab	Citharichthys sordidus	29,30,51,53,65,68
Pacific staghorn sculpin	Leptocottus armatus	1,9,22,24,39,56
Petrale sole	Eopsetta jordani	29
Prickly sculpin	Cottus asper	4,9,22
Rex sole	Glyptocephalus zachirus	8
Speckled sanddab	Citharichthys stigmaeus	30,56
Starry rockfish	Sebastes constellatus	8,18,37,39

Table 3.8. Species list of group 4 fish (benthic living, benthic feeding) samp for DDT or PCBs on the U.S. West Coast.

Common Name	Scientific Name	Data Source
Rock sole	Lepidopsetta bilineata	22,23,24
Dover sole	Microstomus pacificus	8,35,39,48,49,51, 52,57,68
English sole	Parophrys vetulus	5,8,18,22,23,24, 26,27,29,30,37, 39,55,56,69
Starry flounder	Platichthys stellatus	1,9,22,27,30,56,57
C-O turbot	Pleuronichthys coenosus	22

Table 3.9. Coastal mussels: regional changes in total DDT and PCBs over 15 years (1969-83), taken from figures 3.10 and 3.11.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
N. Baja California	1969	34	-		
	1983	6			
San Diego Coast	1969	66		108	
	1983	11	-	33	-
S. California Coast	1969	275		45	
	1983	48	-	14	-
Santa Catalina Is.	1969	70		22	
	1975	120	-*	56	+
	1983	3			
Orange County	1969	670		184	
	1983	33	-*	32	-
Palos Verdes Peninsula	1969	3,240		397	
	1975	619	-*	94	-*
	1983	246		33	
Central California Coast	1969	86		20	
	1983	5	-*	15	-
North Channel Is.	1969	68		21	
	1983	3	-*	1	-*
Gulf of Farallones	1975	7			
	1983	2	-		
Bodega Bay	1969	16		15	
	1983	4	-	3	-

* = A decrease of one order of magnitude or more.

Table 3.10. Bay mussels: regional changes in total DDT and PCBs over 15 years (1969-83), taken from figures 3.12 and 3.13.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Los Angeles Harbor	1969	447			
	1983	245	-		
Santa Barbara Coast	1969	667			
	1983	112	-		
Monterey Bay	1969	102			
	1983	447	+		
Southern San Francisco Bay	1975	22			
	1983	35	+		
Northern San Francisco Bay	1975	19			
	1983	78	+		
South Puget Sound	1975			22	
	1983			90	+
Commencement Bay	1975			55	
	1983			54	0

Table 3.11. Oysters: regional changes in total DDT over 11 years (1966-76) from figure 3.6 and table 3.3.

Region	Years	Mean DDT	Direction of Change
Central California	1966	142	
	1970	260	+
Monterey Bay	1966	576	
	1970	1,034	+
Southern San Francisco Bay	1966	185	
	1970	170	-
	1976	25	
Northern San Francisco Bay	1966	173	
	1970	158	-
Bodega Bay	1966	18	
	1970	29	+
Northern California Coast	1966	17	
	1970	25	+

Table 3.12. Other invertebrates: regional changes in total DDT and PCBs over 13 years (1969-81), taken from figures 3.3 and 3.4.

Species/Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Scallops/					
Southern	1969	32		500	
California Coast	1976	4	-	3	-*
Lobster/					
Southern	1969	37			
California Coast	1976	4	-		
Soft-shell clam/					
Southern San	1975	10			
Francisco Bay	1981	13	+		
Northern San	1975	13			
Francisco Bay	1981	24	+		
Yellow crab/					
Palos Verdes	1975	1,496		369	
	1981	327	-	61	-
Caridean shrimp/					
Elliott Bay	1975			430	
	1981			292	-

* = A decrease of one order of magnitude or more.

