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SWAMP Assement Repot for the Central Coast Region	1998

Central Coast Ambient Monitoring Program 1998 Coastal Confluences Sediment Chemistry Assessment Report

1998

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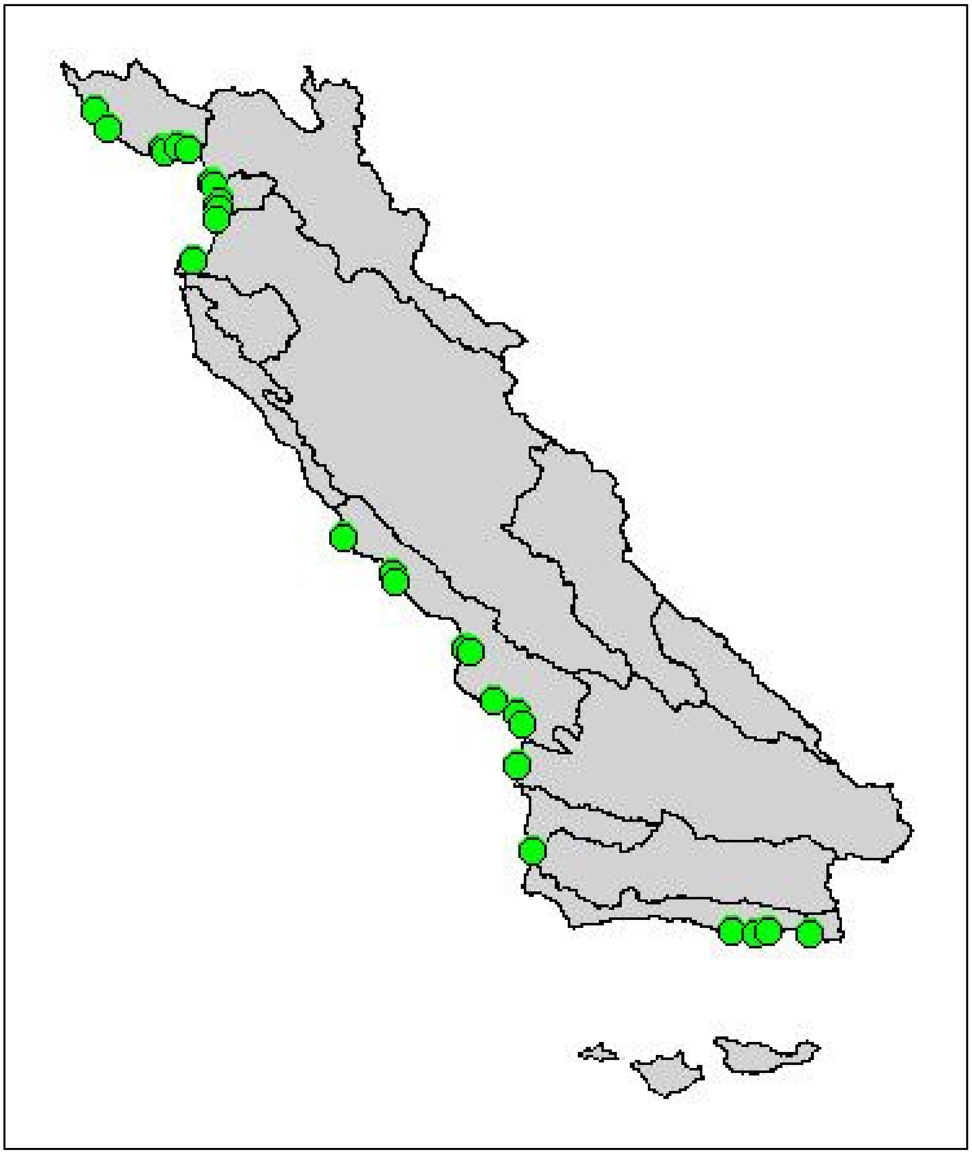


1998 Coastal Confluences Sediment Chemistry Assessment

Contents

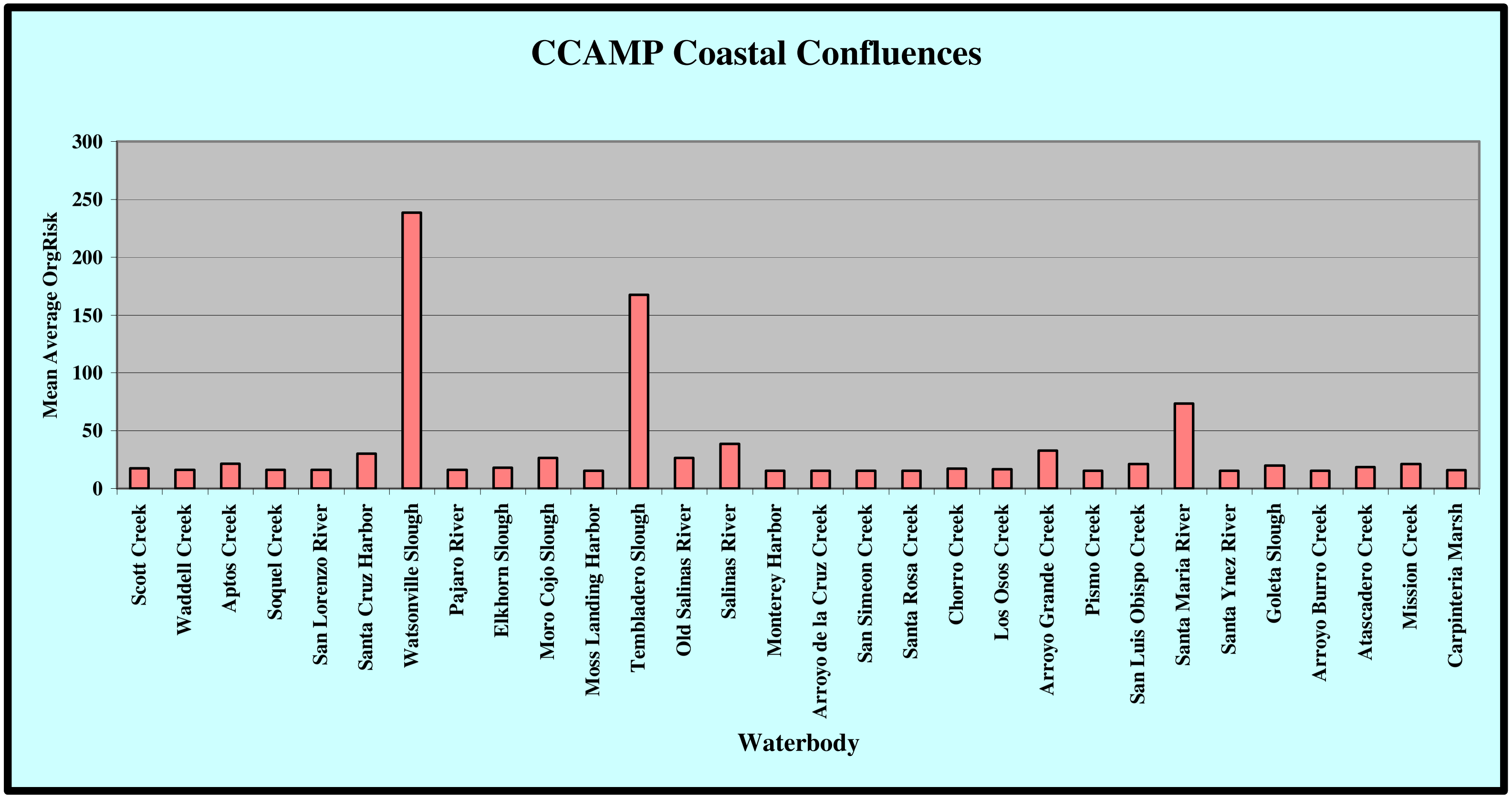
Executive Summary

In March, 1998, a synoptic sediment chemistry survey was conducted at thirty coastal estuaries and lagoons in the Central Coast Region. Because funds for 1998 sampling were limited, only a single sediment sample was collected at each lagoon, and sites were limited to thirty locations. Analysis was conducted for a suite of synthetic organic chemicals and metals; sediment particle size was also analyzed. At several sites, relatively large grain size limited the ability to detect synthetic organic chemicals.

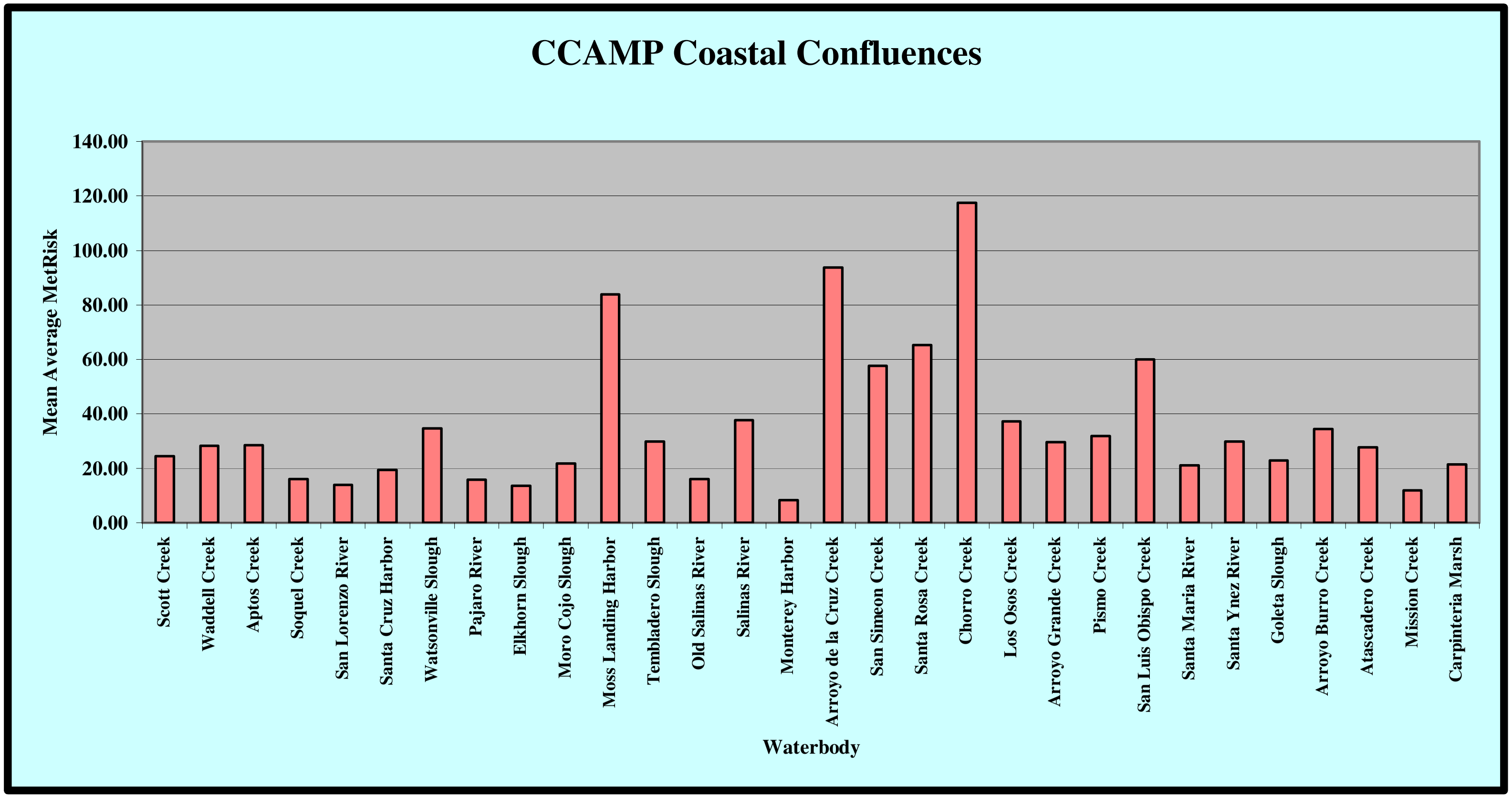
Elevated levels of one or more synthetic organic chemicals were found at Tembladero Slough, Watsonville Slough, Salinas River, Old Salinas River, Moro Cojo Slough, San Luis Obispo Creek, Arroyo Grande Creek, Santa Maria River, Mission Creek, Atascadero Creek (Santa Barbara County), and Goleta Slough. Concentrations at Tembladero Slough and Watsonville Slough were particularly elevated for a broad variety of chemicals. Samples collected at Pajaro River and Moss Landing did not contain an adequate amount of the fine sediment targeted by this study to draw meaningful conclusions. An organic chemical risk index was developed based on various standards and guidelines, and was applied in order to provide a criteria for ranking sites relative to one another.

Elevated levels of various metals were found in San Luis Obispo County, particularly at Arroyo Grande, Chorro, Santa Rosa, San Simeon, and Arroyo de la Cruz creeks, and appear to be associated with the area's serpentine soils and abandoned mines. Santa Rosa Creek was the only location which showed elevated concentrations of mercury. The elevated levels of mercury are probably associated with known inactive mines in the area. In Monterey County, Moss Landing chromium concentrations may be associated with a remediated disposal site in the vicinity. A metals risk index was developed based on various standards and guidelines, and was applied in order to provide a criteria for ranking sites relative to one another.

This study confirms findings of earlier work by other programs and from information contained in long term databases, including the State Mussel Watch Program, the Toxic Substances Monitoring Program, and the Bay Protection and Toxic Cleanup Program. At several sites, the findings of this study indicate a need for followup and further investigation.



CCAMP Organic Chemical Risk Index for 1998 Coastal Confluences Sediment Samples.



CCAMP Metals Risk Index for 1998 Coastal Confluences Sediment Samples.

Introduction

In March, 1998, a synoptic sediment chemistry survey was conducted at thirty coastal confluences in the Central Coast Region. Periodic sampling of these areas is a part of the Central Coast Ambient Monitoring Program (CCAMP) Coastal Confluences monitoring strategy. Because funds for 1998 sampling were limited, only a single sediment sample was collected at each lagoon, and sites were limited to thirty locations.

Major estuaries and lagoons throughout the Region were sampled, as well as a number of smaller lagoons. Coastal confluences included in the sampling effort are shown in Table 1 and Figure 1. Not all targeted CCAMP coastal confluences were sampled in 1998; significant areas along the Big Sur and Santa Barbara County coastlines were not sampled because of funding constraints.

Results are described below, organized by chemical of concern. The discussion section that follows is organized according to geographic location, and includes information from other sources, such as the State Mussel Watch Program.

Results: Organic Chemicals and Metals found at Coastal Confluences

Sediment samples were collected at thirty coastal confluences on the central coast of California. Each sample was analyzed for sediment particle size and total organic carbon, as well as the synthetic organic chemicals and metals described in the Coastal Confluences strategy. Sampling targeted fine-grained sediments, in order to maximize detection of potential problem chemicals.

Analysis for a wide variety of organic chemicals and metals in sediment was conducted. Not all chemicals were detected. The following charts depict the concentrations of analytes which were detected in the region. For each analyte, the twenty sites with the highest concentrations are shown. Samples which were reported as non-detects were assigned one half of the minimum detection limit and appear as low values on the right side of each chart. In some cases laboratory detection limits were higher than threshold values of concern.

Thresholds of concern depicted on the charts include the NOAA Effects Range Median (ERM) and NOAA Effects Range Low (ERL) (Long and Morgan, 1990), and the Probable Effects Level (PEL) and Threshold Effects Level (TEL) (MacDonald, 1994). All of these values are calculated using existing datasets which include information on both toxic effects and chemical concentrations.

The ERM is the median (or 50th percentile) concentration of all toxic samples. The ERL is calculated in the same fashion as the ERM, but represents the 10th percentile of the samples showing toxicity. More recent evaluations (Long, et al., 1998) indicate that a toxicity of approximately 38% is associated with the ERL level.

The PEL and TEL limits are based on a similar compilation of data but are calculated differently. These values are used by the State of Florida. The TEL is the geometric mean of the 15th percentile concentration of the toxic effects data set and the 50th percentile of the no-effect data set; below this value toxic effects are expected only occasionally. The PEL is the geometric mean of the 50^{th} percentile of toxic samples and the 85^{th} percentile of the no-effect data set. Adverse effects are expected frequently over this level.

Unfortunately, sediment quality guideline values have not been established for all chemicals of concern.

Additional information about chemical groups of interest is available from the Agency for Toxic Substances and Disease Registry (ATDSR, 1999), the Cooperative Extension Toxicology Network Pesticide Information Profiles (EXTOXNET), and the U.S. EPA Integrated Risk Information System (IRIS). These organizations provide web sites which include information on acute and chronic toxicity, human and organismal health risk, environmental fate and transport, and other relevant information.

In order to provide context for this regional evaluation, sediment chemistry concentrations collected from the San Francisco Estuary Institute's regional monitoring program (SFEI 1997 Annual Report) and NOAA's contaminant trends study of the Southern California Bight (Mearns, et al. 1991) are cited.

Sediment Particle Size - Sediment samples had widely varying particle sizes, with percentage clay ranging from a high of 46.1% at Waddell Creek to a low of 0.0% at Monterey Harbor and Pajaro River Estuary. Samples with high percentages of coarse material typically do not reveal the presence of chemicals which are bound to the fine sediments in the water body. Figure 2 shows percent clay by weight at each site. In this study samples from some sites which are known to contain elevated levels of organochlorine compounds had low percentages of fine sediments. Though high concentrations are clearly indicative of problems, low concentrations are not themselves conclusive, and must be interpreted in the context of a sample's sediment particle size.

Table 1. 1998 Coastal Confluences Site List (from north to south).

