San Francisco Estuary Regional Monitoring Program for Trace Substances

1997 Annual Report

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Executive Summary

The *1997 Annual Report* is the fifth Annual Report from the Regional Monitoring Program for Trace Substances (RMP) and contains a comprehensive description of RMP results from the 1997 monitoring year. As in previous years, the report includes results from the Base Program (water, sediment, and bivalve monitoring) and results from Pilot and Special Studies completed in 1997, in addition to an update on the RMP Five-Year Review implementation. It also includes papers contributed by RMP investigators and other scientists. These articles address related monitoring activities, and help to provide additional insight into contaminant patterns and the impacts of those contaminants on the San Francisco Estuary.

The 1997 monitoring year proved to be an unusual one, with record-setting precipitation in December and January followed by unusually dry weather in February and March. These weather patterns had a visible effect on RMP results, frequently creating sharp contrasts in results between the first two sampling cruises of the year, and higher than normal contaminant concentrations at many RMP sampling sites in February. These results, and results from the other aspects of the RMP, are summarized below.

Revised RMP Objectives

1. To describe patterns and trends in contaminant concentration and distribution.
2. To describe general sources and loadings of contamination to the Estuary.
3. To measure contaminant effect of selected parts of the Estuary ecosystem.
4. To compare monitoring information to relevant water quality objectives and other guidelines.
5. To synthesize and distribute information from a range of sources to present a more complete picture of the sources, distribution, fates, and effects of contaminants in the Estuary ecosystem.

1997 Review Implementation

The original goals of the RMP have been met, and the Program continues to collect high-quality baseline data, examine trends in the Estuary, and collaborate with other local monitoring programs. However, during a comprehensive Five-Year Review of the program by seven independent scientists and specialists (the Review Panel), it became obvious that many improvements are still possible. These improvements include a refinement of RMP objectives and decision-making processes, as well as clarification of management and scientific questions.

The Review Panel also recommended more specific descriptions of the roles, responsibilities, and authorities of the people and organizations involved in the RMP. They proposed an increase in the amount of interpretation applied to RMP data, and a more thorough integration of other Bay Area monitoring and research program results. The Panel also suggested a revision of RMP objectives. New objectives, adopted by the Steering Committee in early 1998, are listed in the sidebar.

Workgroups of scientific experts were created to examine some of the more important components of RMP monitoring: pollutant groups (chlorinated hydrocarbons, metals, and pesticides), an important matrix (sediment), and pollutant sources, pathways, and loadings. These workgroups have developed additional recommendations for monitoring needs which will be integrated into the design of the RMP.

Water Monitoring

Water Quality and Contaminants

A notable anomaly in water quality in 1997, a result of one of the strongest El Niño events in recent history, was the increase in temperatures in the eastern Pacific Ocean by over five degrees Celsius above normal. And while the surface water temperatures in the northern and southern portions of the Bay were not unusually high, the temperature of Central Bay waters—those closest to the Pacific Ocean—were the highest recorded by the RMP.

Another aberration was the Big Storm in January 1997, which resulted in a combination of high flows and elevated contaminant concentrations that probably caused the mass loadings of many contaminants to the Bay to be higher than in previous years. The extreme hydrologic variation at the beginning of the year created a distinct contrast in conventional water quality parameters between the first two sampling cruises in January and April. During January sampling, salinity in the Bay's surface waters was extremely low and the Baywide mean of total suspended solids (TSS) was the highest recorded by the RMP; in April, salinity had increased to almost twice its January value, while the mean TSS was less than half its January mean.

The Big Storm in January 1997, which resulted in a combination of high flows and elevated contaminant concentrations, probably caused the mass loadings of many contaminants to the Bay to be higher than in previous years.

This contrast between sampling periods was also visible in dissolved trace element concentrations. In January, dissolved concentrations of trace elements were relatively high throughout the Estuary, with chromium, mercury, and lead exhibiting the highest Baywide average concentrations for any cruise since the beginning of the RMP. These dissolved trace element concentrations were especially high in the Northern Estuary and Rivers monitoring stations, while concentrations in the South Bay appeared to be unaffected by the Big Storm. Total (dissolved + particulate) concentrations of some trace elements that are transported primarily in the particulate phase—chromium, copper, mercury, nickel, lead, and zinc—were also sharply elevated in January, and mirrored the declines seen in TSS from January to April.

Organochlorine pesticides also exhibited high concentrations in January, with dissolved and total chlordanes and DDTs at high levels in the Northern Estuary, although clear seasonal variation of pesticides was not visible in the southern reach. Dissolved diazinon exhibited seasonal variability in both northern and southern portions of the Bay. The high dissolved + particulate concentrations of DDTs, chlordanes, and dieldrin in the Northern Estuary suggest that contaminated sediment particles from the Central Valley were transported during January's high flows. Total polychlorinated biphenyl (PCB) concentrations, however, did not increase as a result of the Big Storm, suggesting that sediment particles washed down from the Central Valley were not as contaminated with PCBs as they were with organochlorine pesticides.

Many contaminants were above applicable water quality guideline (WQG) concentrations. Of the ten RMP trace elements that have established WQGs, chromium, copper, mercury, nickel, lead, selenium, and zinc exceeded guideline concentrations at least once, with chromium, mercury, and nickel most frequently above their established guidelines. Quite a few organic contaminants also exceeded established guidelines at least once, with dieldrin, total PCBs, and total PAHs most frequently above their guidelines. The largest number of contaminant concentrations over WQGs were found at the Southern Sloughs, the Northern Estuary, and the Estuary Interface stations.

Many of the fish populations currently in decline in San Francisco Bay rely on resident invertebrates as a key food resource during their early life stages, and their decline may be due to periods of high pesticide concentrations that coincide with the early life stages of these fishes.

Aquatic Toxicity

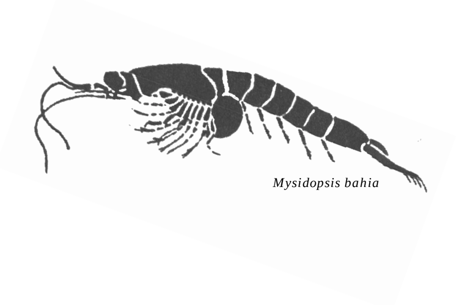
Aquatic toxicity testing revealed toxicity to mysids (*Mysidopsis*) in January at many of the Northern Estuary sites: Grizzly Bay, Napa River, and both River stations. In August, however, mysid toxicity was concentrated in the southern reach of the Bay, with all four South Bay stations showing low to zero percent survival.

A separate study of episodic water toxicity was conducted during the winters of 1996/1997 and 1997/1998, examining the effects of heavy storms (and thus increased river flow) on toxicity. Episodic toxicity is an important concern because contaminant concentrations can vary as a result of runoff following large rainstorms or agricultural pesticide applications. Toxicity frequently coincides with this runoff, and results from this year's study indicate that Northern Estuary waters may be toxic to resident invertebrates for up to a week following such events. Many of the fish populations currently in decline in San Francisco Bay rely on these resident invertebrates as a key food resource during their early life stages, and their decline may be due to periods of high pesticide concentrations that coincide with the early life stages of these fishes.