Table 3.13. Group 1 fish (pelagic living, pelagic feeding): regional changes in total DDT and PCBs over 13 years (1969-81), taken from figures 3.14 and 3.15.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Santa Catalina Is.	1969	495			
	1975	670	-	213	-*
	1981	63		14	
Los Angeles Harbor	1969	3,210			
	1981	154	-*		
Palos Verdes Peninsula	1975	1,128		197	
	1981	193	-	37	-
Santa Monica Bay	1969	21,939			
	1981	353	-*		
Santa Barbara Coast	1969	8,080			
	1981	41	-*		
Elliott Bay	1969	39			
	1975	34	0		

* = A decrease of one order of magnitude or more.

Table 3.14. Group 2 fish (pelagic living, mixed feeding): regional changes in total DDT and PCBs over 13 years (1969-81), taken from figures 3.16 and 3.17.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Southern California	1969	627			
Coast	1981	118	-		
Santa Catalina Is.	1969	194			
	1975	40	-		
Palos Verdes	1975	36,344		2,622	
Peninsula	1981	42,968	+	3,720	+

Table 3.15. Group 3 fish (benthic living, mixed feeding): regional changes in total DDT and PCBs over 13 years (1969-81), taken from figures 3.18 and 3.19.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Santa Catalina Is.	1969	271			
	1975	138	-	44	
	1981			45	0
Palos Verdes	1975	5,453		487	
Peninsula	1981	350	-*	48	-*
Santa Monica Bay	1969	56,000			
	1981	540	-*		

* = A decrease of one order of magnitude or more.

Table 3.16. Group 4 fish (benthic living, benthic feeding): regional changes in total DDT and PCBs over 13 years (1969-81), taken from figures 3.20 and 3.21.

Region	Years	Mean DDT	Direction of Change	Mean PCB	Direction of Change
Southern California Coast	1969	405		240	
	1975	27	-	134	-
Santa Catalina Is.	1969	73		27	
	1975	29	-	58	+
Orange County	1969			406	
	1975			1,197	+
Palos Verdes Peninsula	1969	10,357		1,640	
	1975	17,315	-	1,224	-
	1981	5,994		237	
Santa Monica Bay	1969			946	
	1975			1,766	
Santa Barbara Coast	1969			60	
	1975			60	0
Elliott Bay	1975			1,705	
	1981			1,035	-

Table 4.1. Regions of highest total DDT levels between 1969 and 1976 (among those sampled).

1969-71

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Coastal mussels	3.10a	Palos Verdes	3,240
		Orange County Coast	670
		Los Angeles Harbor	570
		All other areas	Less than 400
Bay mussels	3.12a	Santa Barbara Coast	667
		Los Angeles Harbor	450
		San Diego Coast	358
		All other areas	Less than 110
Oysters	3.6b	Monterey Bay	1,034
		All other areas	Less than 300
Sand crabs	3.6e	Orange County Coast	4,956
		Santa Monica Bay	1,144
		Southern California Coast	400
		All other areas	Less than 150
Zooplankton	table 3.3a	San Pedro Channel	387
		All other areas	Less than 15
Group 1 fish	3.14a	Santa Monica Bay	21,939
		Santa Barbara Coast	8,080
		Los Angeles Harbor	3,210
		All other areas	Less than 500
Group 2 fish	3.16a	Southern California Coast	627
		All other areas	Less than 400
Group 3 fish	3.18a	Santa Monica Bay	56,000
		All other areas	Less than 300
Group 4 fish	3.20a	Palos Verdes	10,357
		Santa Monica Bay	5,344
		All other areas	Less than 900

1975-76

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Coastal mussels	3.10b	Palos Verdes	619
		Santa Catalina Island	120
		All other areas	Less than 10
Lobster	table 3.3b	Palos Verdes	562
		All other areas	Less than 5
Group 1 fish	3.14b	Palos Verdes	1,128
		Santa Catalina Island	670
		All other areas	Less than 200
Group 3 fish	3.18a	Palos Verdes	5,453
		All other areas	Less than 200
Group 4 fish	3.20b	Palos Verdes	17,316
		All other areas	Less than 50

TALLY		
	Palos Verdes:	7 worst site counts
	Santa Monica Bay:	2 worst site counts 2 top 3 counts
	Santa Barbara Coast] So. Calif.Coast] Orange County Coast]	- 1 worst site count 1 top 3 count
	Los Angeles Harbor:	2 top 3 counts

Table 4.2. Regions of highest total DDT levels between 1979 and 1983 (among those sampled).