Site Tag	Site Name
WAD	Waddell Creek lagoon
SCO	Scott Creek lagoon
LOR	San Lorenzo Estuary
SCH	Santa Cruz Yacht Harbor
SOQ	Soquel Creek lagoon
APT	Aptos Creek lagoon
WAT	Watsonville Slough
PJE	Pajaro River Estuary
ELK	Elkhorn Slough
MOS	Moss Landing Harbor
MOC	Moro Cojo Slough
TEM	Tembladero Slough
OLD	Old Salinas River Estuary
SAL	Salinas River Refuge
MON	Monterey Harbor
ADC	Arroyo de la Cruz lagoon
SSC	San Simeon Creek lagoon
SRO	Santa Rosa Creek lagoon
CHO	Chorro Creek mouth
LOS	Los Osos Creek mouth
SLO	San Luis Obispo Creek lagoon
PIS	Pismo Creek lagoon
AGR	Arroyo Grande Creek lagoon
SMA	Santa Maria River Estuary
SYN	Santa Ynez River Estuary
GOL	Goleta Slough
ATA	Atascadero Creek lagoon
ABU	Arroyo Burro lagoon
MIS	Mission Creek lagoon
CAR	Carpenteria Marsh

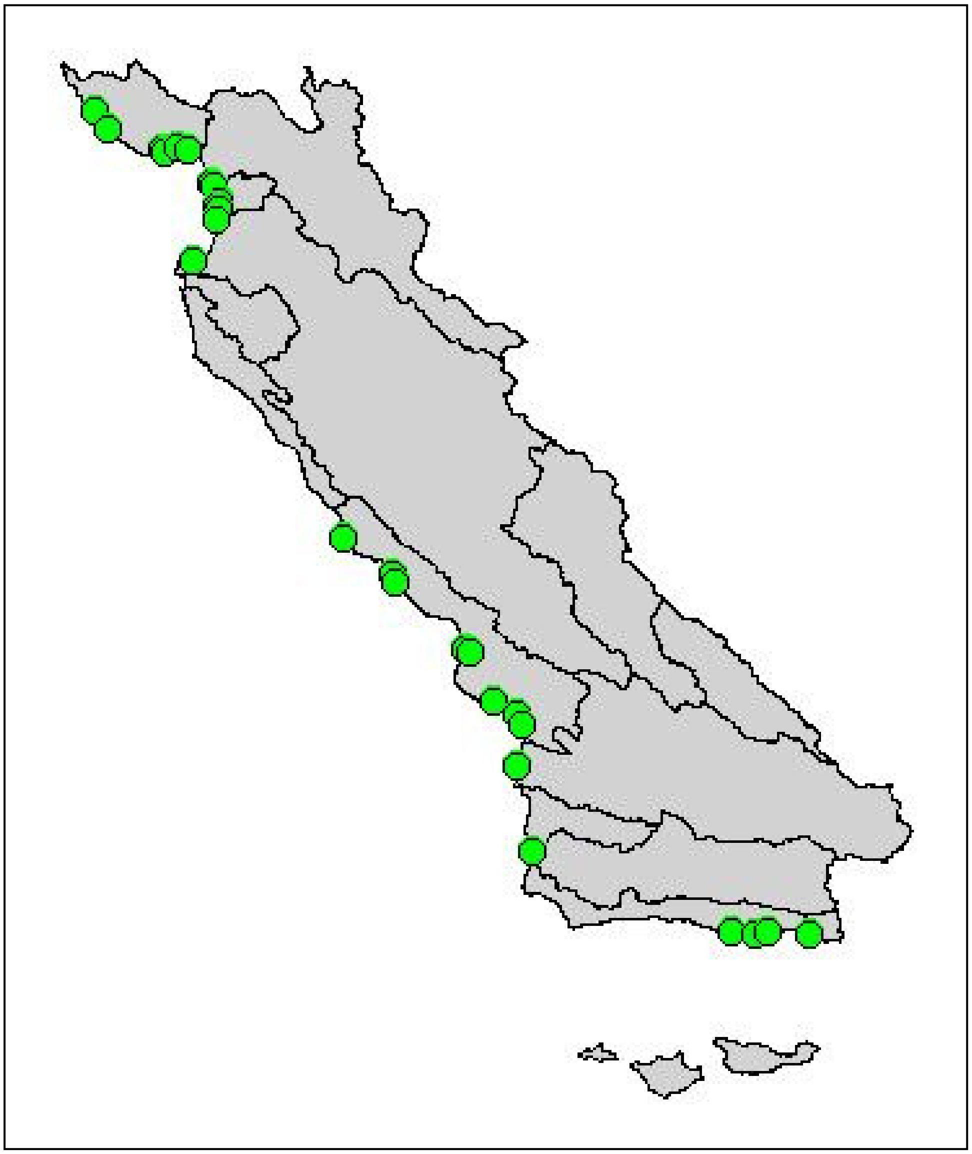


Figure 1. 1998 Coastal Confluence Sites.

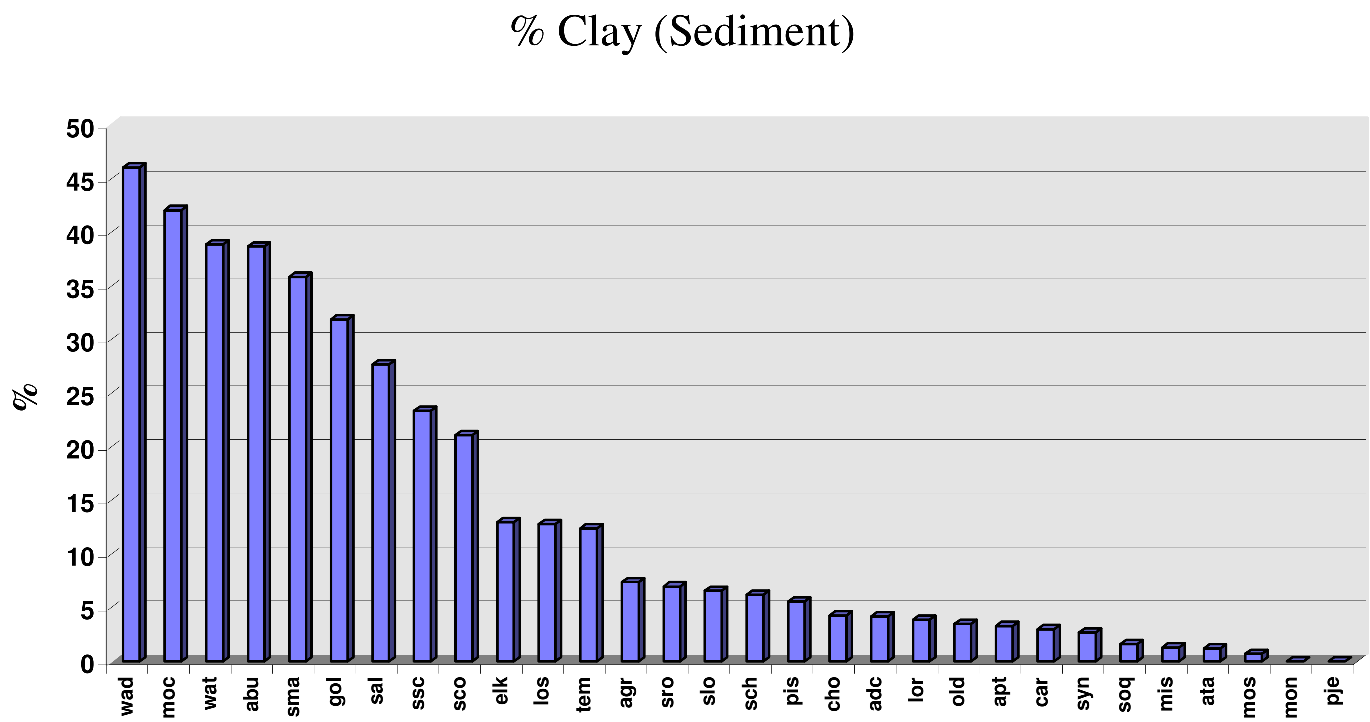


Figure 2. Percent clay in 1998 Coastal Confluences sediment samples

Synthetic Organic Chemicals

DDT and Its Metabolites

DDT has been well documented as a persistent problem in the sediments of the central coast of California (Cotter and Strnad, 1997). It was used historically in agricultural and urban environments, and was commonly used directly in waterways for mosquito abatement. It is one of the chemicals associated with the central coast's largest "toxic hot spot" as defined by the Bay Protection and Toxic Cleanup Program; concentrations at two sites in the Region (Santa Maria Estuary and Upper Tembladero Slough) fell among the highest 5% of samples statewide. The State Mussel Watch Program and the Toxic Substances Monitoring Program have repeatedly detected DDT at elevated levels in mussel and fish tissue at a number of central coast sites.

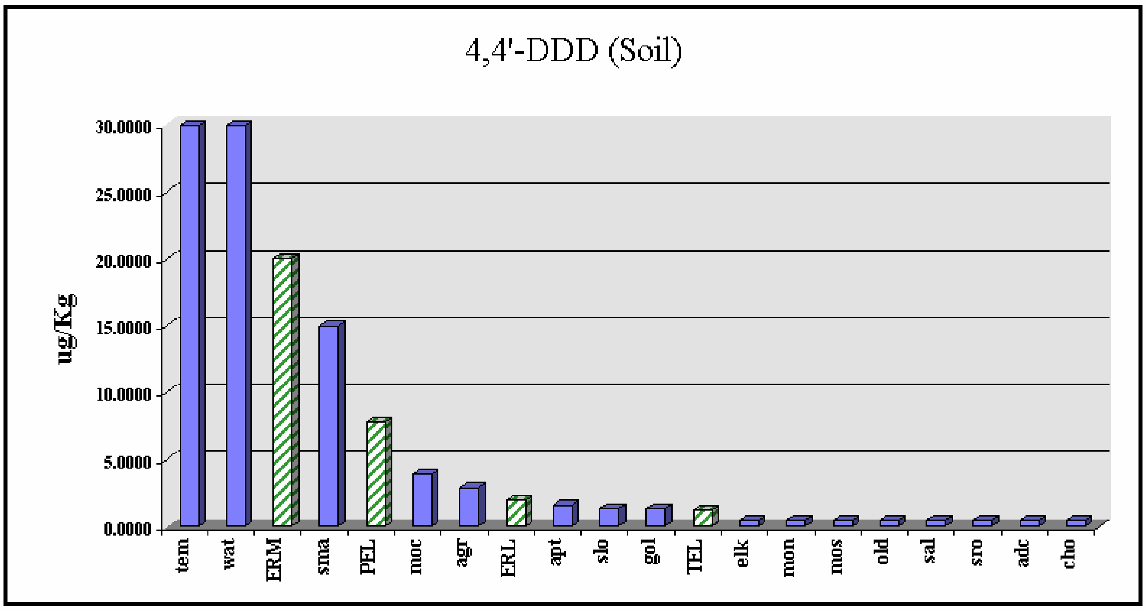


Figure 3. DDD concentrations (mg/kg) in samples at coastal confluences, 1998.

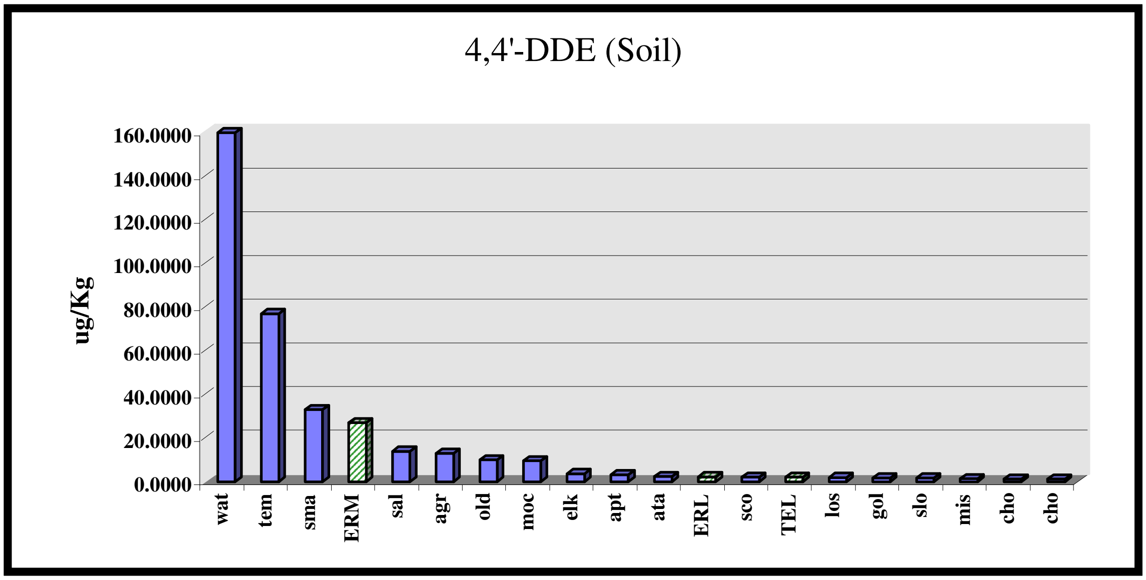


Figure 4. DDE concentrations (mg/kg) in samples at coastal confluences, 1998.

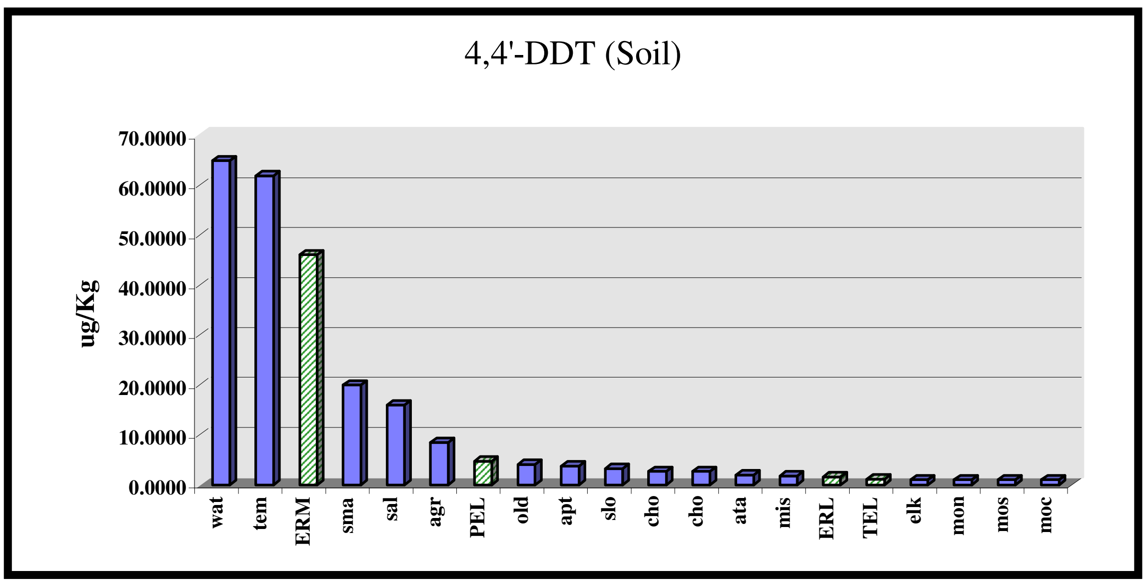


Figure 5. DDT concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: Concentrations in Tembladero Slough, Watsonville Slough, and Santa Maria Estuary exceeded other sites in the Region for total DDT metabolites. Levels at Watsonville Slough and Tembladero Slough were above the NOAA ERM for all three measured forms of DDT. The Salinas Estuary and Arroyo Grande Estuary exceeded the PEL for 4,4'-DDT.

The San Francisco Estuary Institute (SFEI) has monitored DDT levels in the San Francisco estuary for a number of years. Since 1991, average total DDT levels have generally not exceeded 10 ug/kg in San Francisco estuarine sediments, with no concentrations exceeding 32 ug/kg (SFEI, 1997). By contrast, some of the coastal lagoons and estuaries of the central coast of California have shown much higher levels of DDT, even for individual isomers.

Aldrin and Dieldrin

Aldrin and dieldrin are the common names of two insecticides that are closely related chemically. Aldrin is readily converted to dieldrin in the environment, so these two closely related compounds are considered together by regulatory bodies. Their toxicities do not differ significantly. Aldrin and dieldrin were widely used from the 1950s to the early 1970s. Aldrin has been used as a soil insecticide to control root worms, beetles, and termites. Dieldrin has been used in agriculture for soil and seed treatment and in public health to control disease vectors such as mosquitoes and tsetse flies. Dieldrin has also had veterinary use as a sheep dip and has been used in treatment of wood and mothproofing of woolen products. Most uses for aldrin and dieldrin were banned in 1975; at present these compounds are no longer produced in or imported into the United States.

(from Agency for Toxic Substances and Disease Registry, 1999).

There currently are no ERM/ERL's or PEL/TEL values established for aldrin. However, since aldrin breaks down readily to dieldrin, and toxicities are similar, guideline values for dieldrin provide context for interpretation of aldrin concentrations.

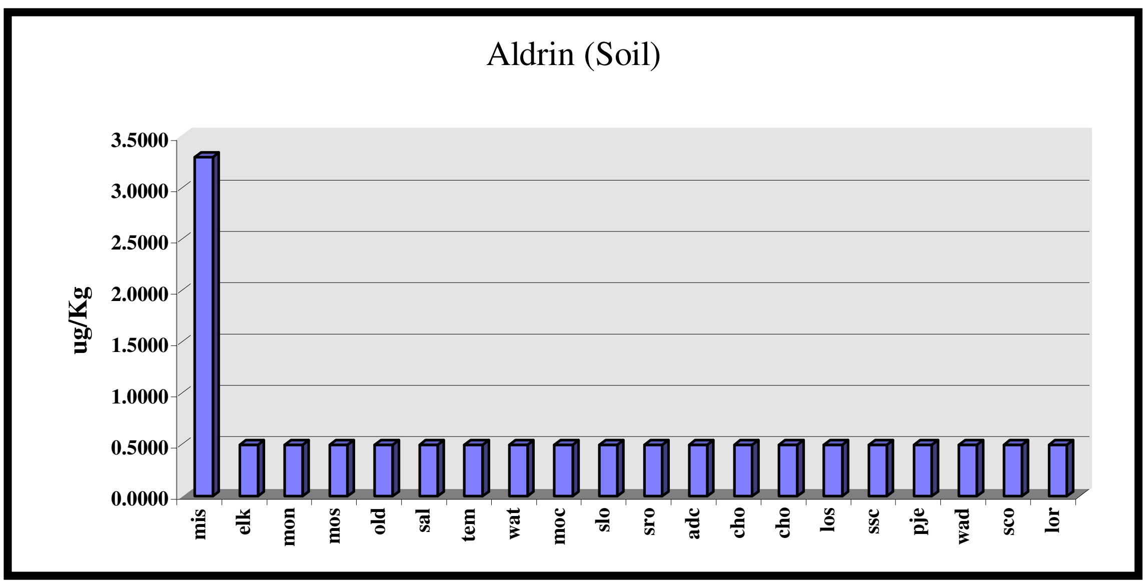


Figure 6. Aldrin concentrations (mg/kg) in samples at coastal confluences, 1998.