Sediment Monitoring

Contaminants in Sediment

As in previous years, most sediment contaminant concentrations were highest in the Southern Sloughs and South Bay, although the flood flows of January appeared to have an effect on contaminant concentrations in the northern reach of the Bay. Mercury concentrations were higher throughout the Estuary in February, and several contaminants, such as copper, lead, selenium, and polycyclic aromatic hydrocarbons (PAHs), had obviously elevated


Mysidopsis bahia

concentrations at the San Joaquin River site in the Northern Estuary. When compared to previous years, both copper and PAHs were higher than in the past at both River sites in the North Bay, while cadmium, chromium, nickel, chlordanes, and DDTs were higher in the South Bay. Trace element concentrations were fairly constant between 1993 and 1997, with few obvious increasing or decreasing trends.

Two different sets of guidelines were used to help interpret RMP results: the Effects-Range guidelines (see sidebar), and the Ambient Sediment Concentration (ASC) guidelines (see Chapter 4) developed by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). The Effects-Range guidelines can be used to predict the potential for biological effects, while ASC guidelines are based on the ambient or "background" concentrations of contaminants in the Bay and can be used to indicate sites where contaminants exceed those background levels.

Sediment contaminant concentrations at most of the RMP sites were frequently above Effects-Range guidelines, with the highest concentrations occurring at the Estuary Interface sites, the Southern Sloughs, and in the South Bay. Most of the 1997 RMP sediment samples had more than one contaminant exceeding these guidelines, suggesting a potential for effects on resident species. ASC guideline exceedances appeared most frequently for nickel and chromium concentrations, as well as for some individual PAH compounds. Both Effects-Range and ASC guidelines had more exceedances in February than in August, suggesting that January's flood flows increased sediment contaminant concentrations and, therefore, potentially increased toxicity.

The Effects Range sediment quality guidelines were developed to identify concentrations of contaminants associated with biological effects in laboratory, field, or modeling studies.

The Effects Range-Low (ERL) value is the concentration equivalent to the lower 10th percentile of the compiled study data. Sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects.

The Effects Range-Median (ERM) is the concentration equivalent to the 50th percentile of the compiled study data. Sediment concentrations above the ERM are "frequently" associated with adverse effects.

Sediment Toxicity

Toxicity to bivalve embryos or amphipods was most pronounced and occurred most frequently in Suisun Bay and at the Rivers sites, and in the South Bay, where more of the samples were toxic than in previous years. RMP investigators are searching for the causes of the observed toxicity, especially at the RMP Rivers stations, where consistent toxicity to bivalves and intermittent toxicity to amphipods has been observed over the past five years. RMP investigators believe metals may be the cause of the persistent toxicity to bivalve embryos at the Rivers sites.

Benthic Pilot Study

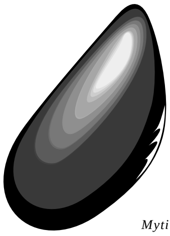
Another method currently being developed by RMP investigators to evaluate sites for contaminant effects is the use of benthic assemblages. The RMP Benthic Pilot study began in 1994, with the objective of assessing the use of benthic information to evaluate the health of the Estuary; its ultimate goal is to use benthic community characteristics to determine ecological effects of sediment contamination. In previous years, the project focused on identifying benthic assemblages specific to the San Francisco Bay Estuary and Delta. In 1997, RMP investigators began evaluating the biological response of benthic communities to sediment contamination. Data are being compiled from additional sources (Bay Protection and Toxic Cleanup Program, Bay Area Dischargers Association Local Effects Monitoring Program, and the Department of Water Resources) and added to the RMP database in order to demonstrate benthic response to contamination. While analysis is not yet complete, preliminary results indicate that most RMP sites are inhabited by many species characteristic of unimpacted conditions.

Bivalve Monitoring

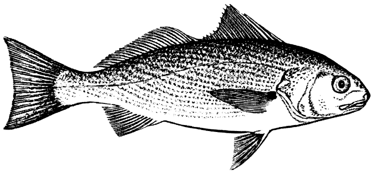
Bioaccumulation results were generally consistent with those of previous years, although the large freshwater inflow during January 1997 caused high mortality in *Mytilus californianus*, a species adapted to oceanic intertidal conditions. Certain contaminant trends in bivalve tissue within the Estuary became more visible in 1997. By combining the databases of the RMP and the State Mussel Watch Program, RMP investigators found statistically significant declines in silver in both the Central and South Bay reaches, and less pronounced declines in mercury and lead concentrations. They also found that chlorinated hydrocarbon (CHC) concentrations in bivalves, after steep declines in the early 1980s, appeared to have leveled off. At some individual stations, for example, declines in PCBs were observed, while no statistically significant trends were detectable at other stations.

In 1997, the bivalve component of the RMP had an increased emphasis on evaluating the effectiveness of bivalve monitoring and how it might be improved. While bivalves are good trend indicators for many contaminants, they do not bioaccumulate all contaminants equally well. Additionally, as the bivalve data review section in Chapter 5 indicates, the high variability of non-contaminant water quality parameters (e.g., salinity, chlorophyll *a*, dissolved oxygen, temperature) during the wet season sometimes makes bioaccumulation difficult to interpret, and the 1997 monitoring year was no exception. Thus, special attention was given to assessing the use of bivalve monitoring within the context of the RMP, and to finding methods of normalizing data that might prove helpful in uncovering contaminant trends within the Estuary.

After extensive evaluation, RMP scientists concluded that while bivalves are effective as a tool for monitoring spatial and temporal trends, they are of limited use when applied to trace elements such as arsenic and mercury—elements that do not accumulate appreciatively above background levels in bivalve tissues. They can, however, provide valuable insight into contaminant concentrations in the Estuary, for



Mytilus



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while water and sediment sampling only provides a brief snapshot of contamination, bivalve bioaccumulation studies provide an integrated measure of water contamination over a three month period.

Pilot and Special Studies

Fish Tissue

As a follow-up to a 1994 Regional Board study, a special study of contaminant concentrations in San Francisco Bay fish was performed. RMP fish sampling in 1997 targeted seven species frequently caught and eaten by Bay fishers at seven popular fishing areas around the Bay. The results revealed that persistent toxic chemicals in Bay fish remained at concentrations of potential human health concern. For instance, mercury exceeded a human health screening value in 44 of 84 Bay samples, with all leopard shark and striped bass samples exceeding the screening value. PCBs and other trace organics were highest in white croaker and shiner surfperch, the two species with the highest fat content in their muscle tissue. PCBs exceeded the human health screening value in more than two-thirds of the Bay samples, while dieldrin, DDT, and chlordane had fewer samples above screening values. Dioxins and dibenzofurans exceeded their screening values in all seven of the analyzed samples.

There was significant variation in contaminant concentrations among Bay locations: Oakland Harbor had significantly elevated concentrations of mercury, PCBs, DDTs, and chlordanes compared with other Bay locations. Mercury concentrations in 1997 were not significantly different from 1994 levels, but statistically significant declines in concentrations from 1994 to 1997 were observed for PCBs, DDTs, chlordanes, and dieldrin. However, continued monitoring is needed in order to establish whether these observed declines are true indications of declining contaminant masses in the Bay instead of variation due to other factors.