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Coastal mussels	3.10c	Palos Verdes	246
		All other areas	Less than 50
Bay mussels	3.12c	Monterey Bay	447
		Orange County Coast	343
		Los Angeles Harbor	244
		All other areas	Less than 160
Caridean shrimp	table 3.3c	Palos Verdes	335
		All other areas	Less than 10
Group 1 fish	3.14c	Santa Monica Bay	353
		Orange County Coast	255
		All other areas	Less than 200
Group 2 fish	3.16c	Palos Verdes	42,968
		Los Angeles Harbor	697
		Santa Monica Bay	498
		All other areas	Less than 120
Group 3 fish	3.18c	Santa Monica Bay	540
		Palos Verdes	350
		All other areas	Less than 10
Group 4 fish	3.20c	Palos Verdes	5,994
		All other areas	Less than 35

TALLY		
	Palos Verdes:	4 worst site counts 1 top 3 count
	Santa Monica Bay:	2 worst site counts 1 top 3 count
	Monterey Bay:	1 worst site count
	Orange County Coast] Los Angeles]	- 2 top 3 counts

Table 4.3. Regions of highest total PCB levels between 1969 and 1976 (among those sampled).

1969-71

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Coastal mussels	3.11a	Palos Verdes	397
		Los Angeles Harbor	200
		Orange County Coast	184
		All other areas	Less than 110
Group 4 fish	3.21a	Palos Verdes	1,640
		Santa Monica Bay	946
		All other areas	Less than 410

1975-76

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Bay mussels	3.13a	Elliott Bay	140
		All other areas	Less than 60
Penaeid shrimp	table 3.4b	Palos Verdes	120
		All other areas	Less than 60
Group 1 fish	3.15a	Elliott Bay	240
		Santa Catalina Island	213
		Palos Verdes	197
		All other areas	Less than 150
Group 3 fish	3.19b	Palos Verdes	487
		Elliott Bay	458
		Commencement Bay	350
		All other areas	Less than 200
Group 4 fish	3.21b	Santa Monica Bay	1,767
		Elliott Bay	1,705
		Palos Verdes	1,224
		Orange County Coast	1,197
		All other areas	Less than 220

TALLY

TALLY	Palos Verdes:	4 worst site counts 2 top 3 counts
	Elliott Bay:	2 worst site counts 2 top 3 counts
	Santa Monica Bay:	1 worst site count 1 top 3 count
	Orange County Coast:	2 top 3 counts

Table 4.4. Regions of highest total PCB levels between 1979 and 1983 (among those sampled).

Species	Source Figure	Regions with Highest Levels	Levels ppb Wet Weight
Annelids	table 3.4c	Elliott Bay	184
		Sinclair Inlet	165
		Commencement Bay	136
		All other areas	Less than 45
Caridean shrimp	table 3.4c	Elliott Bay	292
		Commencement Bay	239
		All other areas	Less than 120
Group 1 fish	3.15b	Vancouver, B.C.	212
		All other areas	Less than 100
Group 2 fish	3.17b	Palos Verdes	3,720
		North California Coast	750
		North San Francisco Bay	477
		All other areas	Less than 300
Group 3 fish	3.19b	Vancouver, B.C.	244
		Santa Monica Bay	130
		All other areas	Less than 65
Group 4 fish	3.21c	Elliott Bay	1,035
		Commencement Bay	439
		All other areas	Less than 250

TALLY	Elliott Bay:	3 worst site counts
	Vancouver, B.C.:	2 worst site counts
	Commencement Bay:	3 top 3 counts
	Palos Verdes:	1 worst site count

Table 4.5. Summary of regions with greatest contamination among those sampled.