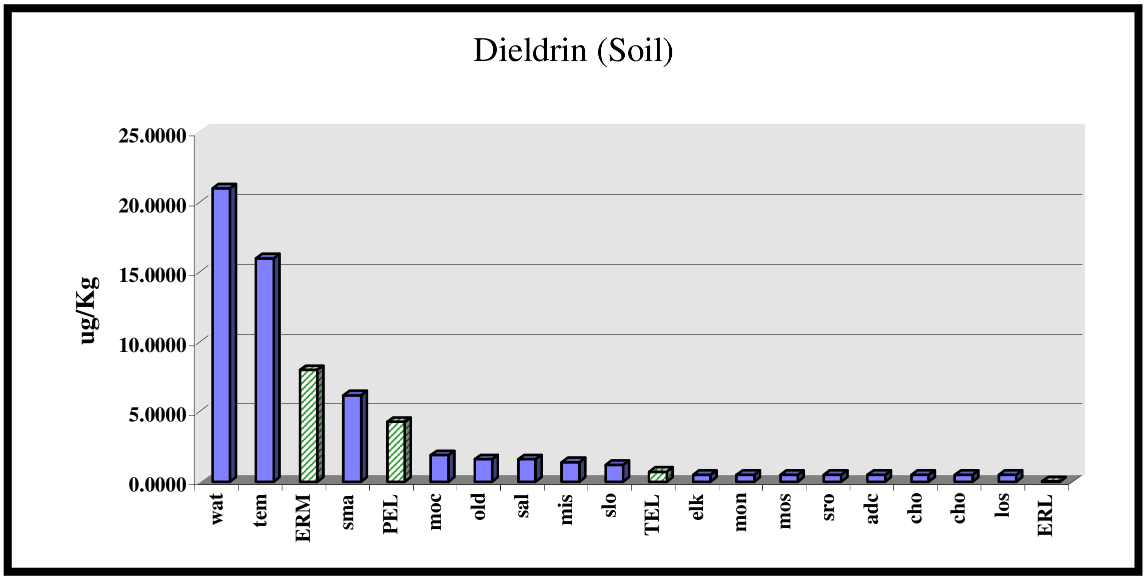


Figure 7. Dieldrin concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments:

Most sites had non-detects for Aldrin, except for Mission Creek, which was somewhat elevated but did not show correspondingly elevated levels of dieldrin. Watsonville Slough and Tembladero Slough exceeded NOAA ERMs for dieldrin. Santa Maria Estuary also contained elevated concentrations. Average dieldrin levels in the San Francisco Estuary did not exceed 0.6 ug/kg, with maximums under 1.0 ug/kg (SFEI, 1997). Comparatively, levels in Watsonville Slough, Tembladero Slough, and the Santa Maria estuary are quite high, exceeding 20 ug/kg at one site.

Laboratory detection limits for this chemical during the 1998 sampling were inadequate; both the ERL and the TEL were lower than the MDL of 1.0 ug/kg. However, it may prove difficult to find a laboratory which can produce detection limits lower than the ERL of 0.02 ug/kg.

<u>Chlordane Compounds</u>

Chlordane was primarily used to control soil pests, and has been widely used as a termiticide and wood preservative, as well as an agricultural pesticide. Its use was limited primarily to termite control in 1974 and was banned entirely in 1988. Chlordane is a complex mixture of over 45 individual isomers and congeners. Chlordane compounds detected in 1998 sediment samples include alpha-chlordane, gamma-chlordane, and heptachlor epoxide. Heptachlor was also used alone as an agricultural insecticide and a termiticide. Heptachlor, like chlordane, was banned for all uses in 1988. Heptachlor-epoxide is a metabolite of Heptachlor. For both alpha-Chlordane and gamma-chlordane, the NOAA-ERL value is lower than the laboratory detection limit. NOAA ERM and ERL values are not available for Heptachlor.

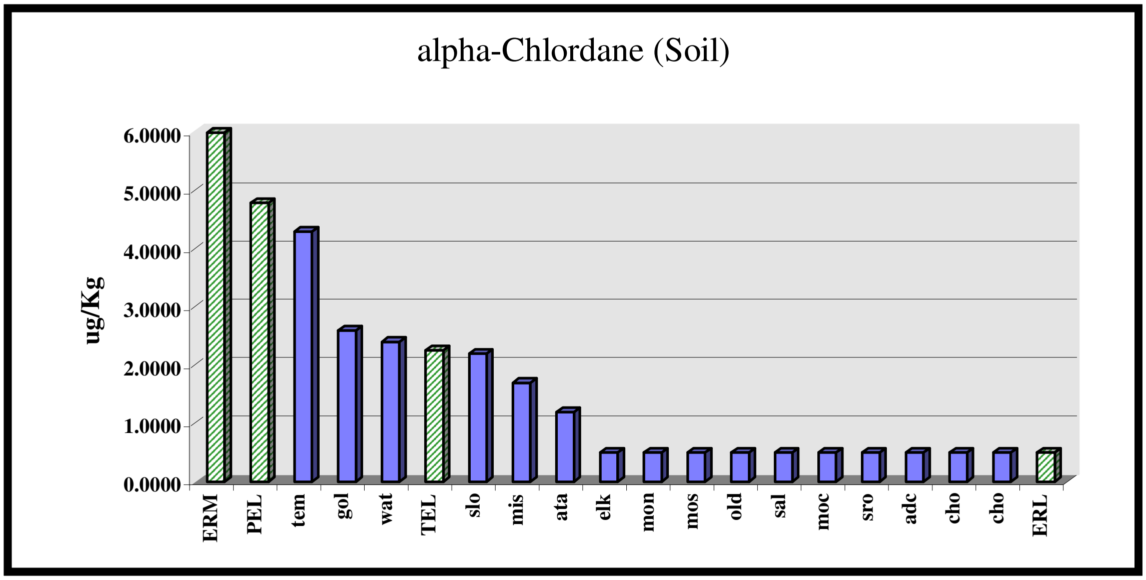


Figure 8. Alpha-Chlordane concentrations (mg/kg) in samples at coastal confluences, 1998.

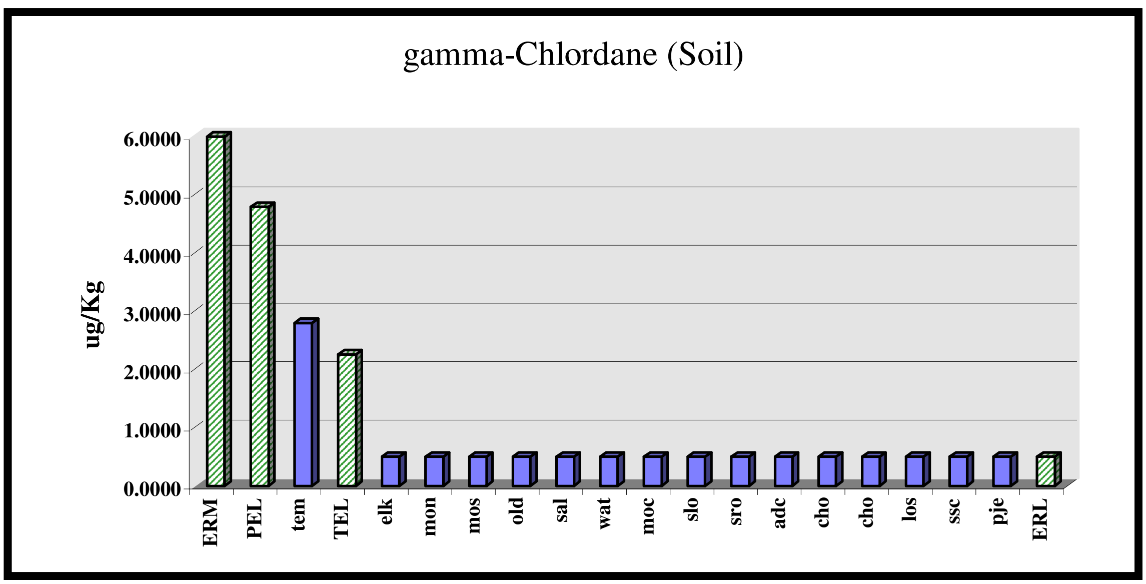


Figure 9. Gamma-Chlordane concentrations (mg/kg) in samples at coastal confluences, 1998.

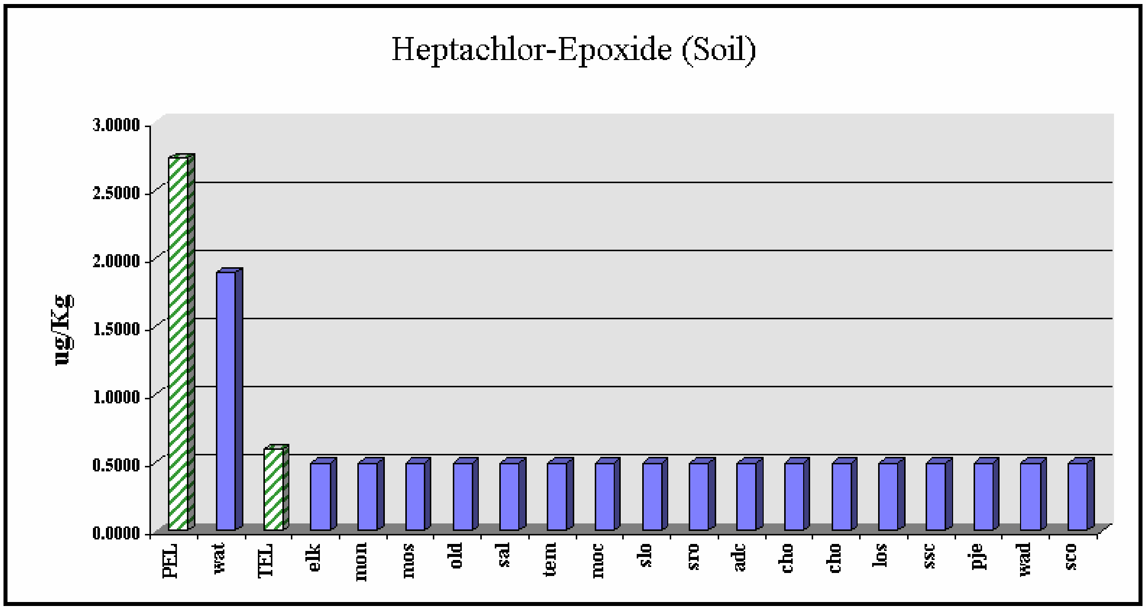


Figure 10. Heptachlor epoxide concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No sites exceeded ERM or PEL values for any compounds in the Chlordane group. However, Tembladero Slough, Watsonville Slough, and Goleta Slough values fell between TEL and PEL values. At several other sites, concentrations exceeded both the detection limit and the ERL, implying possible toxic effects from these chemicals at these locations. Many samples fell below the detection limit.

Total chlordane annual averages in river and estuarine sediment samples taken by SFEI between 1991 and 1997 generally fell below 2 ug/kg, with maximum values never exceeding 4.0 ug/kg. Single samples collected at several Central Coast sloughs were higher than most SFEI averages.

Endosulfan and Related Chemicals

Endosulfan is a chlorinated hydrocarbon pesticide which has been used in the United States on a number of food crops, and also as a wood preservative. Though it has not been applied in its technical form since 1982, it is still commonly used as a component of other pesticides. Technical endosulfan was sold as a mixture of two different forms of the same chemical (alpha- and beta-endosulfan, or endosulfan-I and -II). Like other organochlorine pesticides, it tends to bind to soil and does not readily break down in water. In plants, endosulfan is rapidly broken down to endosulfan sulphate, which is also a chemical of concern.

Endosulfan is primarily toxic to the central nervous system. Animal studies have shown effects on the kidneys, testes, immune system, developing fetus, and liver from longer-term exposure to low levels of endosulfan.

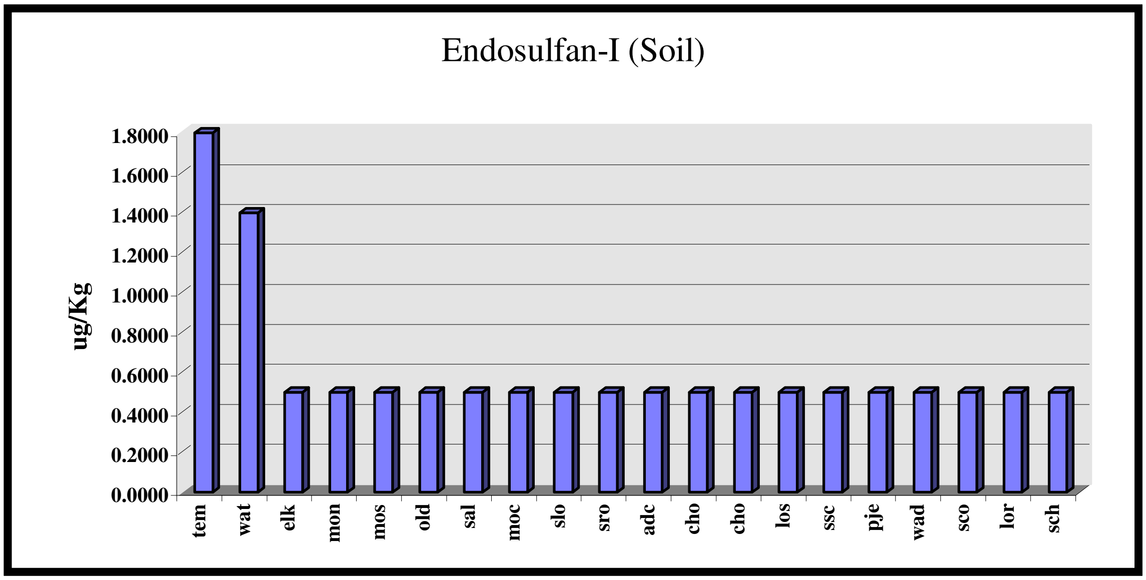


Figure 11. Endosulfan-I concentrations (mg/kg) in samples at coastal confluences, 1998.

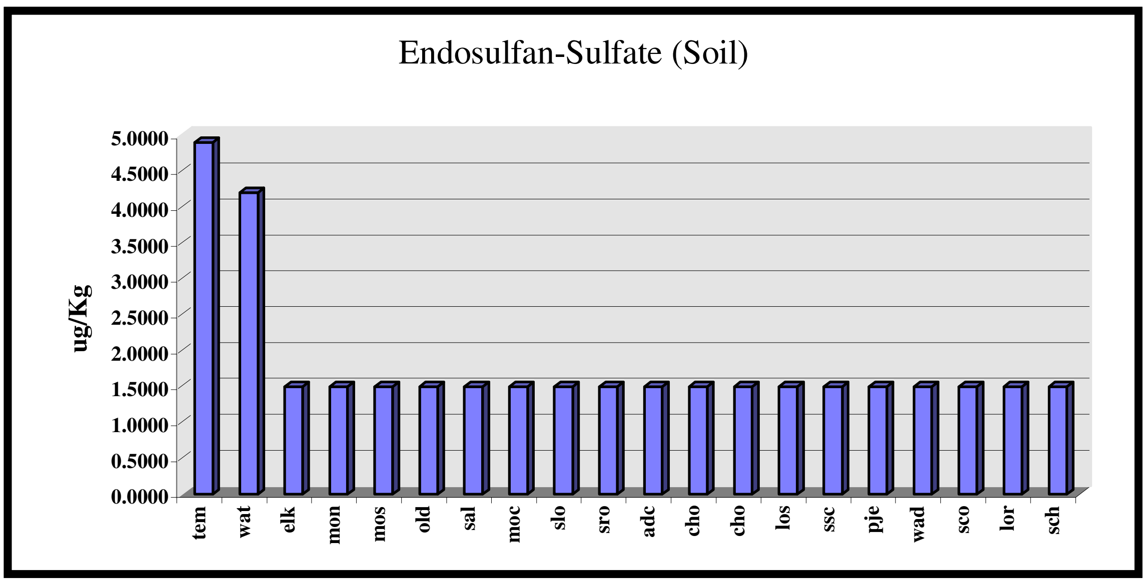


Figure 12. Endosulfan-sulfate concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No sediment guidelines were available for endosulfan or its components and breakdown products; however, both Tembladero Slough and Watsonville Slough had levels elevated over detection limits for both endosulfan-I and endosulfan sulfate.

Endrin and Endrin Aldehyde

Before its use was terminated, Endrin was used as a insecticide and rodenticide. Like other organochlorines, it is not particularly soluble in water and tends to bind to sediment particles. Endrin breaks down slowly in the environment. Endrin aldehyde is not commercially used but is found as an impurity and breakdown product of endrin.

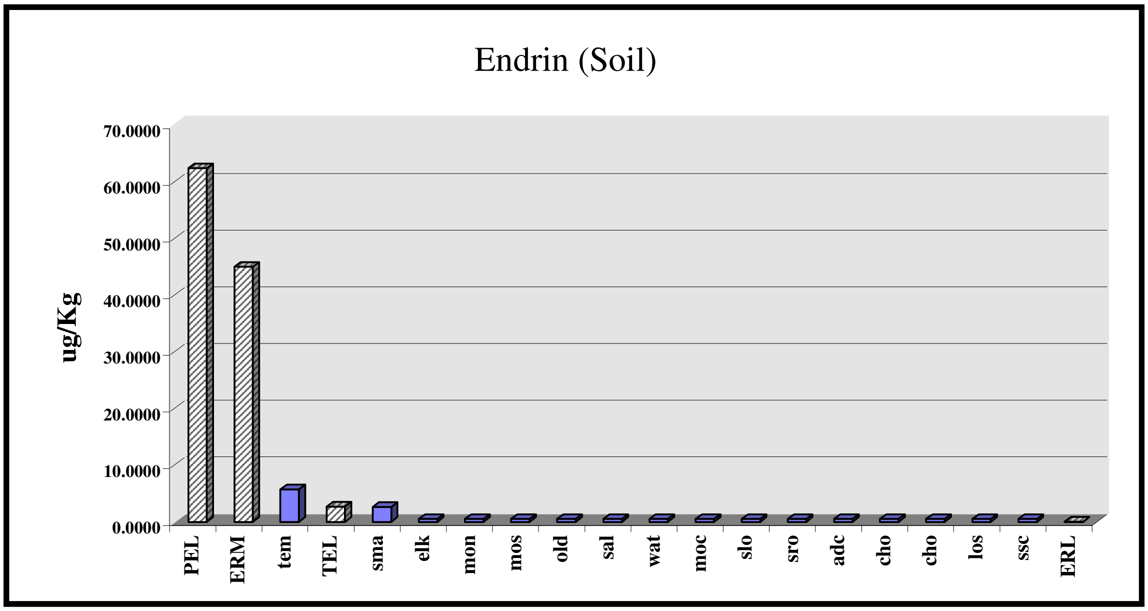


Figure 13. Endrin concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No sites in the Region exceeded the ERM or PEL for Endrin. Because the laboratory detection limit was higher than the ERL, all sites exceeded the ERL. Tembladero Slough exceeded the TEL.

Lindane (Gamma-BHC)

Lindane, referred to here as gamma-BHC, is an organochlorine insecticide, fungicide, and fumigant which has been used in the past on soil-dwelling and plant-eating insects. It is commonly used on a wide variety of crops, in warehouses, in public health to control insect-borne diseases, and with other fungicides as a seed treatment. Lindane is also presently used in lotions, creams, and shampoos for the control of lice and mites (scabies) in humans.