Estuary Interface Pilot Study

Many RMP sampling stations are located along the “spine” of the Estuary in order to monitor locations which, over time, are helpful in determining ambient concentrations for different reaches of the Estuary, and in detecting broad-scale spatial and temporal trends in chemistry and toxicity. During the first three years of RMP monitoring, it became evident that stations at the South Bay Estuary margins tended to exhibit higher concentrations of trace elements and organic pollutants than stations in the deeper portions of the Bay. In an attempt to determine which factors were responsible for this occurrence, and to determine how adjacent watersheds are affecting pollutant inputs, RMP investigators sampled at the interface between bay and upland waters.

Persistent toxic chemicals in Bay fish remained at concentrations of potential human health concern.

Some definite patterns are beginning to emerge after two years of sampling. The particulate fraction of water contaminants entering the Estuary from the Guadalupe River has greatly elevated concentrations of copper, mercury, and nickel compared to the sediment concentrations of these metals in the Southern Sloughs and South Bay. Water organics at the Estuary Interface (EIP) sites were also extremely high, with CHC concentrations higher than at any of the Estuary reaches. Additionally, using PCB fingerprinting methods (see text), SFEI scientists found that PCB concentrations in water were highest at the EIP stations, displaying a concentration gradient between these stations and the South Bay.

Related Monitoring Activities

RMP sample cruises are not exclusively limited to collecting RMP baseline data. During the sediment cruises, for example, U.S. Geological Survey and U.C. Berkeley researchers collected sediment samples in order to examine populations of benthic foraminifers. Sand-sized protozoans, foraminifers are sensitive indicators of marine and estuarine pollution, especially trace metals, and because they have a rapid rate of reproduction they respond relatively quickly to environmental contamination. Preliminary results of sampling in San Francisco Bay have shown that no stations were completely devoid of foraminifers, even at RMP sites characterized by high sediment trace element concentrations.

Another project which utilized 1997 RMP sampling cruises examined nickel concentrations in water in South San Francisco Bay. Because different forms of nickel differ in their degrees of toxicity and different sources discharge different nickel compounds, measurements of nickel speciation in the water column can be important in determining temporal patterns of nickel sources and toxicity in the South Bay. While stronger nickel complexes in the Bay originate mostly from wastewater effluent, the weaker, more toxic nickel-organo complexes are found in surface water runoff. Experiment results showed that the percentage of strongly complexed nickel in the Bay decreases during the wet winter months, when the weaker nickel complexes entering the Estuary via runoff are present. In the drier summer months, concentrations of complexed nickel are at their highest.

Other Monitoring Activities

Two major monitoring programs are currently in place on the Sacramento River: the Sacramento River Watershed Program (SRWP) and the Sacramento Coordinated Water Quality Monitoring Program (CMP). The CMP has been in place since 1992, and is a cooperative effort of three public agencies. Its primary purpose is collecting data to help develop and implement water quality policy

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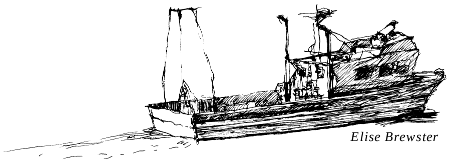
and regulations in the Sacramento area. The SRWP began in 1996 and is a stakeholder-driven effort to restore and protect beneficial uses of the Sacramento River Basin. Both programs involve ambient water quality monitoring, including trace elements, pathogens, and conventional water quality parameters (such as pH, temperature, and dissolved oxygen). The SRWP monitoring also includes toxicity testing, fish tissue monitoring, and biological indicators such as benthic invertebrates, as well as a public outreach and education component which works to promote knowledge and awareness of the watershed. The two programs are being coordinated at several levels: they have adopted compatible sampling and analytical methods, they share sampling duties and the resulting data, and together, the two groups sponsored the State of the Watershed Conference.

Conclusions

In general, contaminant concentrations throughout the Estuary tended to be higher than normal in January, due to high flows from the Big Storm. Water concentrations of mercury, chromium, and lead were at an all-time, Baywide high. Water quality parameters measured in January were also abnormal: salinity in the surface water of the Bay was extremely low, while total suspended solids were the highest ever measured by the RMP. Sediment contaminant concentrations, however, did not seem to be unusually affected by the January floods.

Now in its fifth year, the RMP has established itself as a source of reliable, high-quality data, and in cooperation with other Bay Area monitoring and research programs, it has the potential to provide important insights into contaminant sources and trends in the San Francisco Estuary. The Review Panel declared the Regional Monitoring Program for Trace Substances to be “a valuable environmental monitoring program based on a unique partnership between regulatory agencies and dischargers that can serve as a model for others.” But even before the changes recommended by the Review Panel have been fully implemented, RMP data and research have resulted in major changes to policy development by providing focus for the SFBRWQCB and helping them to identify unanticipated sources of pollution.



Elise Brewster

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CHAPTER 1

Introduction

Introduction

This report describes the results from the 1997 Regional Monitoring Program for Trace Substances (RMP). It is the fifth annual report from the RMP, which began in 1993, and includes data, interpretation, and synthesis from Base Program monitoring, as well as results of pilot and special studies conducted or completed in 1997. Additionally, this report includes several articles contributed by RMP investigators and other researchers. These articles provide perspective and insight on important contaminant issues identified by the RMP, and they describe results from projects that took advantage of RMP field operations. Background information about the RMP, included in previous Annual Reports, is not repeated in this report. Instead, the reader is referred to those reports where appropriate. A full description of the RMP is also included in the *RMP Program Plan* available from the San Francisco Estuary Institute (SFEI) and through our website at http://www.sfei.org.

In 1997, the list of Program Participants was expanded to seventy-seven federal, state, and local agencies and companies. Together with the San Francisco Bay Regional Water Quality Control Board (Regional Board), they participated in the RMP as funders and service providers. They also assisted in directing the RMP through input or participation on the Steering and Technical Review Committees. The RMP Participants are listed on the inside of the back cover.

RMP Objectives

Staff at the Regional Board and SFEI along with representatives of RMP participating agencies developed the Program objectives:

1. Obtain high quality baseline data describing the concentrations of toxic and potentially toxic trace elements and organic contaminants in the water and sediment of the San Francisco Estuary.
2. Determine seasonal and annual trends in chemical and biological water quality in the San Francisco Estuary.
3. Continue to develop a data set that can be used to determine long-term trends in the concentrations of toxic and potentially toxic trace elements and organic contaminants in the water and sediments of the San Francisco Estuary.
4. Determine whether water and sediment quality in the Estuary at large are in compliance with objectives established by the Basin Plan.
5. Provide a database on water and sediment quality in the Estuary which is compatible with data being developed in other ongoing studies in the system, including, but not limited to, wasteload allocation studies and model development, sediment quality objectives development, in-bay studies of dredged material disposal, Interagency Ecological Program (IEP) water quality studies, primary productivity studies, local effects biomonitoring programs, and state and federal mussel watch programs.