Years	No. 1	No. 2	No. 3
DDT			
1969-76	Palos Verdes	Santa Monica Bay	Orange County Coast Los Angeles Harbor Southern California Coast Santa Barbara Coast
1979-83	Palos Verdes	Santa Monica Bay	Monterey Bay Los Angeles Harbor Orange County Coast
PCBs			
1969-76	Palos Verdes	Elliott Bay	Santa Monica
1979-83	Elliott Bay	Vancouver, B.C.	Palos Verdes Commencement Bay

Table 4.6. Summary of fish flesh samples containing more than the FDA limit of total DDT.

Region	Species	Year	No. of Samples Exceeding Limit	Range	Mean
Santa Barbara Channel	Pacific bonito	1971	1	--	8,080
Santa Monica Bay	vermilion rockfish	1970	6	16,000-69,100	29,933
	starry rockfish	1970	6	31,100-76,300	56,000
	bocaccio	1970	6	7,970-28,900	13,945
	Dover sole	1970	2	13,300-13,300	13,300
		1971	1	--	7,200
	English sole	1970	1	--	13,000
	sablefish	1970	3	23,000-23,400	23,267
Palos Verdes	Dover sole	1971	5	5,100-24,000	13,160
		1972	2	17,000-26,000	21,500
		1973	2	16,000-18,000	17,000
		1974	15	5,000-36,000	16,333
		1975	2	11,000-25,000	18,000
		1976	23	7,100-42,000	19,822
		1980	4	5,990-12,990	8,078
	sablefish	1978	1	--	5,600
	black perch	1976	1	--	5,400
	Pacific sanddab	1975	13	5,250-14,000	7,138
		1976	2	6,100- 6,200	6,150
	California scorpionfish	1975	1	--	5,220
	white croaker	1975	10	5,230-176,400	39,173
		1976	1	--	39,000
		1980	1	--	7,600
		1981	1	--	8,100
Palos Verdes	spiny dogfish	1981	4	14,400-200,000	81,225
Orange County Coast	Dover sole	1974	2	7,600-31,000	19,300
	striped mullet	1978	1	--	5,760
Southern California Coast	Dover sole	1974	2	7,600-19,000	13,300
	jack mackerel	1970	1	--	5,700
	TOTAL		120		

Table 4.7. Summary of fish flesh samples containing more than the FDA limit of total PCBs.

Region	Species	Year	No. of Samples Exceeding Limit	Range	Mean
Elliott Bay	English sole	1976	4	3,040-5,900	4,058
		1980	1	--	2,111
Southern Puget Sound	starry flounder	1977	1	--	2,100
Santa Monica Bay	Dover sole	1972	3	2,000-2,800	2,400
		1975	2	2,300-2,500	2,400
Palos Verdes Peninsula	Dover sole	1971	2	2,400-4,100	3,250
		1972	6	2,100-6,300	3,150
		1973	1	--	2,000
		1974	6	2,000-3,800	2,583
		1975	1	--	2,200
		1976	4	2,000-2,400	2,150
	white croaker	1975	4	3,310-9,950	5,870
		1976	1	--	2,800
	spiny dogfish	1981	3	3,100-14,800	7,833
Orange County Coast	Dover sole	1974	1	--	3,000
		1975	2	2,200-3,100	2,650
	striped mullet	1978	1	--	6,420
Southern California Coast	Dover sole	1974	2	3,400-4,000	3,700
	TOTAL		46		

Table 4.8. Direction of changes in mean DDT concentrations with time.