Lindane (or hexachlorocyclohexane, HCH) has historically been inappropriately referred to as "benzene hexachloride" or "BHC". Technical lindane is primarily comprised of the gamma-isomer of HCH. Five other isomers (molecules with a unique structural arrangement, but identical chemical formulas) of HCH are commonly found in technical lindane, but the gamma-isomer is the predominant one, comprising at least 99% of the mixture of isomers. Gamma-HCH has been shown to be the chemically effective isomer.

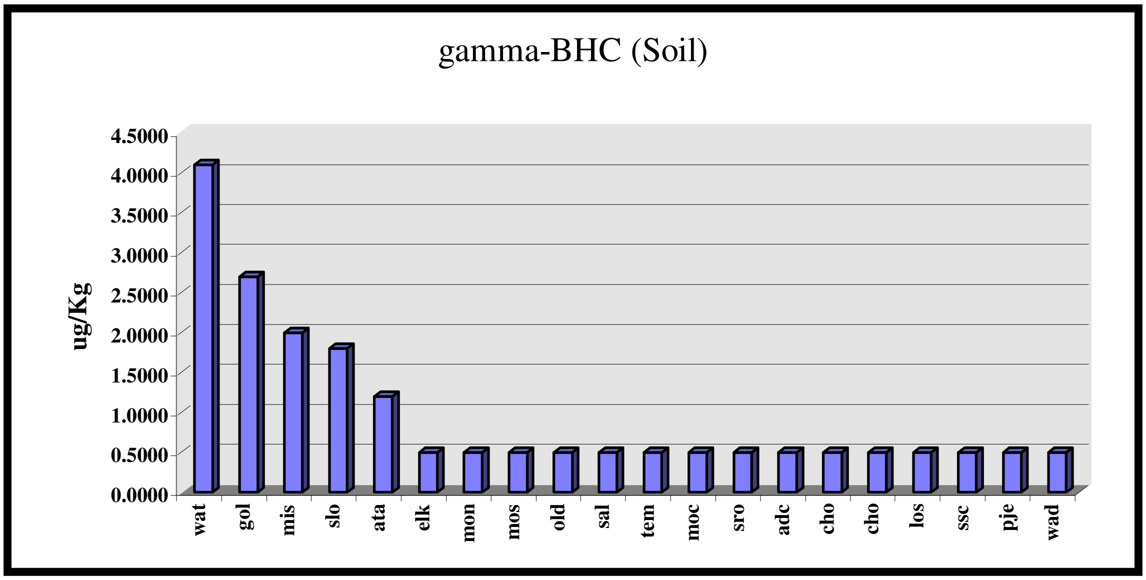


Figure 14. Lindane concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No ERM or ERL values are available for Lindane or gamma-BHC. However, several sites had concentrations over detection limits, including three in the Santa Barbara area (Mission Creek, Atascadero Creek, and Goleta Slough).

<u>Metals</u>

Metals including Cadmium, Chromium, Nickel, Mercury, Lead, Copper and Zinc were analyzed. Cadmium is commonly used in electroplating, batteries, and paint pigments. Coastal upwelling is also a significant source of cadmium in nearshore waters of California. It is potentially toxic to humans and other organisms, and bioaccumulates particularly in kidney and liver tissues. In sediment it is toxic to infaunal organisms. Interestingly, it is inversely related to DDT concentrations in mussel tissue. In some species of fish and invertebrates, individuals which have high chlorinated hydrocarbon concentrations have abnormally low concentrations of cadmium (Mearns, et al., 1991; Brown, et al., 1987). Cadmium and chlorinated hydrocarbons appear to compete for the same glutathione binding sites.

Chromium and nickel are common in soils in portions of the Region, particularly in San Luis Obispo County, where serpentine soils are prevalent. Chromium is used in production of pigments, anti-corrosives, wood preservatives and other applications. Chromium is most toxic in the Chromium XI form, because of its high oxidizing potential. Nickel is also used in industrial applications, particularly plating and circuit board production. Nickel is a lung carcinogen and is also toxic to several physiological systems, including nervous, reproductive, and immunological.

Mercury is a common trace element with no known biological function. Mercury is used in industrial applications to produce chlorine. It is also used in fungicides, electrical equipment, and in dental preparations. On the Central Coast and in other parts of California mercury mining has been an important source of contamination.

Lead used to commonly be used in paints and gasoline additives. Its used has been greatly reduced in recent years. Lead has no necesssary biological function and is toxic to most organisms. It affects virtually all physiological systems.

Copper has many anthropogenic sources, including wastewater discharges, antifouling paints, algicides, metal plating operations, wood preservatives, and others. Although an essential micronutrient, it is also acutely toxic in relatively small concentrations, particularly to aquatic biota.

Zinc is an important micronutrient and is ubiquitous in the environment. A major use of zinc is galvanization of other metals to protect from corrosion It is also widely used in batteries, vehicle tires, and corrosion protective devices in boats and ships. Toxicity requires a relatively high level of exposure, both for humans and in the aquatic environment.

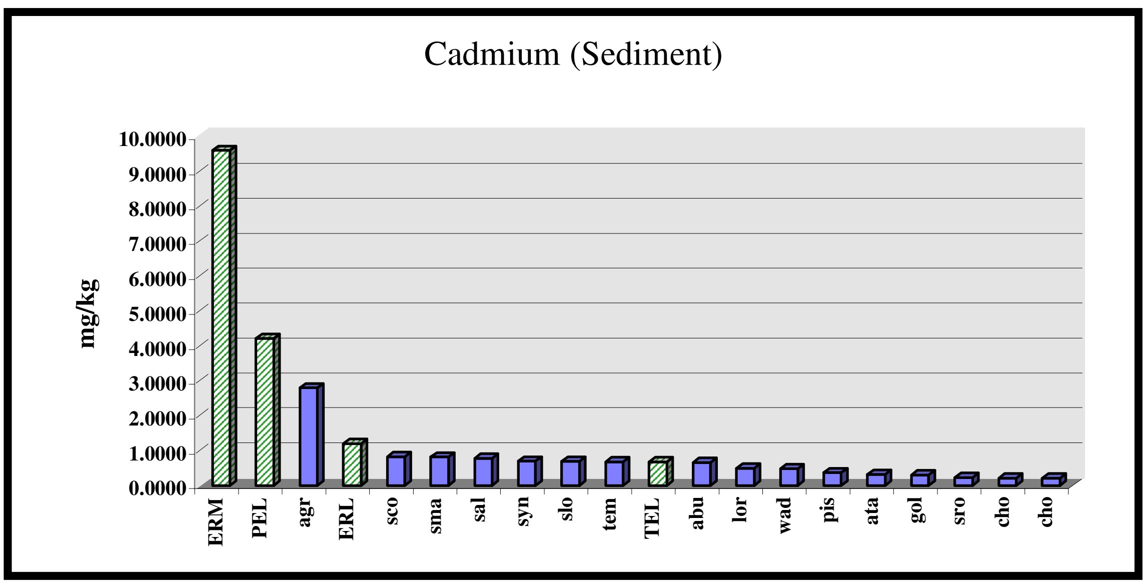


Figure 15. Cadmium concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: Arroyo Grande Creek was the only site sampled which display a conspicuously elevated concentration of cadmium. The national mean sediment cadmium level is 0.398 ppm dry weight (Mearns, 1991). During the 1997 SFEI survey, values in the San Francisco estuary rarely exceeded 0.4 mg/kg and peaked in the southern sloughs at 1.0 mg/kg.

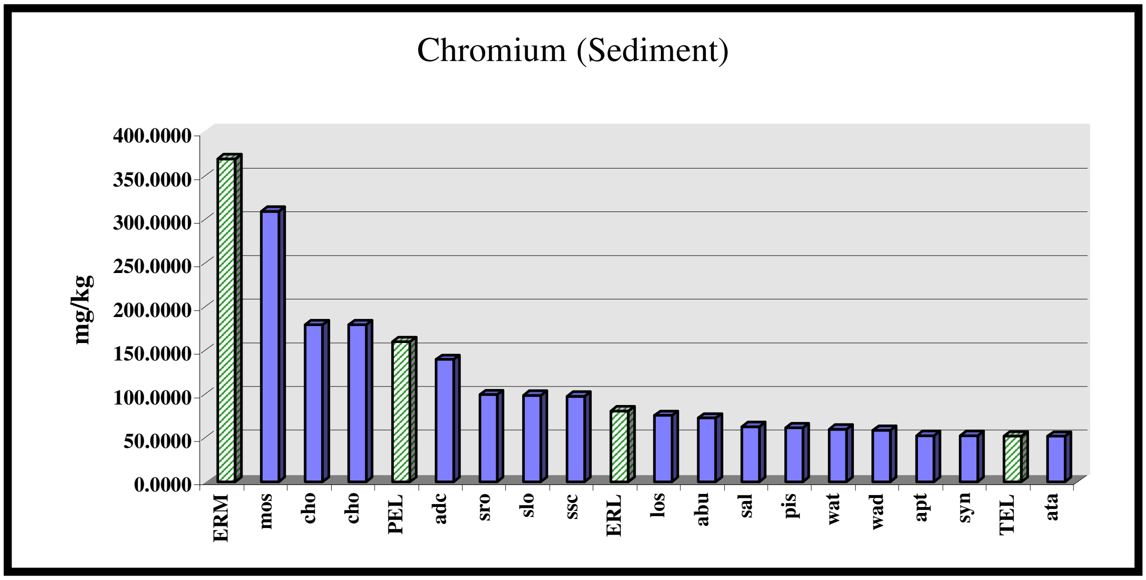


Figure 16. Chromium concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments : Moss Landing Harbor and Chorro Creek had sediment concentrations of chromium exceeding PEL values of 160.4 mg/kg. A number of sites in northern San Luis Obispo county exceeded the ERL. Chromium is common in the serpentine-based soils of the region, particularly in San Luis Obispo county. The PEL was seldom exceeded in samples taken during the 1997 surveys of San Francisco Estuary. The NOAA Status and Trends program cites a national average of 84.3 ppm dw, from all sites (1984 - 1989).

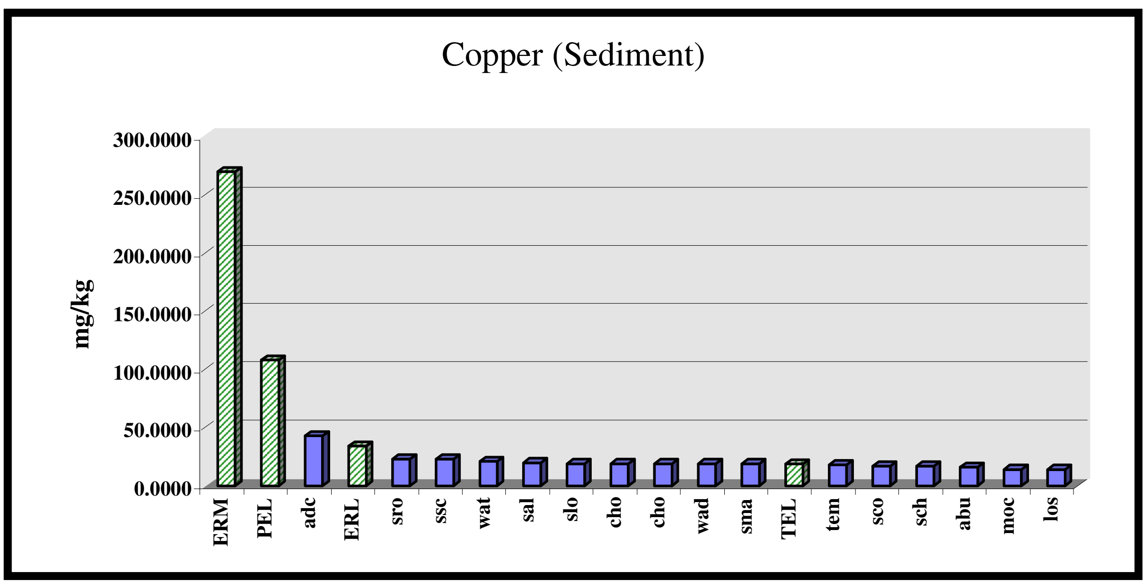


Figure 17. Copper concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: Only one site, Arroyo de la Cruz, showed concentrations elevated above detection limits for copper, at 42 ppm dry weight. In San Francisco, most values fell below 70 and above 30 ppm

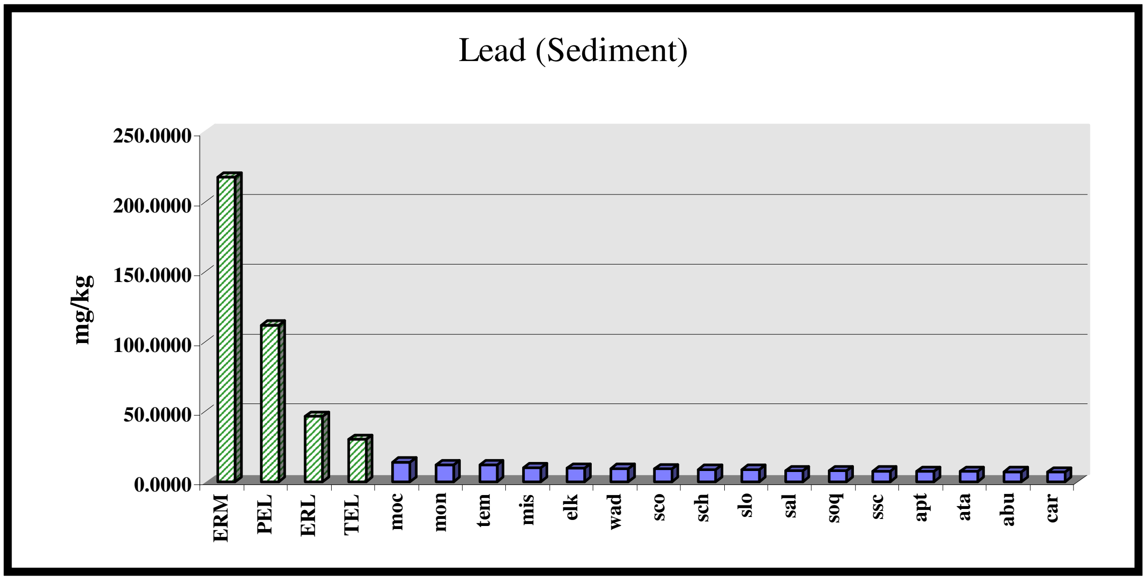


Figure 18. Lead concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No samples taken during this study contained lead at levels that were above the threshold effects levels.

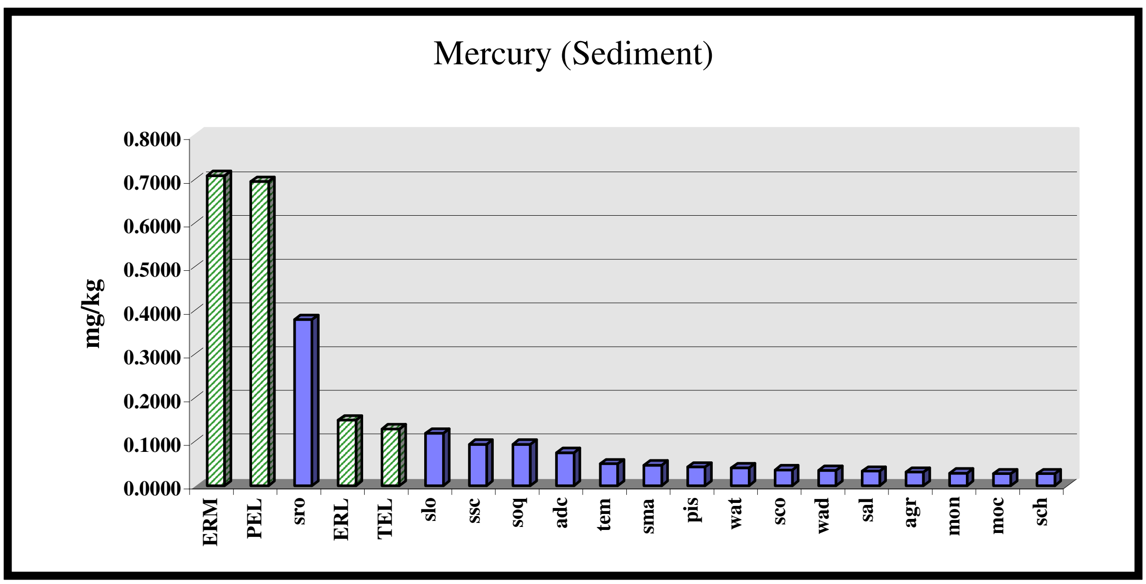


Figure 19. Mercury concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: Mercury levels were elevated over ERLs and PELs at Santa Rosa Creek mouth at 0.38 mg/kg dry weight. An inactive mine which has been the subject of studies described elsewhere in this document is the most likely source. In San Francisco estuary, where mercury is a known problem, most values in the 1997 survey fell below 0.3 mg/kg with one as high as 0.78.

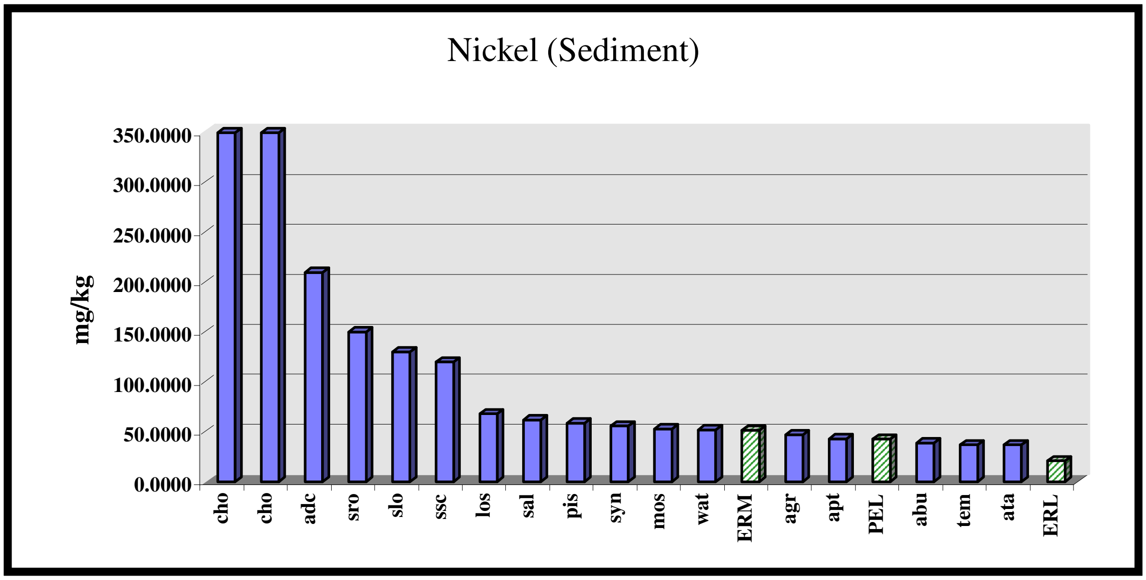


Figure 20. Nickel concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: Many sites in the region contain concentrations which exceed the NOAA ERM value for nickel. Nickel is common in the serpentine-based soils of the region, particularly in San Luis Obispo county. In San Francisco estuary (1997), nickel concentrations ranged from 64 to 190 mg/kg, with most values falling below 120 mg/kg.