Monitoring Design

The RMP sampling design was based on the Bay Protection and Toxic Cleanup Program (BPTCP) Pilot Studies developed by the Regional Board (Flegal *et al.*, 1994). The reasoning behind the original design, with stations located along the “spine” of the Estuary, was to include stations that, in a long-term monitoring program, would indicate spatial and temporal trends in toxicity and chemistry, determine background concentrations for different reaches of the Estuary, and assess whether there were high levels of contaminants or toxicity. Several new stations were added in 1994 to fill spatial gaps and to begin monitoring near major tributaries (SFEI, 1995). Additionally, two stations were added in 1994 in the southern-most end of the Estuary in cooperation with the Cities of San Jose (station C-3-0) and Sunnyvale (station C-1-3) and the Regional Board as part of their National Pollutant Discharge Elimination System (NPDES) monitoring.

The RMP sampling design has provided a picture of the range of conditions found in deeper parts of the Estuary, influenced by riverine, seasonal, and daily natural processes. During the redesign process (see *Chapter 2: 1997 Review Implementation*), options for incorporating more near-shore stations, evaluating overall Estuary condition at statistically representative sites, or conducting intensive embayment studies will be explored.

Five types of samples were collected in the 1997 Base Program:

1. Conventional water quality and chemistry.
2. Aquatic bioassays.
3. Sediment quality and chemistry.
4. Sediment bioassays.
5. Transplanted, bagged bivalve bioaccumulation, survival, and condition.

Table 1.1. Parameters analyzed in water, sediment, and bivalve tissue during the 1997 sampling of the San Francisco Estuary.

A. Conventional Water Quality Parameters

Conductivity
Dissolved Organic Carbon
Dissolved Oxygen (DO)
Hardness (when salinity is <5 ‰)
pH (acidity)
Phaeophytin (a chlorophyll degradation product)
Salinity
Temperature
Total Chlorophyll-*a*
Total Suspended Solids
Dissolved Phosphates
Dissolved Silicates
Dissolved Nitrate
Dissolved Nitrite
Dissolved Ammonia

B. Sediment Quality Parameters

% Clay (<4 µm)
% Silt (4 µm–62 µm)
% Sand (63 µm–2 mm)
% Gravel (>2 mm)
% Solids
pH
Total Ammonia
Total Organic Carbon
Total Sulfide

C. Bivalve Tissue Parameters

% Moisture
Bivalve % Survival
Total Volume
Shell Volume
Dry Flesh Weight
Biological Condition Index

D. Trace elements

	Water	Sediment	Tissue
Aluminum*		●	
Arsenic	●	●	●
Cadmium*	●	●	●
Chromium	●	●	●
Copper*	●	●	●
Iron*		●	
Lead*	●	●	●
Manganese*		●	
Mercury	●	●	●
Nickel*	●	●	●
Selenium	●	●	●
Silver*	●	●	●
Zinc*	●	●	●
Dibutyltin (DBT)			●
Monobutyltin (MBT)			●
Tributyltin (TBT)			●
Tetrabutyltin (TTBT)			●

* Near-total rather than total concentrations for water. Near-total metals are extracted with a weak acid (pH < 2) for a minimum of one month, resulting in measurements that approximate bioavailability of these metals to Estuary organisms.

Table 1.1 (continued). Parameters analyzed.

E. Polycyclic Aromatic Hydrocarbons (PAHs)

	Water	Sediment	Tissue
2 rings			
1-Methylnaphthalene	•	•	•
2,3,5-Trimethylnaphthalene	•	•	•
2,6-Dimethylnaphthalene	•	•	•
2-Methylnaphthalene	•	•	•
Biphenyl	•	•	•
Naphthalene	•	•	•
3 rings			
1-Methylphenanthrene	•	•	•
Acenaphthene	•	•	•
Acenaphthylene	•	•	•
Anthracene	•	•	•
Dibenzothiophene	•	•	•
Fluorene	•	•	•
Phenanthrene	•	•	•
4 rings			
Benz(a)anthracene	•	•	•
Chrysene	•	•	•
Fluoranthene	•	•	•
Pyrene	•	•	•
5 rings			
Benzo(a)pyrene	•	•	•
Benzo(b)fluoranthene	•	•	•
Benzo(e)pyrene	•	•	•
Benzo(k)fluoranthene	•	•	•
Dibenz(a,h)anthracene	•	•	•
Perylene	•	•	•
6 rings			
Benzo(ghi)perylene	•	•	•
Indeno(1,2,3-cd)pyrene	•	•	•
Alkylated PAHs			
C1-Chrysenes	•	•	•
C2-Chrysenes	•	•	•
C3-Chrysenes	•	•	•
C4-Chrysenes	•	•	•
C1-Dibenzothiophenes	•	•	•
C2-Dibenzothiophenes	•	•	•
C3-Dibenzothiophenes	•	•	•
C1-Fluoranthenes/Pyrenes	•	•	•
C1-Fluorenes	•	•	•
C2-Fluorenes	•	•	•
C3-Fluorenes	•	•	•
C1-Naphthalenes	•	•	•
C2-Naphthalenes	•	•	•
C3-Naphthalenes	•	•	•
C4-Naphthalenes	•	•	•

E. PAHs (continued)

	Water	Sediment	Tissue
C1-Phenanthrenes/Anthracenes	•	•	•
C2-Phenanthrenes/Anthracenes	•	•	•
C3-Phenanthrenes/Anthracenes	•	•	•
C4-Phenanthrenes/Anthracenes	•	•	•

F. Synthetic Biocides

	Water	Sediment	Tissue
Cyclopentadienes			
Aldrin	•	•	•
Dieldrin	•	•	•
Endrin	•	•	•
Chlordanes			
alpha-Chlordane	•	•	•
cis-Nonachlor	•	•	•
gamma-Chlordane	•	•	•
Heptachlor	•	•	•
Heptachlor Epoxide	•	•	•
Oxychlordane	•	•	•
trans-Nonachlor	•	•	•
DDTs			
o,p'-DDD	•	•	•
o,p'-DDE	•	•	•
o,p'-DDT	•	•	•
p,p'-DDD	•	•	•
p,p'-DDE	•	•	•
p,p'-DDT	•	•	•
HCHs			
alpha-HCH	•	•	•
beta-HCH	•	•	•
delta-HCH	•	•	•
gamma-HCH	•	•	•
Other			
Diazinon	•		
Mirex	•	•	•
Chlorpyrifos	•		

Table 1.1 (continued). Parameters analyzed.