Region	Species	Source Table	Time Period	Approximate Magnitude of Change	Direction of Change
Elliott Bay	group 1 fish	3.13	1969-71	-1.2x	-
Northern Calif.	oysters	3.11	1966-71	(+1.5x)	(+)
Bodega Bay	oysters	3.11	1966-71	(+1.5x)	-
	coastal mussels	3.9	1969-83	-4x	
Gulf of Farallones	coastal mussels	3.9	1975-83	-3.5x	-
Northern San Francisco Bay	oysters	3.11	1966-71	(-1.2x)	
	bay mussels	3.10	1975-83	+4x	+
	soft-shell clam	3.12	1975-81	+2x	
Southern San Francisco Bay	oysters	3.11	1966-71	(-7x)	
	bay mussels	3.10	1975-83	+1.3x	+
	soft-shell clam	3.12	1975-81	+1.3x	
Monterey Bay	oysters	3.11	1966-71	(+2x)	
	bay mussels	3.10	1969-83	+4x	+
	phytoplankton	3.8b (fig.)	1959-68	(+5x)	
Central California Coast	oysters	3.11	1966-71	(+1.5x)	
	coastal mussels	3.9	1969-83	-18x	-
Santa Barbara Coast	group 1 fish	3.13	1969-81	-20x	
	bay mussels	3.10	1969-83	- 6x	-
North Channel Is.	coastal mussels	3.9	1969-83	-20x	-
Santa Monica Bay	group 1 fish	3.13	1969-81	-70x	-
	group 2 fish	3.15	1969-81	-100x	
Palos Verdes	yellow crab	3.12	1975-81	-5x	
	white croaker	3.8f (fig.)	1975-81	-5x	
	coastal mussels	3.9	1969-83	-10x	
	group 4 fish	3.16	1969-81	-2x	
	group 1 fish	3.13	1975-81	-6x	-
	group 2 fish	3.14	1975-81	+1.2x	
	group 3 fish	3.15	1975-81	-12x	
Los Angeles Harbor	bay mussels	3.10	1969-83	-2x	
	group 1 fish	3.13	1969-81	-20x	-
Orange County Coast	coastal mussels	3.9	1969-83	-20x	-
Santa Catalina Island	group 4 fish	3.16	1969-76	-2x	
	group 3 fish	3.15	1969-76	-2x	
	coastal mussels	3.9	1969-83	-20x	-
	group 1 fish	3.13	1969-81	-8x	
	group 2 fish	3.14	1969-81	-5x	
Southern California Coast	lobster	3.12	1969-76	-9x	
	group 4 fish	3.16	1969-76	-15x	
	scallops	3.12	1969-76	-8x	-
	coastal mussels	3.9	1969-83	-5x	
	group 2 fish	3.14	1969-81	-5x	
San Diego Coast	coastal mussels	3.9	1969-83	-6x	-
North. Baja	coastal mussels	3.9	1969-83	-5x	-

NOTE: Parentheses indicate changes before regulation of DDT.

Table 4.9. Direction of changes in mean PCB concentrations with time.

Region	Species	Source Table	Time Period	Magnitude of Change	Direction of Change
Elliott Bay	caridean shrimp	3.12	1975-81	-1.5x	
	group 4 fish	3.16	1975-81	-1.5x	-
Commencement Bay	bay mussels	3.10	1975-83	0	0
South. Puget Sound	bay mussels	3.10	1975-83	+4x	+
Bodega Bay	coastal mussels	3.9	1969-83	-5x	-
Central California	coastal mussels	3.9	1969-83	-1.5x	-
Santa Barbara	group 4 fish	3.16	1969-76	(0)	(0)
North Channel Is.	coastal mussels	3.9	1969-83	-20x	-
Santa Monica	group 4 fish	3.16	1969-76	(+1.5x)	(+)
Palos Verdes	yellow crab	3.12	1975-81	-6x	
	white croaker	3.9d (fig.)	1975-80	-7x	
	coastal mussels	3.9	1969-81	-12x	
	group 4 fish	3.16	1969-81	-8x	
	group 3 fish	3.15	1969-81	-10x	-
	group 1 fish	3.13	1975-81	-5x	
	group 2 fish	3.14	1975-81	+1.3x	
	Dover sole	3.9c (fig.)	1971-81	-17x	
Orange County	coastal mussels	3.9	1969-83	-6x	
	group 4 fish	3.16	1969-76	(+3x)	-
Santa Catalina Is.	coastal mussels	3.9	1969-76	(+2.5x)	
	group 4 fish	3.16	1969-76	(+2x)	
	group 2 fish	3.13	1975-81	-15x	+/-
	group 3 fish	3.15	1975-81	0	
Southern Calif.	group 4 fish	3.16	1969-76	(-1.8x)	
	scallops	3.12	1969-76	(-167x)	-
	coastal mussels	3.9	1969-83	(-3x)	
San Diego Coast	coastal mussels	3.9	1975-83	-3.3x	-

NOTE: Parentheses indicate changes before regulation of PCBs.