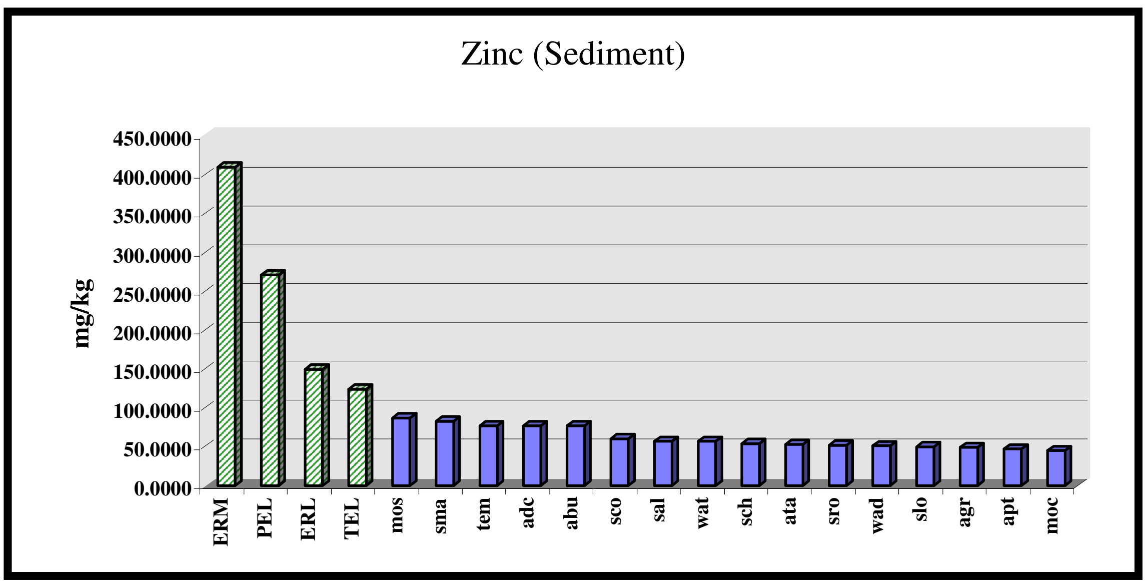


Figure 21. Zinc concentrations (mg/kg) in samples at coastal confluences, 1998.

Comments: No sites had zinc concentrations in sediment which exceeded threshold effects values. Most sites in the San Francisco estuary (1997) had levels exceeding 75 mg/kg.

Discussion: Coastal Confluences by Geographic Area

Because the first round of coastal confluences sampling included only a single sample from each site, this discussion includes consideration of data from several other programs. The State Mussel Watch Program and Toxic Substances Monitoring Program have collected data on chemical levels in mussel and fish tissue in watersheds, estuaries and nearshore waters for many years and provide context for the single round of CCAMP sampling.

In order to perform screening evaluation of chemical and trace element data sets from CCAMP sampling, the State Mussel Watch Program, and the Toxic Substances Monitoring Program, a risk factor was developed for each trace element and organic compound sampled. Standards and guidelines were assembled using the NOAA Sediment Quality guidelines (SQUIRTS) (1999), the Water Quality Objectives data base developed by Jon Marshack of the State Water Resources Control Board (1998), Toxic Equivalency Potentials developed by the Environmental Defense Fund (1999), and Reference Dosage and Maximum Contaminant Levels developed by the US Environmental Protection Agency.

Guidelines used to develop the Risk-weighted Index are shown in Appendix 1. In all, over 60 guidelines are incorporated in the CCAMP risk factors. Unfortunately no single guideline list includes all constituents that must be evaluated by CCAMP. The intent in combining the various guidelines was to represent a relative risk factor for each constituent. Over 500 constituents were ranked. The various standards had reasonably high correlations with the resulting risk factors (0.51 to 0.99). Ranking was accomplished by establishing a percentile rank for each consituent for a given guideline and then averaging the ranks of all guidelines for the constituent. Risk-weighted indices were derived by multiplying the risk factor for a specific chemical by its concentration in the sample.

Santa Cruz and San Mateo Counties - Coastal confluences sampled in the northern portion of the Region, in Santa Cruz and San Mateo County, are shown in Figure 22. None of these sites showed organic chemicals or metals at levels of concern. When examining State Mussel Watch Data for the same geographic area, several metal concentrations were elevated in tissue collected from Santa Cruz Harbor. Copper and zinc exceeded Median International Standards in single samples collected in the harbor in 1989 and 1995. Silver exceeded the 95^{th} percentile of all State Mussel Watch data in several samples from Natural Bridges. One data point from Santa Cruz Harbor exceeded the 85^{th} percentile for tributyltin in 1989. Overall, coastal confluences in this portion of the Region appear to be minimally impacted by metals or organic chemicals, with the possible exception of Santa Cruz Harbor.

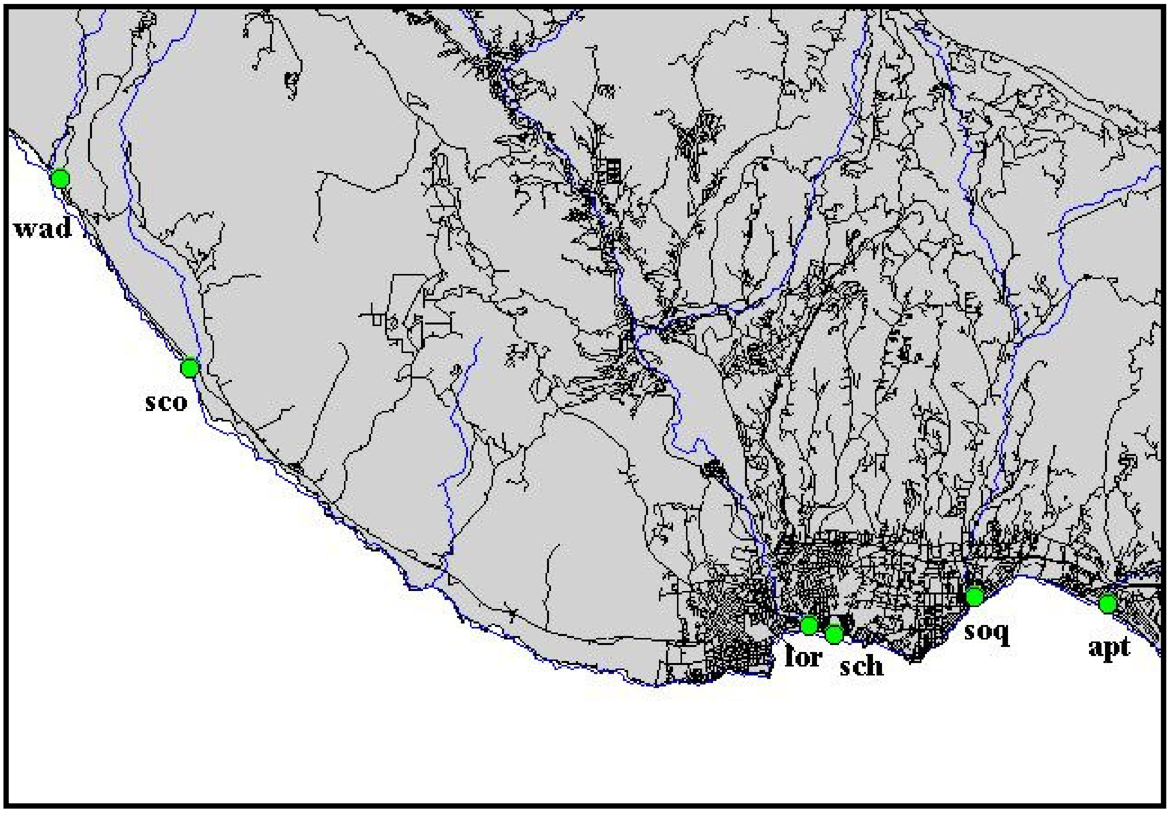


Figure 22. Sampling sites in Santa Cruz County, from Waddell Creek south to Aptos Creek.

Central and Southern Monterey Bay - Coastal confluences data showed a number of chemicals at levels of concern in this geographic area. In particular, Watsonville Slough and Tembladero Slough samples exceeded NOAA ERMs for 4,4-DDD, 4,4 -DDT, 4,4-DDE, and dieldrin, and exceeded ERLs for alpha-chlordane. Both sites had levels of endosulfan and endosulfan-sulfate which were high compared to the rest of the Region. The Tembladero sample exceeded the TEL for gamma-chlordane and endrin. The Watsonville sample exceeded the TEL for heptachlor-epoxide and was high in Lindane.

Several samples at sites which would be expected to contain high concentrations of organic chemicals did not; however, these samples all had a low percentage of fines (less than 5% clay). These included the Pajaro River estuary, Monterey Harbor, Moss Landing, and the Old Salinas River Estuary. When concentrations were normalized to the fraction of fine particles, both the Moss Landing Harbor and Old Salinas River sites showed concentrations similar to Watsonville and Tembladero Slough. The Pajaro Estuary and Monterey Harbor samples had 0% fines, and thus were not normalized. Figure 23 shows site concentrations normalized for fines for 4,4-DDT.

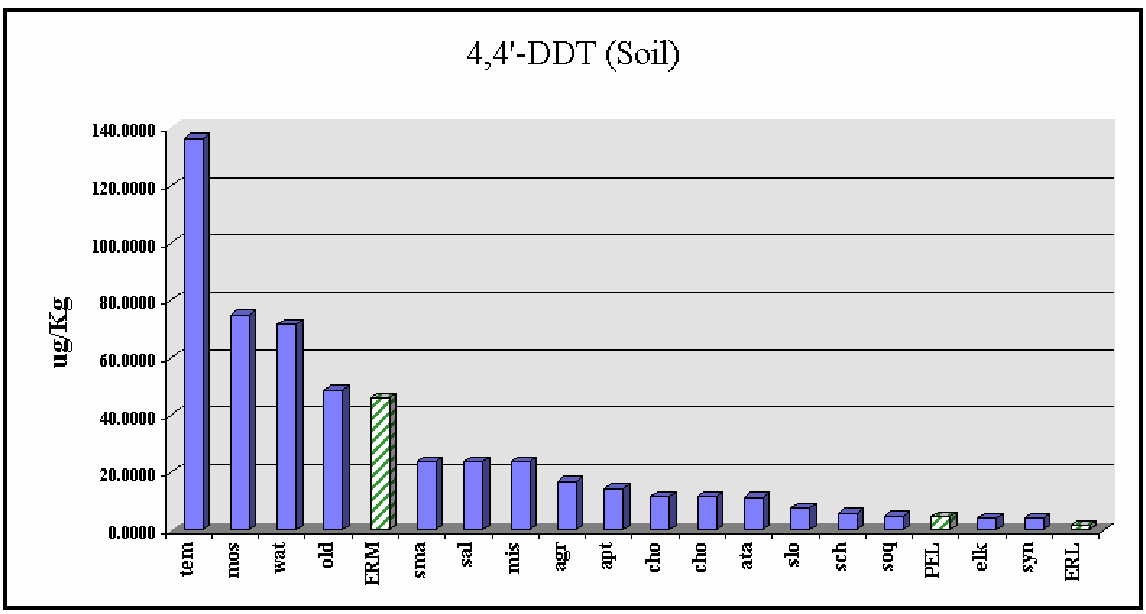


Figure 23. DDT concentrations (mg/kg) in sediment samples from coastal confluences, 1998, normalized to the fraction of fine particles.

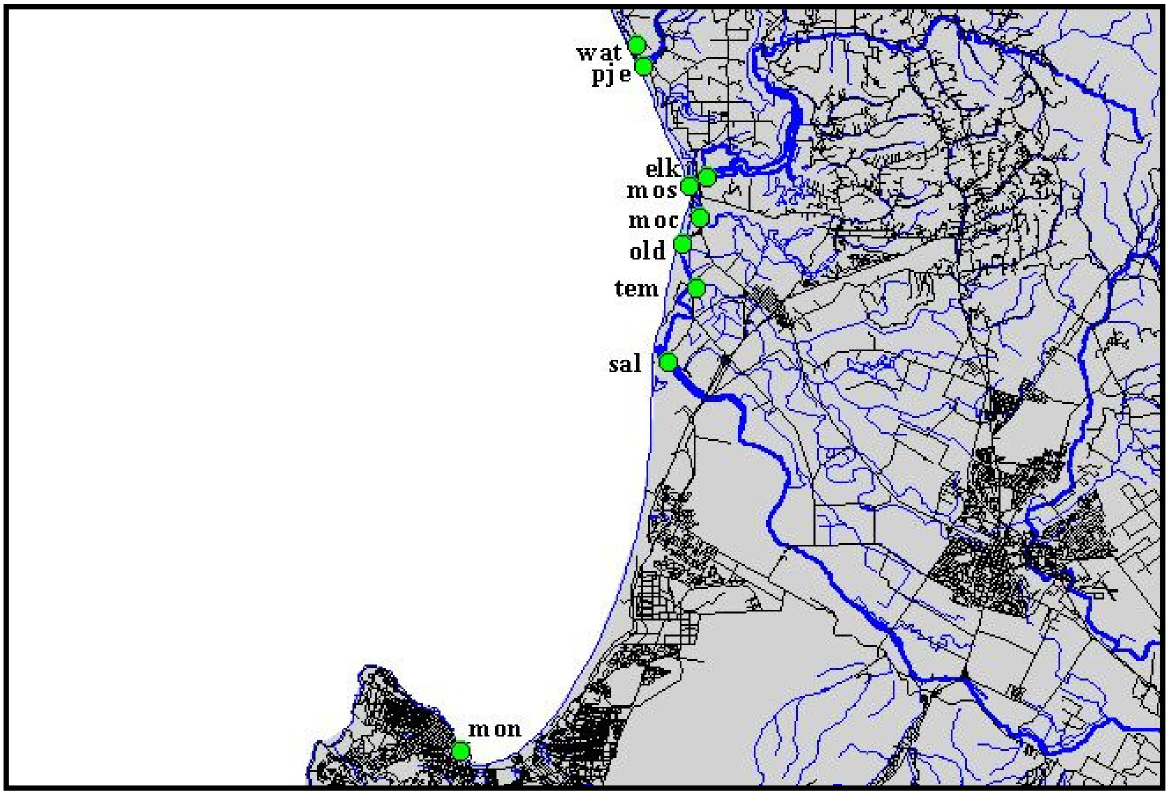


Figure 24. Monterey County from Pajaro River Estuary south to Salinas River Estuary

State Mussel Watch and Toxic Substances Monitoring Program data from this part of the Central Coast confirm that many now-banned organochlorine compounds still plague numerous waterbodies in the area. The CCAMP Risk-weighted Index for synthetic organic chemicals clearly depicts the geographic distribution of this problem (Figures 25 and 26). The chemicals found are varied, as shown from samples collected from Moss Landing Harbor between 1977 and 1995 (Figure 27).

Time trends for several organic chemicals in mussel tissue at Sandholdt Bridge at Moss Landing Harbor are shown in Figure 28. Concentrations of several chemicals increased dramatically following high rain fall seasons of 1982-83 and 1994-95. Nesting failure of the Caspian Tern (a bird species of special interest) in Elkhorn Slough in 1995 was attributed to high tissue levels of DDT resulting from storm-driven sediments. In spite of these chemicals being banned for many years they persist in sediments and are transported during periods of high rainfall and stream flows. Because of these problems Moss Landing Harbor and upstream tributaries have been declared one of two 'toxic hot spots' on the central coast. A detailed discussion of the problems, additional monitoring information, and clean up recommendations can be found in the Central Coast Toxic Hot Spot Clean Up Plan (SWRCB, 1999).

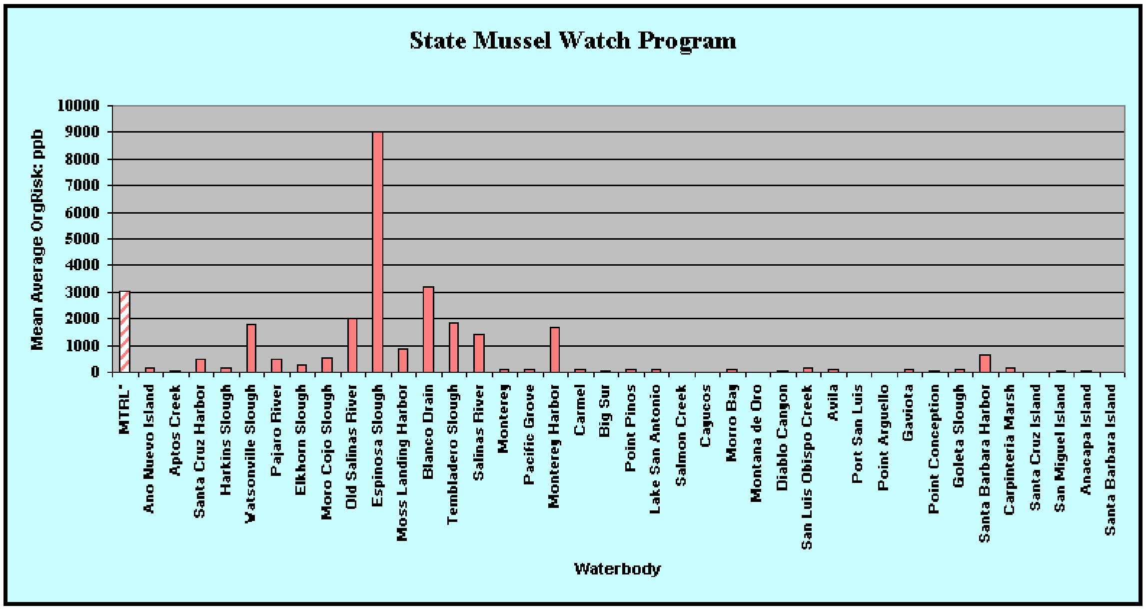


Figure 25. CCAMP Risk-weighted Index for Synthetic Organic Chemicals, from north to south, derived from State Mussel Watch database, all years.