G. PCBs and Related Compounds

	Water	Sediment	Tissue
Hexachlorobenzene	•	•	•
PCB 008	•	•	•
PCB 018	•	•	•
PCB 028	•	•	•
PCB 031	•	•	•
PCB 033	•	•	•
PCB 044	•	•	•
PCB 049	•	•	•
PCB 052	•	•	•
PCB 056	•	•	•
PCB 060	•	•	•
PCB 066	•	•	•
PCB 070	•	•	•
PCB 074	•	•	•
PCB 087	•	•	•
PCB 095	•	•	•
PCB 097	•	•	•
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PCB 138	•	•	•
PCB 141	•	•	•
PCB 149	•	•	•
PCB 151	•	•	•
PCB 153	•	•	•
PCB 156	•	•	•
PCB 158	•	•	•
PCB 170	•	•	•
PCB 174	•	•	•
PCB 177	•	•	•
PCB 180	•	•	•
PCB 183	•	•	•
PCB 187	•	•	•
PCB 194	•	•	•
PCB 195	•	•	•
PCB 201	•	•	•
PCB 203	•	•	•

Complete listings of all parameters measured in 1997 are included in Table 1.1. Methods of collection and analysis are detailed in *Appendix A*. RMP data included in this report can be obtained by contacting SFEI or by accessing SFEI's website at http://www.sfei.org.

Locations of the twenty-two RMP and two Southern Slough (C-3-0, C-1-3) sampling stations are shown on the inside of the front cover; Table 1.2 lists the station names, codes, locations, and sampling dates for all 1997 stations. Water, sediment, or bioaccumulation sampling sites with the same station name may have different station codes as they are situated at slightly different locations (latitude, longitude) due to practical considerations, such as sediment type or ability to deploy bivalves. For example, at the South Bay site, BA20 is the water station code, and BA21 is the sediment station code.

Sampling occurred during three periods in 1997: during the wet season (January–February), a period of declining Delta outflow (late April), and during the dry season (July–August). The rationale for taking seasonal "snapshots" is to relate contaminant data during hydrologically different periods of the year with higher-frequency measurements conducted by the U.S. Geological Survey, and to evaluate the influence of natural variability on the contaminant signal. As part of the RMP re-design, the use of more intensive data on tides, Delta outflow, salinity gradients, algal blooms, and other parameters will be evaluated in greater detail to minimize the natural noise around any signals of water quality improvement or degradation over time.

Not all parameters were measured at all RMP stations each sampling period. Sampling activities at each station are listed in Table 1.2. Water samples were collected at all stations during all three sampling periods; however, trace organic contaminants in water were only measured at eighteen RMP stations and at San Jose (C-3-0). Aquatic bioassays were conducted at eight RMP stations and at Sunnyvale and San Jose (C-1-3 and C-3-0) during the wet- and dry-season sampling periods.

Sediment sampling was conducted during the wet- and dry-season sampling periods only. Sediment samples were collected from all RMP stations, except the Golden Gate station (BC20, this site is very deep). Sediment toxicity was measured at fourteen RMP stations and at San Jose (C-3-0) during the wet- and dry-season sampling periods. Measurements of ammonia and sulfides in sediment were also conducted in 1997 to support interpretation of sediment toxicity data.

Bivalve trace metal bioaccumulation was measured at eleven RMP stations, bivalve trace organic bioaccumulation was measured at fourteen RMP stations, and bivalve survival and condition was measured at thirteen RMP stations during the wet- and dry-season sampling periods.

Water and sediment samples were collected from the *R/V David Johnston* chartered through the University of California, Santa Cruz. Each sampling cruise started with water sampling at all RMP stations. Sediment sampling was then conducted with a separate run through the Estuary. Each complete sampling run required three to five days. Bivalve monitoring consisted of three parts: deployment of transplants from reference sites, maintenance, and retrieval. Most of this work was conducted aboard the *R/V Questuary*, owned by San Francisco State University. The California Department of Water Resources provided back-up services for bivalve cruises.

Field sampling was coordinated by Applied Marine Sciences in Livermore, California. Principal Investigators who conducted various kinds of analyses are listed in Table 1.3. Individual staff members of RMP data generators are listed in the *Acknowledgements*.

References

Flegal, A.R., R.W. Risebrough, B. Anderson, J. Hunt, S. Anderson, J. Oliver, M. Stephenson, and R. Packard. 1994. San Francisco Estuary Pilot Regional Monitoring Program: Sediment Studies. San Francisco Bay Regional Water Quality Control Board, State Water Resources Control Board.

SFEI. 1995. 1994 Annual Report: San Francisco Estuary Regional Monitoring Program for Trace Substances. Prepared by the San Francisco Estuary Institute, Richmond, CA. 339p.

Table 1.2. Summary of RMP 1997 sampling stations and activities.