Table 5.1. Summary of Additional Samples Required to Confirm or Reject Trends: Total DDT

Species	Last Sampled	Area	Planned Sampling	Purpose
Sole or bay mussels	*	Skagit River Mouth, WA	*	Verify apparent geographic trend (see note)
Sole or bay mussels	*	Bellingham Bay	*	
Sole	*	Central California	*	
Coastal mussels	*	Central California	CMW-1985-86	"
				Validate Apparent:
Oysters	1972	Humboldt Bay, CA	*	Increase
Oysters	1976	San Francisco Bay	*	Decrease
Bay mussels	1984	San Francisco Bay San Francisco Bay	CMW-1985-86 NS&T MW	Increase
Oysters	1971	Monterey Bay	*	Increase
Bay mussels	1984	Monterey Bay	CMW-1985-86 NS&T MW	Increase
Salmon	1976	Elliott Bay	*	No change
Sole	*	Outer Washington Coast	*	Provide geographic trend data
Sole	1971	Oregon Coast	NS&T/1985-86	
Sole	1981	Puget Sound (other than Elliott Bay)	NS&T/1985-86	"
Salmon	1971	Central Puget Sound	*	Provide temporal trend information
Northern anchovy	1971	Camano Island, WA	*	
Pacific cod, Dover sole, or hake	1971	Columbia River Estuary	*	"
Bocaccio	1976	Yaquina Head, OR	*	"

* Not known.

Note: Fish and shellfish from these areas have contained very low levels of DDT (CMW - Calif. Mussel Watch; NS&T - Natl. Status and Trends Program Benthic Surveillance; NS&T MW - Natl. Status and Trends Program Mussel Watch)

Table 5.2. Summary of Additional Samples Required to Confirm or Reject Trends: PCBs

Species	Last Sampled	Area	Planned Sampling	Purpose
Sole	*	Northern Puget Sound	*	Verify apparent geographic trends (see note)
	*	Washington Coast	*	
	*	Columbia River Estuary	NS&T/1985-86	
	*	San Francisco Bay	NS&T/1985-86	
	*	Monterey to Bodega Head	NS&T/1985-86	
	*	Central California	*	"
	*	San Diego Coast	NS&T/1985-86	"
	*	Baja California	*	"
Bay mussels	*	Willapa Bay, WA	NS&T MW	Provide temporal trends
Bay mussels	*	Tillamook Bay, OR	NS&T MW	
Oysters	1980	Coos Bay, OR	*	"
Clams	1981	" "	*	"
Striped bass	1981	" "	*	"
Striped bass	1981	Northern California	*	"
Dungeness crab	1976	" "	*	"
Coastal mussels	1984	" "	CMW-1985-86 NS&T MW	"
Coastal mussels	1984	Monterey Bay	NS&T MW	"
Bay mussels	1984	" "	CMW1985-86	"
Dungeness crab	1976	Gulf of Farallones	*	"
Coastal mussels	1983	San Francisco Coast	*	"
				Validate Apparent:
Bay mussels	1983	Commencement Bay	NS&T MW	No Change
Bay mussels	1983	Southern Puget Sound	NS&T MW	Increase
Dover sole	1976	Santa Barbara Coast	*	No Change
Sole	1976	Santa Monica Bay	NS&T/1985-86	Increase
Dover sole	1976	Santa Catalina Island	*	Increase

* Not known.

Note: Fish and shellfish from these areas have contained very low levels of PCBs (CMW - Calif. Mussel Watch; NS&T - Natl. Status and Trends Program Benthic Surveillance; NS&T MW - Natl. Status and Trends Program Mussel Watch)

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APPENDIX

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