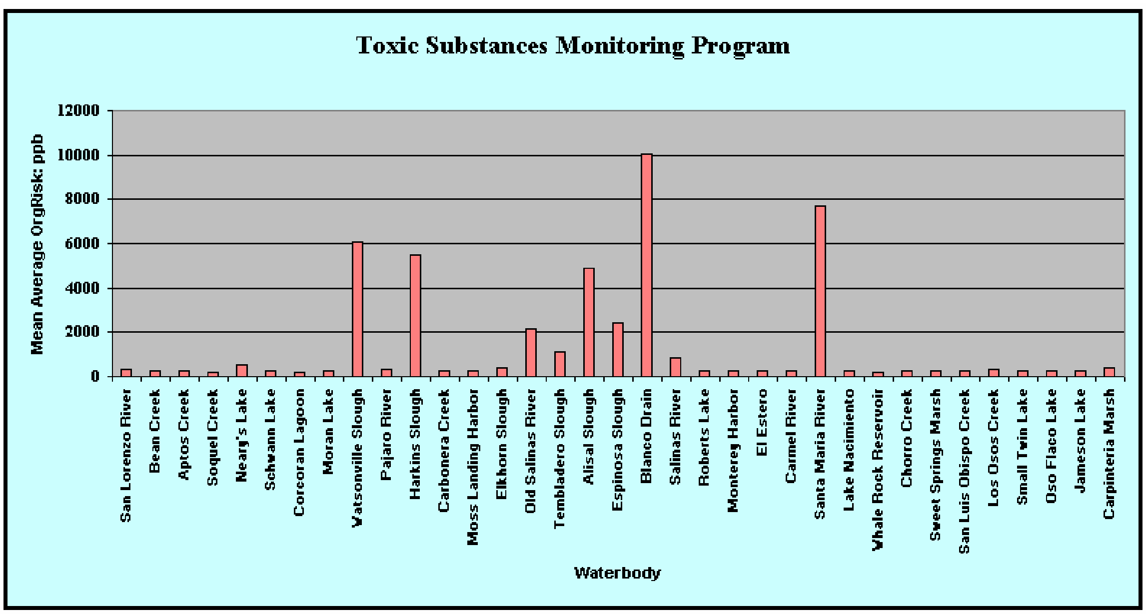


Figure 26. CCAMP Risk-weighted Index for Synthetic Organic Chemicals , from north to south, derived from Toxic Substances Monitoring Program database, all years.

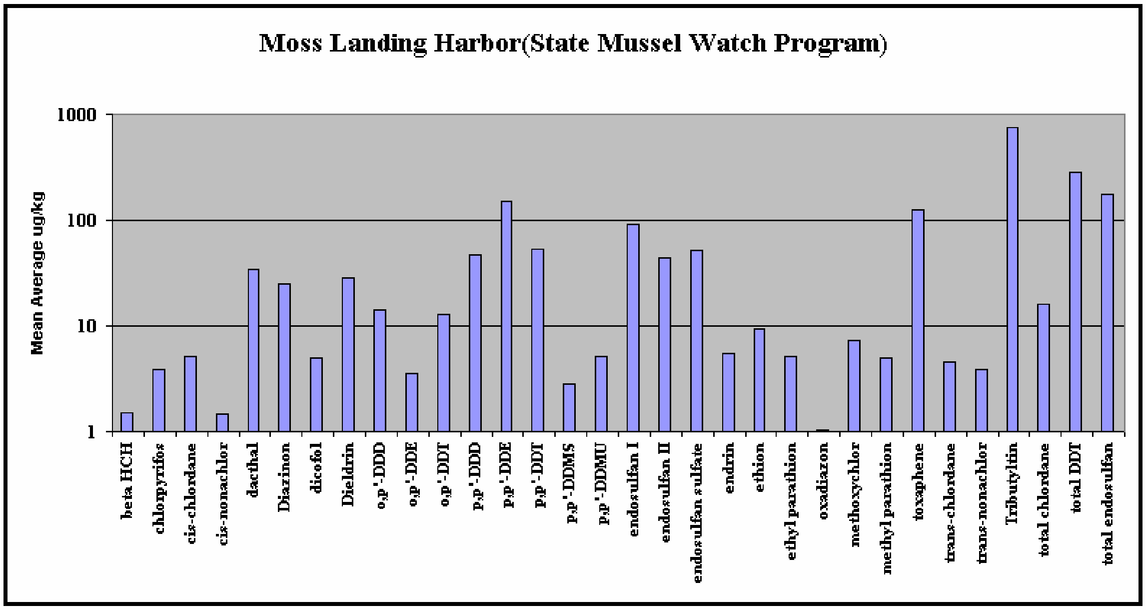


Figure 27. Average chemical concentrations detected in mussel tissue from samples taken at Moss Landing Harbor, State Mussel Watch Program, 1977 - 1995.

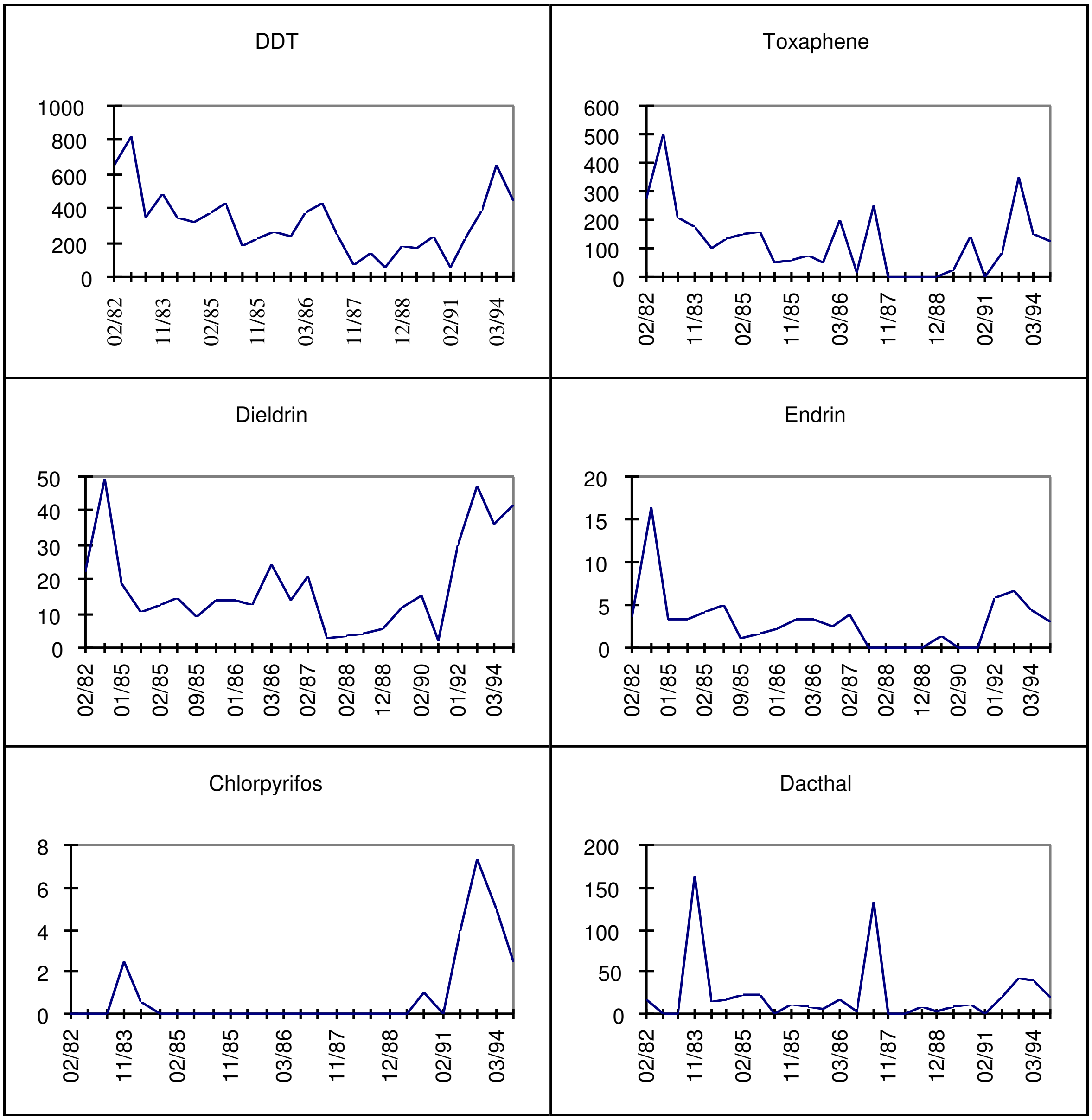


Figure 28. Time trend data for several pesticides in mussel tissue at Sandholdt Bridge in Moss Landing Harbor (1982 - 1995).

The CCAMP sample from the Pajaro River estuary had 0% fine sediment, and no chemicals were detected at levels of concern. Other data indicate that organochlorine chemicals are present at elevated levels in the estuary. Hunt (1999) found toxicity associated with organochlorines in the lower Pajaro watershed and Watsonville Slough. Toxic Substances Monitoring Program fish tissue samples also show elevated levels of organochlorines, particularly dieldrin and DDT in Watsonville Slough (Figure 29). Some dieldrin levels in fish tissue collected from the Slough exceeded the Food and Drug Administration Action Level for Chemical and Poisonous Substances by three-fold.

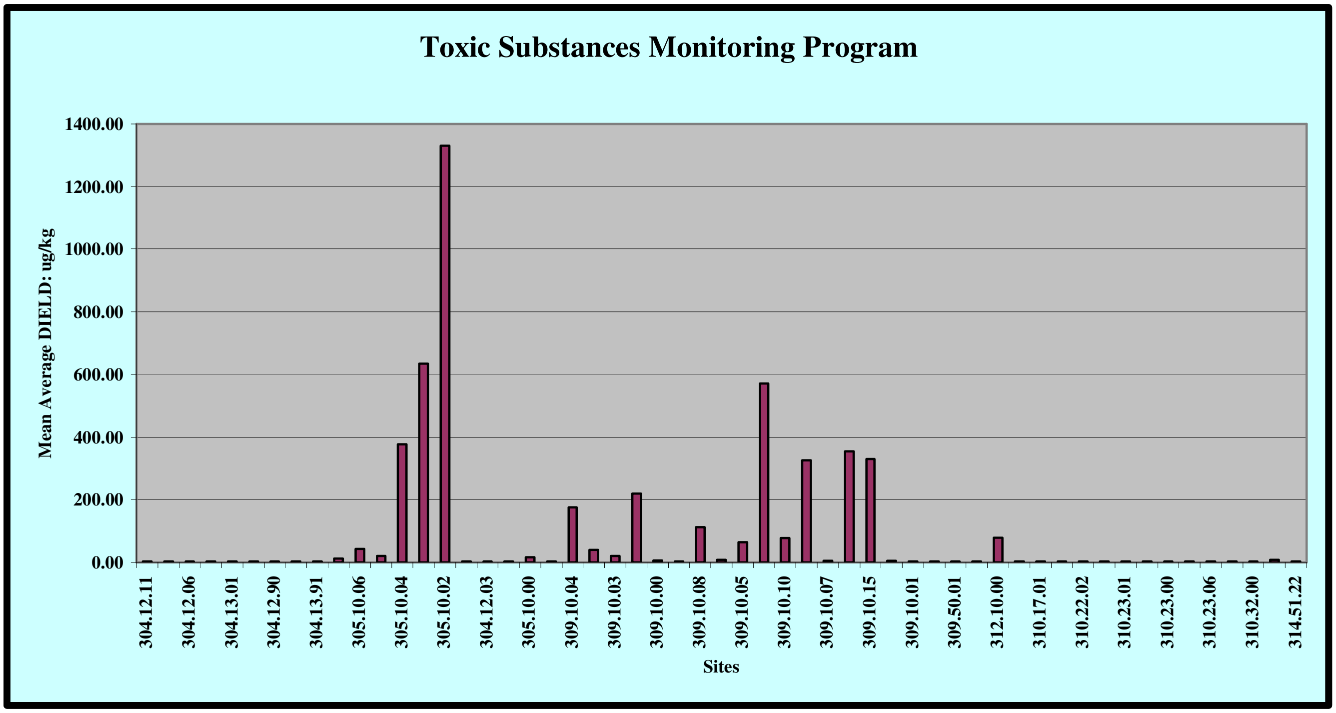


Figure 29. Toxic Substances Monitoring Program site fish tissue mean concentrations of Dieldrin (ug/kg), 1982 - 1995. (Pajaro Estuary and Watsonville Slough are 305.10).

CCAMP coastal confluences sampling found few metal concentrations in sediment in the Monterey Bay area at levels of concern. At Moss Landing Harbor, the chromium concentration exceeded the PEL and the ERL, though not the ERM. A waste deposit containing high chromium concentrations previously existed at a nearby facility; though this site was remediated, it may still be the source of elevated chromium levels. Nickel concentrations at Watsonville, Salinas, and Moss Landing exceeded the ERM; however, compared to ambient levels elsewhere in the region these levels are not unusual. No other metals from the area showed unusual concentrations.

The State Mussel Watch database was examined for additional information on metals in the Monterey area. Mussel Watch tissue data shows zinc elevated over the MIS in Monterey Harbor (Figure 30), and copper elevated relative to other central coast sites. These trace elements are commonly found in association with boating and marinas. Copper is used as an anti-fouling paint on boat hulls, and zinc is used in prevention of electrolytic corrosion. Tissue lead levels from Monterey Harbor were elevated in the 1980's as a result of a lead slag pile. This pile has since been removed and lead levels in sediment sampled more recently by the Bay Protection and Toxic Cleanup Program were at relatively normal concentrations (SWRCB, 1999).

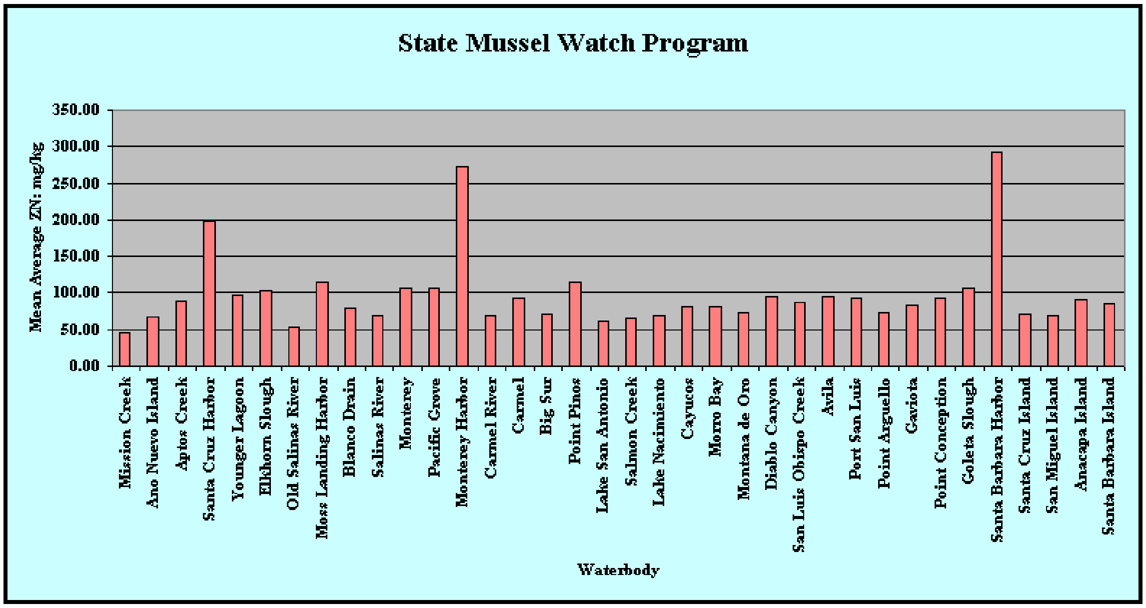


Figure 30. Average Zinc concentrations at State Mussel Watch sites on the Central Coast, showing peaks in harbor areas (1977-1995)

Lowest levels of cadmium in mussel tissue from the Monterey Bay area are found in the lower Salinas River. A summary of contaminate trends in the southern California Bight, covering samples collected over the 50 years between 1941 to 1991 (Mearns, 1991), indicates that cadmium depressions may be associated with elevated levels of chlorinated hydrocarbons. Brown et al. (1987) suggested that chlorinated hydrocarbon metabolites compete with cadmium and other metals for glutathione binding sites. Low levels of cadmium at these sites may be the result of high levels of DDT and other organochlorines. Overall, cadmium concentrations in tissue are relatively high on the central coast, relative to the Median International Standard.

<u>San Luis Obispo County and Northern Santa Barbara County</u> - CCAMP sampling sites in San Luis Obispo and northern Santa Barbara Counties are shown in Figure 31. A number of samples from the northern San Luis Obispo area had metal concentrations at elevated levels. This probably stems from the high serpentine component of many soils in this area, and the chromite, mercury, and manganese mines found in several of the watersheds. Chromium concentrations were elevated above the ERL for Chorro Creek, Arroyo de la Cruz, San Luis Obispo Creek, and San Simeon Creek. Nickel levels exceeded the ERM for all of the above sites, as well as Los Osos and Santa Rosa Creek sites. Copper exceeded the ERL at Arroyo de la Cruz. Mercury levels exceeding the ERL and the TEL were found at the Santa Rosa Creek estuary. Both Santa Rosa Creek and Curti Creek, one of its tributaries, have known contamination problems. This probably results primarily from the inactive Oceanic Mine, historically the most productive mercury mine in the county (CCRWQCB, 1999).

Organic chemicals were not detected in northern San Luis Obispo County. San Luis Obispo Creek had slightly elevated levels of dieldrin and alpha-chlordane. The primary areas in which organic chemicals were detected were Arroyo Grande Creek and Santa Maria Estuary. These sites had elevated levels of DDD, DDE, and DDT. Santa Maria Estuary also had elevated levels of dieldrin and endrin. Toxic Substances Monitoring Program data (Figure 32) show DDT levels at the Santa Maria Estuary (Site 312.10) at an extremely high level in fish tissue from a single sampling event in 1992. Bay Protection and Toxic Cleanup Program also found elevated levels of DDT and Dieldrin in Santa Maria estuary sediments and high toxicity. Figure 33 shows average toxicity and sample count for Bay Protection data; unfortunately, few samples were taken in the Santa Maria Estuary.

Petroleum product pollution from UNOCAL activities is a known serious problem in the Santa Maria Estuary and adjacent lands. Petroleum pollution is also a significant problem at Avila Beach adjacent to San Luis Obispo Creek. The extent of these problems has been documented as part of cleanup efforts and is beyond the scope of this report.