Station Name	Station Code	Type of Sample	Measurements Made	Dates Sampled			Latitude			Longitude		
							deg	min	sec	deg	min	sec
Coyote Creek	BA10	water	Q,M,O,T	1/23	4/18	7/30	37	28	20	122	3	80
	BA10	sediment	Q,M,O,T	2/5		8/14	37	28	20	122	3	80
	BA10	bioaccumulation	M,O,C	5/8		9/25	37	28	19	122	3	83
South Bay	BA20	water	Q,M,O	1/22	4/17	7/29	37	29	69	122	5	34
	BA21	sediment	Q,M,O,T	2/5		8/13	37	29	64	122	5	25
Dumbarton Bridge	BA30	water	Q,M,O	1/22	4/17	7/29	37	30	90	122	8	11
	BA30	sediment	Q,M,O,T	2/5		8/14	37	30	87	122	8	7
	BA30	bioaccumulation	M,O,C	5/8		9/25	37	30	80	122	8	8
Redwood Creek	BA40	water	Q,M,O,T	1/23	4/17	7/30	37	33	67	122	12	57
	BA40	bioaccumulation	M,O,C	5/8		9/25	37	32	82	122	11	70
	BA41	sediment	Q,M,O,T	2/5		8/13	37	33	67	122	12	62
San Bruno Shoal	BB15	water	Q,M,O	1/22	4/17	7/29	37	37	0	122	17	0
	BB15	sediment	Q,M,O,T	2/5		8/13	37	37	0	122	17	0
Oyster Point	BB30	water	Q,M,O	1/22	4/17	7/29	37	40	20	122	19	75
	BB30	sediment	Q,M,O	2/6		8/13	37	40	21	122	19	77
Alameda	BB70	water	Q,M,O	1/24	4/16	7/31	37	44	66	122	19	30
	BB70	sediment	Q,M,O,T	2/4		8/13	37	44	84	122	19	40
	BB71	bioaccumulation	M,O,C	5/8		9/25	37	41	73	122	20	38
Yerba Buena Island	BC10	water	Q,M,O	1/24	4/15	7/31	37	49	36	122	20	96
	BC10	bioaccumulation	M,O,C	5/8		9/25	37	49	12	122	20	81
	BC11	sediment	Q,M,O,T	2/4		8/12	37	49	44	122	20	93
Golden Gate	BC20 *	water	Q,M,O	1/25			37	51	81	122	32	20
		water	Q,M,O		4/16		37	51	81	122	32	20
		water	Q,M,O			8/1	37	51	81	122	32	20
Horseshoe Bay	BC21	sediment	Q,M,O,T	2/4		8/12	37	49	98	122	28	43
	BC21	bioaccumulation	M,O,C	5/10		9/26	37	49	87	122	28	65
Richardson Bay	BC30	water	Q,M	1/24	4/15	8/1	37	51	81	122	28	66
	BC32	sediment	Q,M,O	2/4		8/12	37	51	82	122	28	72
Point Isabel	BC41	water	Q,M	1/24	4/15	7/31	37	53	30	122	20	55
	BC41	sediment	Q,M,O	2/4		8/12	37	53	34	122	20	55
Red Rock	BC60	water	Q,M,O	1/24	4/15	7/31	37	55	0	122	26	0
	BC60	sediment	Q,M,O,T	2/4		8/12	37	55	0	122	25	97
	BC61	bioaccumulation	Q,M,O	5/9		9/26	37	55	70	122	28	13
Petaluma River	BD15	water	Q,M,O,T	1/28	4/22	8/5	38	6	66	122	29	0
	BD15	sediment	Q,M,O	2/1		8/9	38	6	66	122	29	0
	BD15	bioaccumulation	M,O,C	5/9		9/26	38	6	77	122	30	5
San Pablo Bay	BD20	water	Q,M,O	1/28	4/22	8/5	38	2	92	122	25	19
	BD20	bioaccumulation	M,O,C	5/9		9/26	38	2	72	122	25	71
	BD22	sediment	Q,M,O	2/1		8/9	38	2	86	122	25	24
Pinole Point	BD30	water	Q,M,O,T	1/28	4/22	8/5	38	1	48	122	21	65
	BD30	bioaccumulation	M,O,C	5/9		9/26	38	1	0	122	22	5
	BD31	sediment	Q,M,O	2/1		8/9	38	1	49	122	21	71
Davis Point	BD40	water	Q,M,O	1/28	4/22	8/5	38	3	12	122	16	62
	BD40	bioaccumulation	M,O	not deployed		9/24	38	3	26	122	15	63
	BD41	sediment	Q,M,O,T	2/1		8/9	38	3	11	122	16	65
Napa River	BD50	water	Q,M,O,T	1/29	4/23	8/6	38	5	79	122	15	2
	BD50	sediment	Q,M,O,T	2/1		8/9	38	5	79	122	15	61
	BD50	bioaccumulation	M,O,C	5/9		9/24	38	4	84	122	14	82
Pacheco Creek	BF10	water	Q,M	1/29	4/24	8/6	38	3	9	122	5	80
	BF10	sediment	Q,M,O	1/31		8/8	38	2	85	122	5	66
Grizzly Bay	BF20	water	Q,M,O,T	1/29	4/23	8/6	38	6	96	122	2	31
	BF20	bioaccumulation	M,O,C	5/10		9/24	38	6	49	122	3	37
	BF21	sediment	Q,M,O,T	1/31		8/8	38	6	97	122	2	35
Honker Bay	BF40	water	Q,M	1/29	4/23	8/6	38	4	0	121	56	0
	BF40	sediment	Q,M,O	1/31		8/8	38	4	0	121	55	0
Sacramento River	BG20	water	Q,M,O,T	1/30	4/24	8/7	38	3	56	121	48	59
	BG20	sediment	Q,M,O,T	1/31		8/8	38	3	36	121	48	63
	BG20	bioaccumulation	M,O,C	5/10		9/27	38	3	58	121	47	50
San Joaquin River	BG30	water	Q,M,O,T	1/30	4/24	8/7	38	1	40	121	48	45
	BG30	sediment	Q,M,O,T	1/31		8/8	38	1	36	121	48	44
	BG30	bioaccumulation	M,O,C	5/10		9/27	38	1	27	121	48	32
San Jose	C-3-0	water	Q,M,O,T	1/23	4/18	7/30	37	27	85	121	1	60
	C-3-0	sediment	Q,M,O,T	2/6		8/14	37	27	72	121	58	53
Sunnyvale	C-1-3	water	Q,M,T	1/23	4/18	7/30	37	26	8	122	0	64
	C-1-3	sediment	Q,M	2/6		8/14	37	26	13	122	0	67
Standish Dam†	BW10	water	Q,M,O	2/8	4/10	8/2	37	27	10	121	55	45
	BW10	sediment	Q,M,O	2/8		8/7	37	27	20	121	55	45
Guadalupe River†	BW15	water	Q,M,O	2/8	4/8	8/2	37	25	34	121	1	60
	BW15	sediment	Q,M,O	2/8		8/7	37	25	33	121	58	47

M = trace elements
O = trace prgamocs
* location dependent on salinity
T = toxicity (aquatic and/or sediment)
Q = water and/or sediment quality
C = bivalve condition index
† Estuary Interface Pilot Station

Table 1.3. 1997 RMP contractors and principal investigators.

Field Logistics	Dr. Bob Spies and Dr. Andrew Gunther Applied Marine Sciences, Livermore, CA
BADA Program Manager	Mr. David Tucker City of San Jose, Environmental Services Dept., CA
Trace Element Chemistry	Dr. Russ Flegal, UC Santa Cruz, CA Dr. Eric Prestbo, Brooks-Rand, Seattle, WA
Trace Organic Chemistry	Dr. Bob Risebrough, Bodega Bay Institute, CA Dr. José Sericano, Texas A&M University, TX Dr. Walter Jarman, UC Santa Cruz, CA
Sediment Trace Metals and Trace Organics	Mr. Bill Ellgas East Bay Municipal Utility District, Oakland, CA
Water Hardness	Ms. Lynda Taylor Union Sanitary District, Fremont, CA
Water Toxicity Testing	Dr. Scott Ogle Pacific Eco-Risk Laboratories, Martinez, CA
Sediment Toxicity Testing	Mr. John Hunt and Mr. Brian Anderson Marine Pollution Laboratory, Granite Canyon, CA
Bagged Bivalve Sampling	Mr. David Bell Applied Marine Sciences, Livermore, CA
Bivalve Trace Metals	Mr. Jim Salerno City and County of San Francisco, CA
Bivalve PAHs and PCBs	Mr. Bhupinder Dhaliwal Central Contra Costa Sanitary District, Martinez, CA
USGS Water Quality	Dr. James Cloern, USGS, Menlo Park, CA
USGS Sediment Transport	Dr. David Schoellhamer, USGS, Sacramento, CA
Pilot Study on Benthic Macrofauna	Dr. Bruce Thompson San Francisco Estuary Institute, Richmond, CA Ms. Heather Peterson Dept. of Water Resources, Sacramento, CA
Fish Contamination Pilot Study	Dr. Jay Davis San Francisco Estuary Institute, Richmond, CA Ms. Karen Taberski SF Bay Regional Water Quality Control Board, Oakland, CA Mr. Russ Fairey Moss Landing Marine Laboratory, Moss Landing, CA
Estuary Interface Pilot Study	Dr. Rainer Hoenicke San Francisco Estuary Institute, Richmond, CA Mr. Dane Hardin Applied Marine Sciences, Livermore, CA

CHAPTER 2

1997 Review Implementation

Five-Year Program Review Summary

In early 1997, seven independent scientists and specialists skilled in matters pertaining to monitoring design, data analysis, quality assurance, and science administration and management evaluated the Regional Monitoring Program (RMP). This external program review was part of the initial program design. The purpose of the review was to examine the technical underpinnings, structure, function, and performance of the RMP and its staff, contractors, and administrative structure. The following is the Executive Summary and the Conclusions and Recommendations for Implementation from the panel's Final Report[1].

The Regional Monitoring Program for Trace Substances (RMP) in the San Francisco Estuary has successfully produced high-quality data on chemical contaminants and their toxicity throughout San Francisco Bay. Since its inception in 1993, it has combined shared support, direction, and participation by regulatory agencies and regulated organizations/industries in a model of collective responsibility. As a result, it is developing an expanding database of information that has helped to address important decision-making needs of regulatory agencies and other Program Participants.

This report presents the findings and recommendations of an in-depth review of the RMP carried out during its fifth year of operation. This review was an integral part of the Program's initial five-year plan and was carried out by a panel of nationally recognized experts in a range of fields. Its objectives were to:

- determine the successes and shortcomings of the RMP,
- identify parts of the Program that should be retained or amplified to maintain performance at a high level, and
- suggest changes or additions to meet present and future needs.

The RMP has faithfully addressed its guiding objectives and has achieved notable successes during its first five years of operation. These include:

- Establishing and carrying out a large, complex technical program with few, if any, problems.
- Gathering extremely high-quality data that describe the present state of the Bay.
- Producing data that have been used in a variety of environmental management decisions by regulatory agencies, dischargers, and industry.
- Establishing a climate of cooperation and a commitment to participation among an extremely wide range of regulators, dischargers, industry representatives, and scientists.
- Fostering the involvement of other government and academic scientists with valuable knowledge and expertise.
- Preparing and widely disseminating thorough and accurate yearly reports on the Program's data and accomplishments.
- Implementing a thorough quality control system for laboratory analysis and data management.
- Setting up a World-Wide-Web site to make the Program's data more widely available to potential users.

As a result of these successes, the Review Panel found widespread support for the RMP, many instances of its usefulness, and a firm commitment that it should be continued for at least another five years.

The Review Panel also found, however, that these very successes, along with five years' experience and the benefit of hindsight, have raised serious issues that must be addressed if the RMP is to fulfill its potential. The Review Panel believes

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[1] The full final report is available through SFEI.

that complex programs, such as the RMP, must continue to evolve in response to their users' needs if they are to avoid the "monitoring trap" of simply collecting data for its own sake. In the RMP's case, two core themes consistently arose in the evaluations the Review Panel carried out from a variety of perspectives (basic objectives, study design, data analysis, information management, organizational dynamics, and management).

The first theme is the need for more detailed definitions of all aspects of the RMP, in particular

- core program objectives,
- specific management and scientific questions needed to focus study design and data analysis,
- the roles, responsibilities, and authorities of all parties to the RMP,
- decision-making processes, and
- methods of identifying and resolving healthy conflict.

The RMP's original objectives provided effective guidance during the Program's early years. However, at present they are not sufficiently detailed or specific enough to effectively focus the Program's efforts on management's key information needs. As a result, much of the current data analysis, interpretation, and reporting is diffuse and not particularly relevant. Similarly, the Program's commitment to consensus-based management has helped build an important degree of involvement and commitment on the part of all parties to the RMP. On the other hand, it has also resulted in an inability to directly address important issues, such as developing more detailed objectives, where there is disagreement among some of the parties. The Panel recommended that the RMP make it a high priority to address the issues listed above as part of developing a new five-year plan.

The second theme is the need for the RMP to broaden its scientific horizons in order to increase the usefulness of its results in decision-making. The Panel strongly recommended that the RMP undertake modeling and analysis to place the RMP data in the context of other data from San Francisco Bay. In particular, historical data can provide a larger perspective within which to interpret the relatively short time series of data developed to date by the RMP. These other datasets represent a valuable resource that is currently being under-utilized.

In addition, the Panel recommended that the RMP address a wider range of fundamental scientific issues that are key to any attempts to interpret the implications of the RMP's monitoring data. These issues include such questions as the annual input of key pollutants to the Bay, the response of the Bay system to past reductions in pollutant input, and the relationship between observed patterns and trends of key pollutants and various kinds of sources, both human and natural.

The Review Panel believes that such issues are not unique to the RMP, but are challenges that typically face complex environmental monitoring and management programs. The Review Panel further believes that the parties to the RMP have the commitment, understanding, and ability to successfully meet these challenges and to continue to make the RMP a model of cooperative environmental problem solving.

The Review Panel outlined a large number of recommendations to improve both the short- and long-term performance of the RMP. Some of these recommendations require little, if any, additional funding and can be implemented relatively quickly. Others are larger in scope or more fundamental in nature and require more time and effort to implement. These include, for example, special studies to integrate data from other studies into the RMP and to begin developing mass-balance models to provide a context for interpreting RMP results. They also include efforts to clarify the roles and responsibilities of the parties to the RMP and to develop a revised set of program objectives. The Review Panel believes that this last set of recommendations is of the utmost importance and should be given the highest priority.

One of the RMP's major strengths is that the technical and administrative personnel involved in the project believe very strongly in it. For example, SFEI has already begun to implement many of the more straightforward recommendations in the draft report of this review issued on 20 May 1997. Other recommendations, however, are more difficult to implement. They may address more fundamental and potentially contentious issues (e.g., the development of new study objectives) or ones that require the full involvement of all parties to the RMP (e.g., clearer definition of roles, responsibilities, and authorities). In the final analysis, each recommendation will be evaluated and considered for its overall value to the Program and only those considered necessary to the Program will be implemented as interest, time, and money allow.

This chapter provides some guidance for this evaluation and for planning the implementation of high-priority recommendations. It documents the overall conclusions the Review Panel derived from interviews, analysis, and discussions with technical and administrative personnel associated with the RMP. These in turn led to a preliminary prioritization of the recommendations made in the body of the report and a suggested plan for implementing the most critical ones. The Review Panel understands, nevertheless, that it is the responsibility of the Regional Board, the Steering Committee, and SFEI to evaluate each recommendation and determine whether or not it should or can be implemented.

Overall Conclusions of the Review

- The Regional Monitoring Program for Trace Substances in the San Francisco Estuary is a valuable environmental monitoring program based on a unique partnership between regulatory agencies and dischargers that can serve as a model for others.
- The data from the RMP are of very high-quality and reflect, in many cases, state-of-the-art analysis for environmental parameters that is unequaled in a monitoring program of this size.
- Participants in the RMP believe that the Program is important and valuable to them and will, in the long run, be of benefit to regulators, dischargers, and the population of the Bay Area.
- The RMP has operated on a consensus management model to date. The quality of the program can best be preserved in the future by a more specific description of the roles, responsibilities, and authorities of the parties involved, as well, as of key decision-making processes.
- Participants in the RMP agree that the Program should be continued for at least another five years; a strategic plan is needed to guide the development of the Program through those years.
- The original objectives of the RMP served it well during its early years; however, they are diffuse and non-specific. Study design, field execution, data analysis, and reporting would benefit from development of more specific objectives based upon the needs of the Regional Board and the Participants.
- The overall value of the RMP can be improved by applying a greater degree of interpretation to the data being collected, as well as, a more thorough integration into the RMP of the results from other monitoring and research programs in the Bay Area, both past and present.