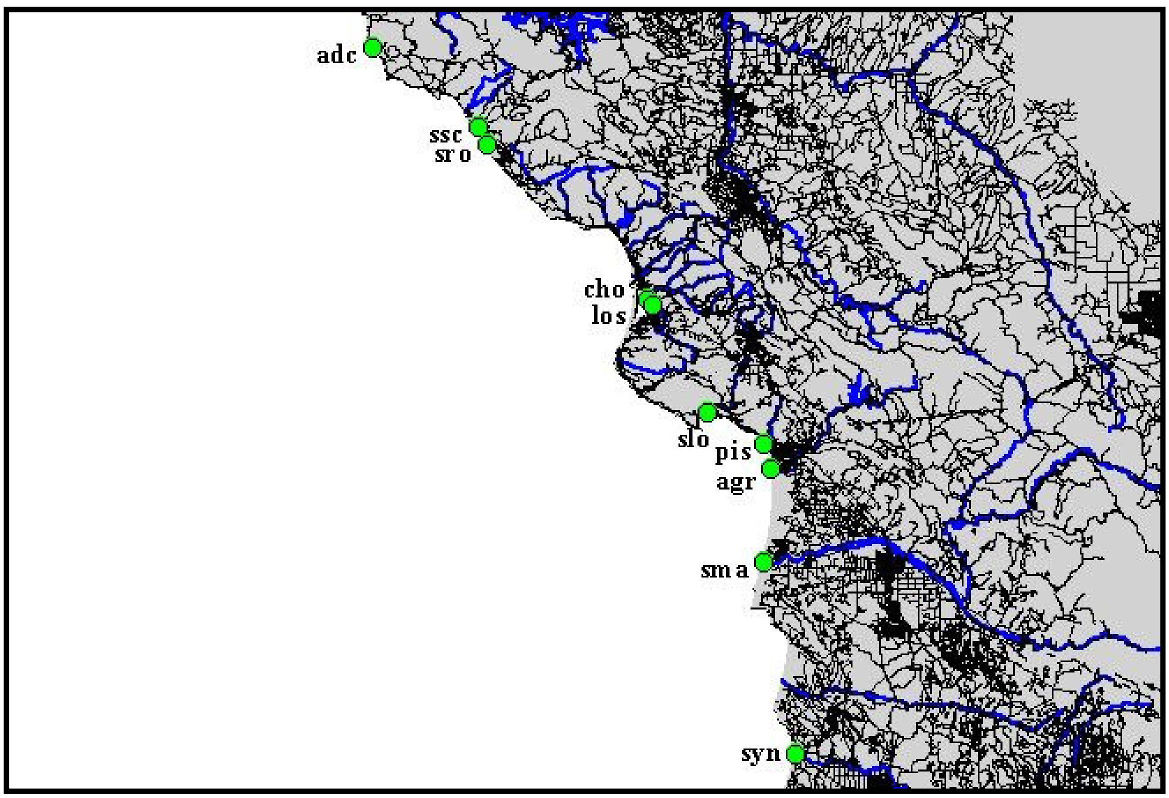


Figure 31. San Luis Obispo County and northern Santa Barbara County sites, from Arroyo de la Cruz lagoon south to the Santa Ynez River Estuary.

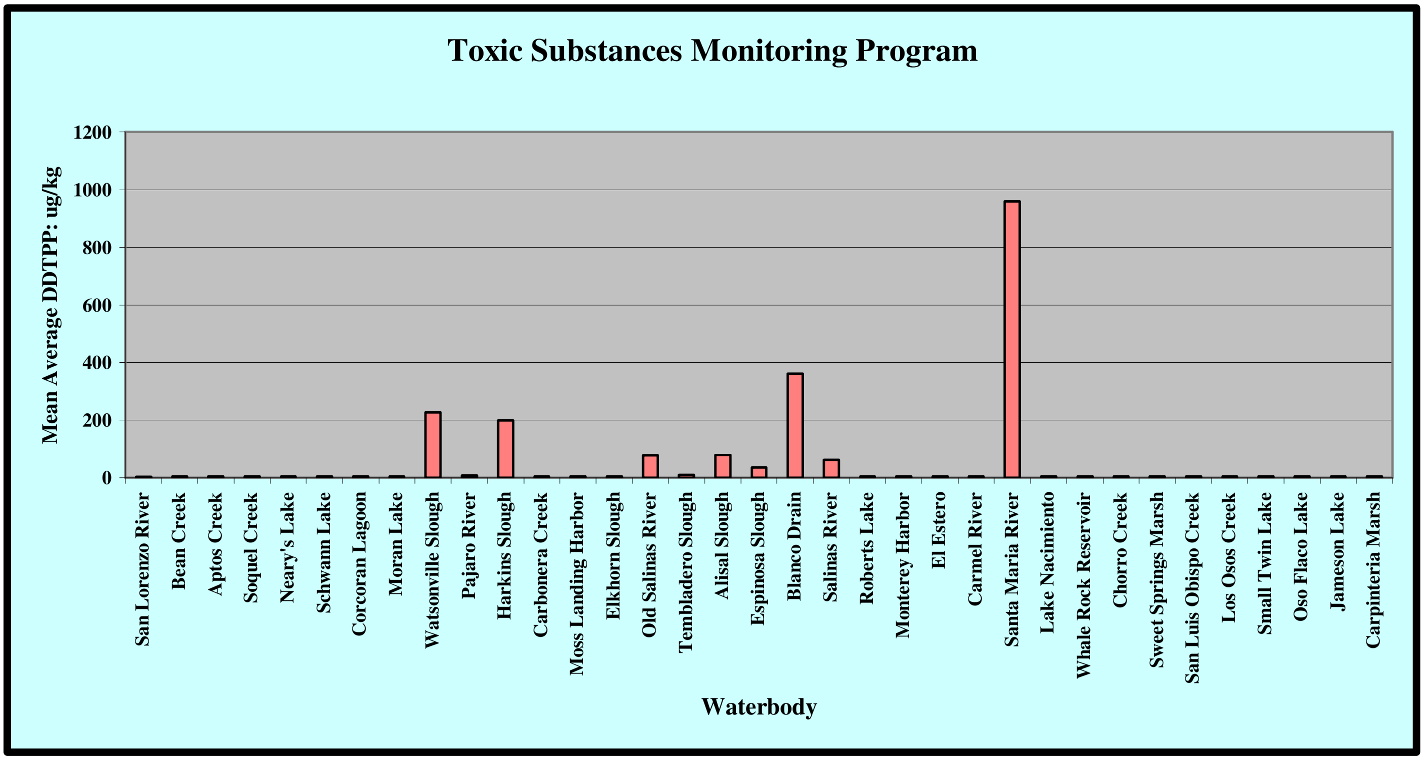


Figure 32. Average p,p-DDT concentrations in fish tissue from central coast waterbodies (1982 - 1995).

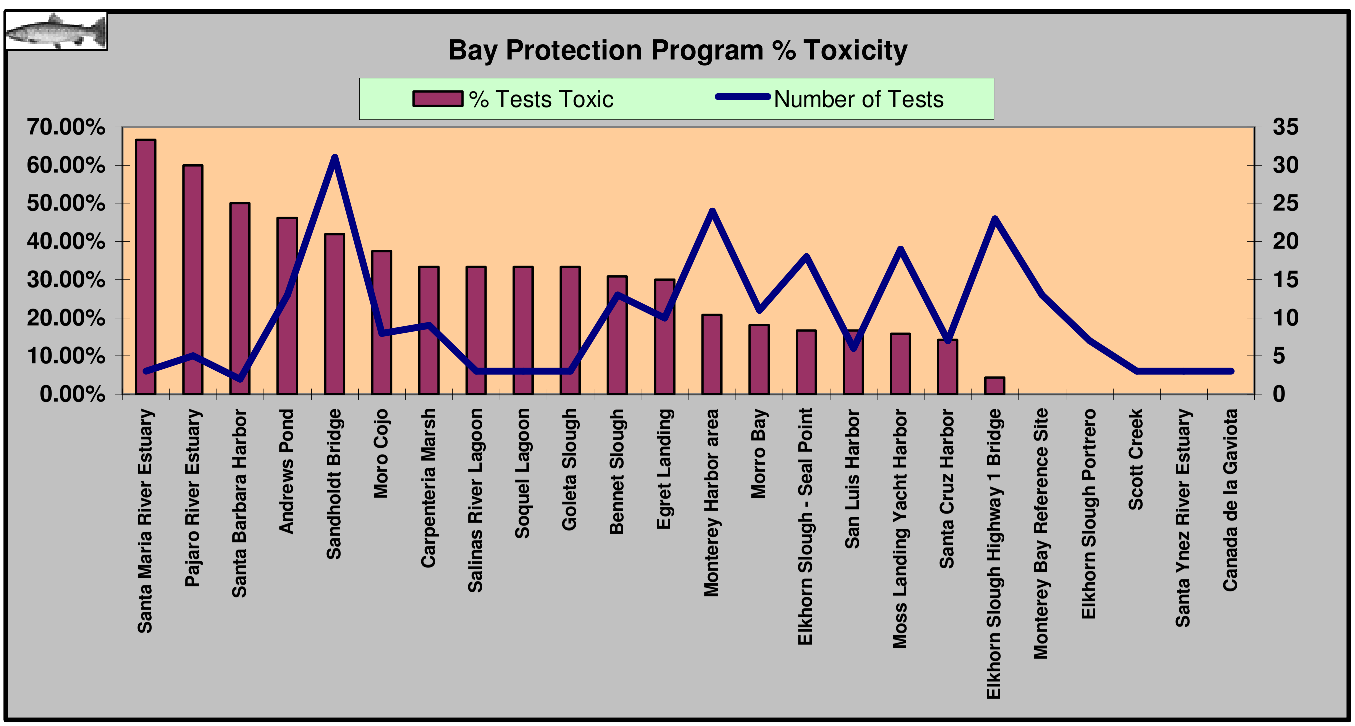


Figure 33. Average toxicity and sample count at Bay Protection and Toxic Substances Monitoring Program sites, 1992 - 1996.

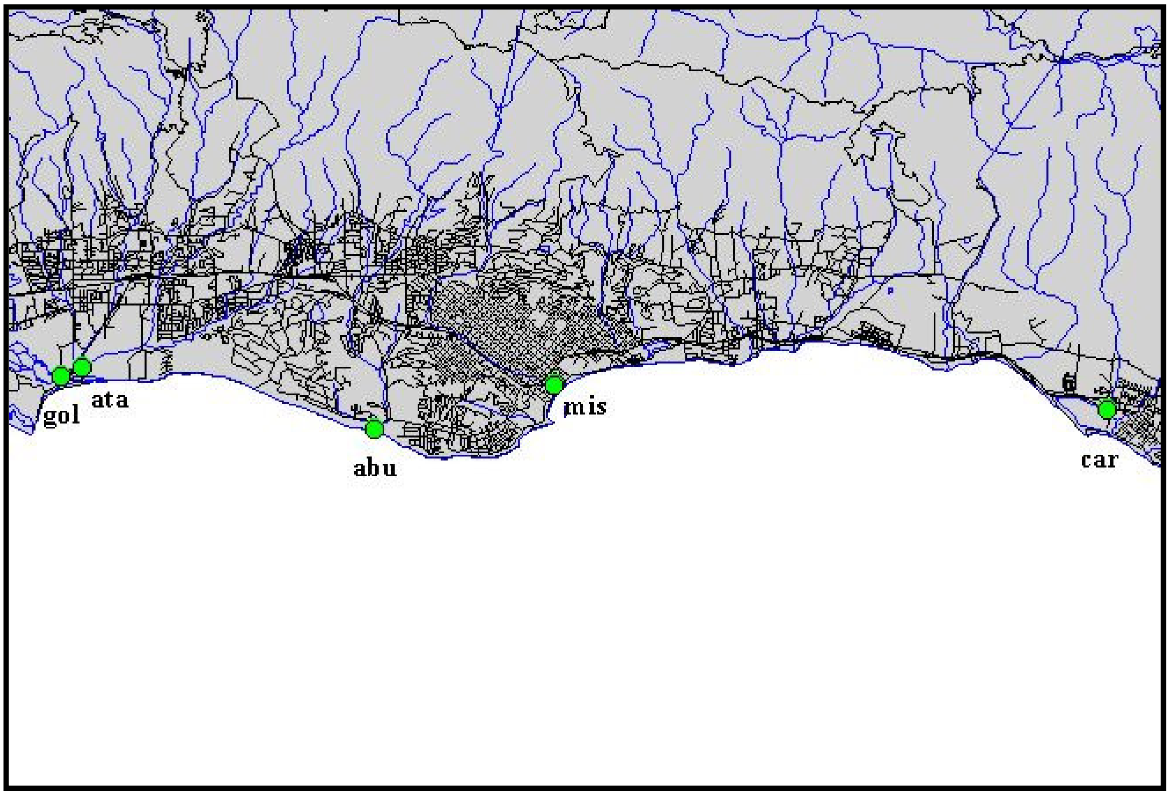


Figure 34. Santa Barbara County sites, from Goleta Slough east to Carpenteria Marsh.

Southern Santa Barbara County - CCAMP sampling detected no metals at elevated concentrations at the five sites sampled in the southern Santa Barbara area (Figure 34). However, several synthetic organic chemicals were found at elevated concentrations. Goleta Slough, Atascadero Creek, and Mission Creek sediments contained alpha-chlordane concentrations greater than the ERL. Concentrations of alpha-chlorane at Goleta Slough exceeded the TEL. The same three sites had elevated concentrations of Lindane. Both of these chemicals were used as fumigants in urban environments prior to 1988. Mission Creek sediment contained elevated levels of aldrin and dieldrin at concentrations above the ERL and TEL When concentrations are normalized to fine particle size fraction the concentrations of Aldrin and Dieldrin appear to be an even more serious problem at this site.

Though Santa Barbara Harbor was not one of the coastal confluence sites sampled by CCAMP, like other harbors on the central coast it contains elevated levels of zinc and copper in mussel tissue, as evidenced by tissue concentrations from the State Mussel Watch database (see Figure 30).

Recommendations and Followup

- It is recommended that the Bay Protection and Toxic Cleanup Plan (SWRCB, 1999), developed for Moss Landing Harbor and its tributary areas, be implemented. This plan addresses problems resulting from organochlorine compounds at Tembladero Slough, Salinas River, Old Salinas River, and Moro Cojo Slough.
- Cleanup of existing pesticide storage and handling facilities in the vicinity of Watsonville Slough and Salinas River is underway and remediation performance evaluation monitoring will be conducted. This monitoring should include focused sediment and bioaccumulation sampling to detemine status and trends after remediation.
- Pesticide TMDL development associated with these waterbodies will result in additional source identification and remediation recommendations. The Sediment TMDL for the Salinas, currently in development, will aide in assessment of chemicals which are predominately bound to sediments.
- Year 2000 CCAMP monitoring in the Santa Maria River Watershed will include sediment and bioaccumulation sampling and benthic invertebrate assessment which should further characterize the extent and degree of problems in this estuary and its watershed.
- Santa Rosa Creek is one of several waterbodies which are the subject of a recently completed mine assessment study (CCRWQCB, 1999). The problem detected at Santa Rosa Creek is most likely resulting from mercury associated with the inactive Oceanic mine. Sediment retention and wetland treatment has been recommended in the study as feasible form of mitigation. CCAMP will conduct followup bioaccumulation monitoring of crayfish in the Santa Rosa Creek drainage to determine if a human health risk from consumption exists.
- A TMDL for metals is currently being developed for Chorro Creek. Metals have been identified as a priority problem for the Morro Bay National Estuary Program, and are addressed in its Comprehensive Conservation and Management Plan. The mines associated with Chorro Creek and its tributaries are also addressed in the RWQCB mine study (1999); this report makes recommendations for remediation. Implementation of these various plans should proceed in a timely fashion.
- The chromium remediation site at Moss Landing (National Refractories) should be investigated as a possible source of continuing elevated chromium and appropriate action should be taken if necessary.
- CCAMP resampling of cadmium at Arroyo Grande Creek should be conducted to confirm the single sample taken in 1998. If elevated levels are confirmed then additional focused monitoring should be used to identify sources. Similar resampling should be conducted for copper at Arroyo de la Cruz.
- Though copper and zinc in harbors are elevated over the rest of the Region in State Mussel Watch Program data, CCAMP sampling did not confirm this. An aggressive effort is underway to improve boating and marina practices, particularly in the Monterey Bay National Marine Sanctuary.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. U.S. Dept. of Health and Human Services. http://www.atsdr.cdc.gov/atsdrhome.html

Brown, D.A., R.W. Gossett, and S.R. McHugh. 1987. Oxygenated metabolites of DDT and PCBs in marine sediments and organisms. In: Oceanic Processes in Marine Pollution. Volume 1: Biological Processes and Wastes in the Ocean.

Central Coast Regional Water Quality Control Board, 1999. Inactive Metal Mines in Four San Luis Obispo County Watersheds - Surface Water Quality Impacts and Remedial Options.

Cotter, P. and L. Strnad. 1997. Compilation of Monitoring Data for the Elkhorn Slough Watershed and the Lower Salinas River Drainage Area. California Coastal Commission.

Environmental Defense Fund, 1999. Toxic Equivalency Potentials. http://www.scorecard.org/chemical-profiles/

Hunt, John W., B. Anderson, B. Phillips, W. Piekarski, M. Englund, R. Tjeerdema, Victor deVlaming. 1999. Aquatic Toxicity in the Pajaro River Watershed: Tributary Sources and Chemicals of Concern.

Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 62. National Oceanic and Atmospheric Administration, Seattle, WA. 86 pp.

Long, E.R., L.J. Field, and D.D. MacDonald. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environmental Toxicology and Chemistry 17:714-727.

MacDonald, D.D. 1994. Approach to the Assessment of Sediment Quality in Florida Coastal Waters. Volume 1 - Development and Evaluation of Sediment Quality Assessment Guidelines. Prepared for the Florida Department of Environmental Regulation. MacDonald Environmental Services, Ltd. Ladysmith, British Columbia. 126 pp.

Marshack, J. 1998. State Water Resources Control Board. http://www.swrcb.ca.gov/~rwqcb5/wq_goals/index.html

Mearns, 1991, National Oceanic and Atmospheric Administration: Contaminant Trends in the Southern California Bight: Inventory and Assessment.

NOAA Sediment Quality guidelines (SQUIRTS). 2000. http://www.nwn.noaa.gov/sites/hazmat/cpr/sediment/SQGs.html

Office of Environmental Health Hazard Assessment (OEHHA). February, 1992. Monterey Bay Marine Environmental Health Survey: Health Evaluation. California Environmental Protection Agency.

Rasmussen, D. and H. Blethrow. 1991. Toxic Substances Monitoring Program 1988-89 Data Report. State Water Resources Control Board, California Environmental Protection Agency. 91-1WQ.

Rasmussen, D. 1992. Toxic Substances Monitoring Program 1990 Data Report. State Water Resources Control Board, California Environmental Protection Agency. 92-1WQ.

Rasmussen, D. 1993. Toxic Substances Monitoring Program 1991 Data Report. State Water Resources Control Board, California Environmental Protection Agency. 93-1WQ.

Rasmussen, D. 1995a. State Mussel Watch Program 1987-1993 Data Report (94-1WQ). State Water Resources Control Board, California Environmental Protection Agency.

Rasmussen, D. 1995b. Toxic Substances Monitoring Program 1993-94 Data Report. State Water Resources Control Board, California Environmental Protection Agency. 95-1WQ.

Rasmussen, D. 1996. State Mussel Watch Program 1993-1995 Data Report (96-2WQ). November. State Water Resources Control Board, California Environmental Protection Agency.

Rasmussen, D. 1997. Toxic Substances Monitoring Program 1994-95 Data Report. State Water Resources Control Board, California Environmental Protection Agency.

San Francisco Estuary Institute. 1999. Annual Report: San Francisco Estuary Regional Monitoring Program for Trace Substances. San Francisco Estuary Institute, Richmond, CA.

State Water Resources Control Board. 1999. Consolidated Toxic Hot Spot Cleanup Plan. Division of Water Quality.

State Water Resources Control Board. 1998. Final Functional Equivalent Document – Water Quality Control Policy for Guidance on the Development of Regional Toxic Hot Spot Cleanup Plans. Division of Water Quality.

State Water Resources Control Board, Central Coast Regional Water Quality Control Board California Department of Fish and Game, Moss Landing Marine Laboratories, University of California Santa Cruz. 1998. Chemical and Biological Measures of Sediment Quality in the Central Coast Region.

U.S. Environmental Protection Agency. November, 1999. Reference Dosage and Maximum Contaminant Levels. http://www.epa.gov/ngispgm3/iris/

Guidelines used to develop the CCAMP Risk Index

Organization	Source	Screening Value
• Environmental Defense Fund	Toxic Equivalency Potential	Cancer TEP in Water
• Environmental Defense Fund	Toxic Equivalency Potential	Non-Cancer TEP in Water
• University of California Cooperative Extension	Pesticide Information Profiles	Reference Dose
• California Dept. of Health Services	Drinking Water Standard Maximum Contaminant Level	Primary MCL
• California Dept. of Health Services	Drinking Water Standard Maximum Contaminant Level	Secondary MCL
• California Environmental Protection Agency	Water Quality Criterion	Cancer Potency Factor
• California Environmental Protection Agency	Proposition 65	Proposition 65 Regulatory Level
• Department of Health Services		Recommended Public Health Level
• Department of Health Services	California State Action Level	Toxicity
• Department of Health Services	California State Action Level	Taste & Odor
• National Academy of Sciences		Suggested No Adverse Response Level
• National Academy of Sciences	Drinking Water and Health	One-in-a-Million Cancer Risk
• State Water Resources Control Board	Water Quality Goal	Agricultural Water Quality Goal
• State Water Resources Control Board	California Inland Surface Waters Plan Drinking Water Sources	Human Health Protection - 30 day average
• State Water Resources Control Board	California Inland Surface Waters Plan (Non-Drinking Water)	Human Health Protection - non-drinking water
• State Water Resources Control Board	California Inland Surface Waters Plan (Non-Drinking Water)	Freshwater Aquatic Life - 4-day average
• State Water Resources Control Board	California Inland Surface Waters Plan (Non-Drinking Water)	Freshwater Aquatic Life - Daily Average
• State Water Resources Control Board	California Inland Surface Waters Plan (Non-Drinking Water)	Freshwater Aquatic Life - 1-hour average
• State Water Resources Control Board	California Inland Surface Waters Plan (Non-Drinking Water)	Freshwater Aquatic Life -Instantaneous Maximum
• State Water Resources Control Board	California Enclosed Bays and Estuaries	Human Health Protection - 30 day average
• State Water Resources Control Board	California Enclosed Bays and Estuaries	Saltwater Aquatic Life Protection - 4-day average
• State Water Resources Control Board	California Enclosed Bays and Estuaries	Saltwater Aquatic Life Protection - Daily average
• State Water Resources Control Board	California Enclosed Bays and Estuaries	Saltwater Aquatic Life Protection - 1-hour average
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	Human Health Protection (30-day average)
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	6-month median
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	30-day average
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	7-day average
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	Daily Maximum
• State Water Resources Control Board	California Ocean Plan Numerical Water Quality Obectives for Marine Aquatic Life Protection	Instantaneous Maximum
• U.S. Environmental Protection Agency	Drinking Water Standard Maximum Contaminant Level	Primary MCL
• U.S. Environmental Protection Agency	Drinking Water Standard Maximum Contaminant Level	Secondary MCL
• U.S. Environmental Protection Agency	Drinking Water Standard Maximum Contaminant Level	MCL Goal

• U.S. Environmental Protection Agency	Integrated Risk Information System	IRIS Reference Dose
• U.S. Environmental Protection Agency		Suggested No Adverse Response Level
• U.S. Environmental Protection Agency	Integrated Risk Information System	IRIS One-in-a-Million Cancer Risk
• U.S. Environmental Protection Agency	Health Advisory	Suggested No Adverse Response Level for Cancer
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Non-Cancer Public Health
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	One-in-a-Million Incremental Cancer Risk
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Taste and Odor
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	4-day Average
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	24-Hour Average
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Maximum Concentration (1-hour average)
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Instantaneous Maximum
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Acute Toxicity
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Chronic Toxicity
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Fresh Water Aquatic Life)	Other freshwater toxicity
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	4-day average
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	24-hour average
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	1-hour average
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	Instantaneous Maximum
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	Acute Toxicity
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	Chronic Toxicity
• U.S. Environmental Protection Agency	National Ambient Water Quality Criteria (Saltwater Aquatic Life)	Other saltwater toxicity
• National Oceanographic and Atmospheric Administration	Freshwater Sediment Screening	Background
• National Oceanographic and Atmospheric Administration	Freshwater Sediment Screening	Lowest ARCs
• National Oceanographic and Atmospheric Administration	Freshwater Sediment Screening	Threshold Effects Level
• National Oceanographic and Atmospheric Administration	Freshwater Sediment Screening	Probable Effects Level
• National Oceanographic and Atmospheric Administration	Freshwater Sediment Screening	Upper Effects Threshold
• National Oceanographic and Atmospheric Administration	Marine Sediment Screening	Threshold Effects Level
• National Oceanographic and Atmospheric Administration	Marine Sediment Screening	Effects Range Low
• National Oceanographic and Atmospheric Administration	Marine Sediment Screening	Effects Range Median
• National Oceanographic and Atmospheric Administration	Marine Sediment Screening	Probable Effects Level
• National Oceanographic and Atmospheric Administration	Marine Sediment Screening	Apparent EffectsThreshold
• National Oceanographic and Atmospheric Administration	Fresh Water Screening	Criteria Maximum Concentration
• National Oceanographic and Atmospheric Administration	Fresh Water Screening	Criteria Continuous Concentration
• National Oceanographic and Atmospheric Administration	Marine Water Screening	Criteria Maximum Concentration
• National Oceanographic and Atmospheric Administration	Marine Water Screening	Criteria Continuous Concentration

Central Coast Ambient Monitoring Program
Coastal Confluences Monitoring Strategy

The CCAMP monitoring strategy for coastal confluences calls for annual sampling at approximately 40 sites where freshwater surface flows enter the sea. River and stream mouths, estuaries, and lagoons are the focus of this aspect of the CCAMP strategy. Annual sampling at these sites is intended to provide a basis for assessments of trends and broad scale performance evaluation of water quality management efforts. The Coastal Confluences element of the program also provides an important screening tool for water quality problems in nearshore areas as well as in associated coastal watersheds.

Water column chemistry of coastal confluence sites is conducted as a part of CCAMP watershed characterizations. The Coastal Confluences component of the program includes assessment of sediment chemistry, tissue bioaccumulation, interstitial water toxicity, and benthic assemblages. The use of these multiple methods is intended to provide a "weight of evidence" approach for water and habitat quality assessments. Other programs, such as the Bay Protection and Toxic Cleanup Program, have similarly relied upon multiple methodologies to produce a "weight of evidence" assessment.

Sampling Methodologies

<u>Tissue Bioaccumulation</u> - Fish or shellfish samples are collected to assess presence of chemicals which bioaccumulate in tissues. Shellfish are placed at selected sites for a six week period during the winter by the State Mussel Watch Program. Depending on salinity, corbicula clams or California mussels are transplanted to each site.

Bivalves are used in the Mussel Watch program because they are hardy, sessile, and because they accumulate certain pollutants in their tissues to levels higher than concentrations of the same substances in surrounding waters. This makes laboratory detection of these substances easier in mollusk tissues than in the water these animals originate in. Mussels are the most commonly used bivalve. Normally, California mussels (*Mytilus californianus*) are collected from a relatively "clean" control area and then transplanted into areas to be monitored. Bivalves are suspended in nylon-mesh bags in shallow water, collected without contamination, and analyzed.

Freshwater clams (*Corbicula fluminea*) are collected at clean freshwater control areas, and transplanted to sample sites in estuaries where salinity is low and mussels cannot survive. Collection, processing, and analysis of clams are the same as with mussels, except that for trace elements analyses all internal parts of clams (including gonads) are included for analysis and for organic analyses 100 clams per sample are used.

Resident fish are collected from selected sites during the fall by the Toxic Substances Monitoring Program. Depending on the habitat being sampled, fish are collected using electrofishing gear or seines. Composite samples, using six fish of each species, are collected whenever possible. The number and size uniformity of the fish in each composite depends upon their availability. Replicate composites are collected and analyzed to measure the variability of toxicant concentrations in single species composites collected at the same time and place. Collection of the same species from all stations is desirable to minimize possible variation in the data due to differences in pollutant uptake between species. However, this is not always possible due to the variety of habitat sampled and limited collection time available in the program.

Field and analytical procedures are conducted by the CDFG according to program quality assurance protocols. Chemical analysis of tissue includes hydrocarbons, priority organics, metals, PCBs and other constituents deemed necessary.
The standard analyte list for the State Mussel Watch Program is shown in Table 1.

Benthic Macroinvertebrate Sampling - Rapid bioassessment sites are sampled using California Rapid Bioassessment Protocols and quality assurance guidance (Harrington, 1996). Fresh water lake protocols have been modified for use in estuaries and coastal lagoons. Sampling requires netting in estuarine margin habitat, within several feet of the shoreline. Current research is examining the utility of this approach alongside more traditional sediment coring.

Sediment Chemistry - Sediment samples are collected at each coastal confluence site once during the sampling year, and are analyzed by a commercial laboratory. Sampling targets fine grain sediments. Laboratory analysis includes the constituents listed in Table 2.

Table 1. Trace metals, Synthetic Organic Compounds, and Polynuclear Aromatic Hydrocarbons Analyzed by the State Mussel Watch Program.

Trace Elements	
Aluminum	Nickel
Arsenic	Lead
Cadmium	Selenium
Chromium	Silver
Copper	Titanium
Mercury	Zinc
Manganese	
Synthetic Organic Compounds	
aldrin	ethion
cis-chlordane	HCH, alpha
trans-chlordane	HCH, beta
chlordene, alpha	HCH, gamma
chlordene, gamma	HCH, delta
chlorpyrifos	heptachlor
dacthal	heptachlor epoxide
DDD, o, p'	HCB
DDD, p, p'	methoxychlor
DDE, o, p'	cis-nonachlor

DDE, p, p'	trans-nonachlor
DDMU, p, p'	oxadiazon
DDT, o, p'	oxychlordan
DDT, p, p'	parathion, ethyl
diazinon	parathion, methyl
dichlorobenzophenone-p, p'	PCB 1248
dicofol (Kelthane)	PCB 1254
dieldrin	PCB 1260
endosulfan I	tetradifon (Tedion)
endosulfan II	toxaphene
endrin	
Polynuclear Aromatic Hydrocarbons (PAHs)	
naphthalene	fluoranthene
1-methylnaphthalene	pyrene
2-methylnaphthalene	benz[a]anthracene
biphenyl	chrysene
2,6-dimethlynaphthalene	benzo[b]fluoranthene
acenaphthylene	benzo[k]fluoranthene
2,3,5-trimethylnaphthalene	benzo[e]pyrene
fluorene	benzo[a]pyrene
phenanthrene	perylene
anthracene	indeno[1,2,3-cd]pyrene
1-methylphenanthrene	dibenz[a,h]anthracene
benz[ghi]perylene	

Table 2. Analyte List for Sediment Samples

Analyte	EPAMethod	Units		Analyte	EPAMethod	Units
% Clay	Plumb	%		Benzo(k)fluoranthene	8270B	ug/Kg
% Sand	Plumb	%		beta-BHC	8080A	ug/Kg
% Silt	Plumb	%		Chrysene	8270B	ug/Kg
% Solids	160.3	%		delta-BHC	8080A	ug/Kg
Azinphos-methyl	8140	ug/Kg		Dibenzo(a,h)anthracene	8270B	ug/Kg
Bolstar	8140	ug/Kg		Dieldrin	8080A	ug/Kg
Cadmium	6020	mg/kg		Endosulfan-I	8080A	ug/Kg
Chlorpyrifos	8140	ug/Kg		Endosulfan-II	8080A	ug/Kg
Chromium	6020	mg/kg		Endosulfan-Sulfate	8080A	ug/Kg
Copper	6020	mg/kg		Endrin	8080A	ug/Kg
Coumaphos	8140	ug/Kg		Endrin Aldehyde	8080A	ug/Kg
Demeton-O	8140	ug/Kg		Endrin Ketone	8080A	ug/Kg
Demeton-S	8140	ug/Kg		Flouranthene	8270B	ug/Kg
Diazinon	8140	ug/Kg		Flourene	8270B	ug/Kg
Dichlorvos	8140	ug/Kg		gamma-BHC	8080A	ug/Kg
Disulfoton	8140	ug/Kg		gamma-Chlordane	8080A	ug/Kg
Ethoprop	8140	ug/Kg		Heptachlor	8080A	ug/Kg
Fensulfothion	8140	ug/Kg		Heptachlor-Epoxide	8080A	ug/Kg
Fenthion	8140	ug/Kg		Indeno(1,2,3-cd)pyrene	8270B	ug/Kg
Lead	6020	mg/kg		Methoxychlor	8080A	ug/Kg
Mercury	7471	mg/kg		Naphthalene	8270B	ug/Kg
Merphos	8140	ug/Kg		PCBs	8080A	ug/Kg
Mevinphos	8140	ug/Kg		Phenanthrene	8270B	ug/Kg
Naled	8140	ug/Kg		Pyrene	8270B	ug/Kg
Nickel	6020	mg/kg		Toxaphene	8080A	ug/Kg
Parathion-methyl	8140	ug/Kg		4,4'-DDD	608	ug/L
Particle Size Wt.(<0.002mm)	Plumb	gm		4,4'-DDE	608	ug/L
Particle Size Wt.(>.0156mm)	Plumb	gm		4,4'-DDT	608	ug/L
Particle Size Wt.(>0.002mm)	Plumb	gm		Aldrin	608	ug/L
Particle Size Wt.(>0.0039mm)	Plumb	gm		alpha-BHC	608	ug/L
Particle Size Wt.(>0.0078mm)	Plumb	gm		alpha-Chlordane	608	ug/L
Particle Size Wt.(>0.0313mm)	Plumb	gm		Azinphos-methyl	614	ug/L
Particle Size Wt.(>0.0625mm)	Plumb	gm		beta-BHC	608	ug/L
Particle Size Wt.(>0.125mm)	Plumb	gm		Cadmium	200.8	ug/L
Particle Size Wt.(>0.25mm)	Plumb	gm		Chromium	200.8	ug/L
Particle Size Wt.(>0.5mm)	Plumb	gm		Copper	200.8	ug/L
Particle Size Wt.(>16mm)	Plumb	gm		delta-BHC	608	ug/L
Particle Size Wt.(>1mm)	Plumb	gm		Demeton-O	614	ug/L
Particle Size Wt.(>2mm)	Plumb	gm		Diazinon	614	ug/L
Particle Size Wt.(>32mm)	Plumb	gm		Dieldrin	608	ug/L
Particle Size Wt.(>4mm)	Plumb	gm		Disulfoton	614	ug/L
Particle Size Wt.(>8mm)	Plumb	gm		Endosulfan-I	608	ug/L

Table 2 (continued). Analyte List for Sediment Samples

Analyte	EPAMethod	Units		Analyte	EPAMethod	Units
Phorate	8140	ug/Kg		Endosulfan-II	608	ug/L
Ronnel	8140	ug/Kg		Endosulfan-Sulfate	608	ug/L
Stirphos	8140	ug/Kg		Endrin	608	ug/L
Tokuthion	8140	ug/Kg		Endrin Aldehyde	608	ug/L
Trichloronate	8140	ug/Kg		Endrin Ketone	608	ug/L
Weight Coarse	Plumb	gm		Ethion	614	ug/L
Weight Fine	Plumb	gm		gamma-BHC	608	ug/L
Weight Total	Plumb	gm		gamma-Chlordane	608	ug/L
Zinc	6020	mg/kg		Hardness	130.2	mg/L
4,4'-DDD	8080A	ug/Kg		Heptachlor	608	ug/L
4,4'-DDE	8080A	ug/Kg		Heptachlor-Epoxide	608	ug/L
4,4'-DDT	8080A	ug/Kg		Lead	200.8	ug/L
Acenaphthene	8270B	ug/Kg		Malathion	614	ug/L
Acenaphthylene	8270B	ug/Kg		Mercury	200.8	ug/L
Aldrin	8080A	ug/Kg		Methoxychlor	608	ug/L
alpha-BHC	8080A	ug/Kg		Nickel	200.8	ug/L
alpha-Chlordane	8080A	ug/Kg		Parathion-ethyl	614	ug/L
Antracene	8270B	ug/Kg		Parathion-methyl	614	ug/L
Benzo(a)fluoranthene	8270B	ug/Kg		PCBs	608	ug/L
Benzo(a)pyrene	8270B	ug/Kg		Toxaphene	608	ug/L
Benzo(b)fluoranthene	8270B	ug/Kg		Zinc	200.8	ug/L
Benzo(g,h,i)perylene	8270B	ug/Kg				

Sediment Particle Size - Sediment is analyzed for particle size distribution as well as for percent clay, silt, and sands. Particle size is an important consideration when evaluating sediment chemistry data, because many organic compounds, such as the organochlorine pesticides, tend to bind to clay particles. Therefore samples which exhibit a high percentage of clay are more likely to have higher concentrations of certain adsorbant chemicals. Chemical concentrations should be viewed in the context of sediment particle size. Particle size parameters are included in Table 2.

Interstitial Water Toxicity and/or Sediment Interface Toxicity - Toxicity of sediment and/or interstitial water is conducted in conjunction with sediment chemistry sampling, using organisms appropriate for site specific salinity conditions. In the event that toxicity is found, the site is resampled to conduct Toxicity Identification Evaluations, to better identify the chemicals causing toxicity.