Prioritizing Recommendations

The Five-Year Review compiled many recommendations to be considered for implementation. Whereas some of these can be implemented immediately and with little effort, many that focus on the objectives and design of the Program are closely interrelated and should be implemented only following a careful consideration of their relationships.

Recommendations for Immediate Implementation

Table 2.1 summarizes those recommendations that the Review Panel believes can be incorporated rather easily into the RMP's operations.

With two exceptions (recommendations 5a and 5b), implementation for all the recommendations in Table 2.1 fall to SFEI. Recommendation 5a calls for the Regional Board to clarify and define precisely what their responsibilities are in the RMP.

Table 2.1. Recommendations in the Five-Year Review report that can be implemented simply and directly. The recommendations are numbered according to their appearance in each chapter of the report, i.e., number 2e corresponds to recommendation "e" at the end of Chapter 2 of the Final Report. "Responsible Party" is the organization the Review Panel saw as having the best opportunity to implement the recommendation. "Implementation Approach" indicates the steps the Review Panel believes are needed to implement the recommendation. Evaluations of "Financial Impact" are subjective estimates by the Review Panel.

Recommendation	Responsible Party	Implementation Approach	Financial Impact
2e Make RMP information more widely available	SFEI	WWW; publications; presentations	slight
3f Use more sophisticated data presentation	SFEI; Chapter authors	Evaluate presentation methods	slight
4b Document fully the data management system	SFEI; Subs	Descriptive writing	slight
4d Develop computer-assisted quality checks	SFEI	Software development	moderate
4e Conduct recommended lab intercomparisons	SFEI; Subs	Expand intercomparison program	moderate
4g Store data back-ups off site weekly	SFEI	Procure storage site	slight
4h Provide for development of data management staff	SFEI	Courses; workshops	moderate
4j Increase citation of contributions	SFEI	Descriptive writing	slight
4k Analyze citations of RMP data	SFEI	Accounting	slight
4l Analyze WWW site usage statistics	SFEI	Add software to WWW site	slight
4m Develop specific list of PCB congeners	SFEI	Evaluate data	slight
4n Describe laboratory analysis methods in more detail	SFEI; Subs	Descriptive writing	slight
4o Describe accuracy measurements in more detail	SFEI; Subs	Descriptive writing	slight
4p Automatically calculate derived values	SFEI	Software development	slight
4q Add citation information to RMP Annual Report	SFEI	None	slight
4r Word newsletter titles more judiciously	SFEI	None	none
5a Clarify Regional Board responsibilities	Regional Board	Policy statement	none
5b Request from Executive Officer for 5-year plan	Regional Board	Official letter	none
6a Review direct charges internal to SFEI	SFEI	Accounting	slight
6b Define in-kind contributions from staff and contractors	SFEI	Evaluations; interviews; accounting	slight
6c Create technical/logistics manager	SFEI	Talent search	substantial
6d Schedule changes in contractors when possible	SFEI	Planning	slight
6e Implement competitive bidding where possible	SFEI	Planning	slight
6g Prepare Steering Committee agendas early	SFEI	Done	none
7a Accept Five-Year Review report and recommendations	Regional Board; S.C.	Done	none

This item should receive high priority within the Regional Board, since a definition of the Regional Board's responsibilities affects the implementation of other recommendations that directly address the design and execution of the Program.

Recommendation 5b calls for the Executive Officer of the Regional Board to request that parties to the RMP devise a new five-year plan for the Program. This five-year plan would cover the years 1998 through 2002, and would be the primary vehicle for implementing the major recommendations made by the Review Panel (see below).

Most of the recommendations for immediate implementation would have a minor financial impact on the RMP budget. By and large, they represent slight to moderate increases in labor at the technical level. The Review Panel believes that a different division of labor within SFEI would aid implementation and keep financial impact to a minimum. The Review Panel suggests that SFEI emphasize greater use of less highly trained personnel in the more routine data processing, analysis, and report-writing functions, leaving staff at the higher levels to concentrate on more conceptual evaluations.

Perhaps the most expensive of the recommendations in Table 2.1 is the expansion of the laboratory intercomparison program. This would require that SFEI contract with additional laboratories for chemical analysis of split samples taken from the routine sample stream. While additional QA/QC would not necessarily improve the overall quality of RMP data, it would improve its credibility. The relative value of this recommendation should be weighed against other claims on budget resources.

Recommendations for Gradual Implementation

The remaining recommendations fall into two main categories. The first includes specific studies the Review Panel believes are needed to address important scientific and technical issues. These are summarized in Table 2.2 in a sequence that reflects the Review Panel's judgment of their relative importance. It is most essential to integrate data from both current and historical studies into the RMP. This will provide the context needed to assess sources, define impacts, and evaluate design issues, such as the potential value of using TSS to define exceedances[2], defining the seasonality of the data, and estimating the rates of burial of contaminant-laden particles in the Bay ecosystem.

The other category consists of recommendations that go to the very heart of the Program: the design of the sampling, analysis, and interpretive components of the RMP, and the formulation of new objectives for the RMP. *The Review Panel considers these "developmental" activities the most important part of the Five-Year Review report. Failure to address and reach some reasonable resolution about these issues would likely lead the RMP into the "monitoring trap" (Chapter 2, Chapter 3 of the Final Report) of collecting data for the sole purpose of collecting data. To avoid the regression of the RMP, therefore, the Review Panel believes that all parties should give the highest priority to implementing the following recommendations (see also Table 2.3):*

- To undertake to define carefully the roles of the parties;
- To define the real data needs and the uses to which the RMP data will be put;
- To expand the program objectives in detail (the form of the questions asked) and scope (the conditions evaluated by the RMP and its geographic scope); and
- To evaluate the design of the RMP so that it provides the data needed to answer the questions stated in the revised objective statement.

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[2] The RMP has begun to develop regressions between total aqueous concentrations of many trace contaminants and total suspended solids (TSS). This should be expanded to test the validity of using only TSS measurements to monitor exceedances of water quality criteria. It seems that this should be possible because invariably those exceedances are due to high concentrations of particle-bound copper, mercury, nickel, or PCB. These data strongly suggest that present exceedances are due in large part to the historical pool of contaminants in Bay sediments. The Review Panel suggests that this implication be considered in any attempt by the RMP to link water quality patterns to current sources of contamination.

Table 2.2. Recommendations in the Five-Year Review report that suggest specific studies or activities to be undertaken by the RMP. Recommendations that overlap with those in other chapters are cross-referenced.

Recommendation	Cross-Listing	Responsible Parties	Implementation Approach	Financial Impact
2a Integrate other data for holistic appraisal	2b, 3d, 4c, 7b, 7c	SFEI; RB; RMP Subs	Develop study plan/work plan by RMP workgroup; new subcontract or increased effort by SFEI.	substantial
2b Assess sources; develop mass-balance inventory	2a, 3c	SFEI; RB	Develop work plan by RMP workgroup; subcontract or increased effort by SFEI.	substantial
2c Define impacts on resources and beneficial uses		SFEI; Steering Committee; RB	Develop work plan by RMP workgroup; increased effort by SFEI, RB, and SC.	substantial
3g Use TSS measurements to define exceedances		SFEI; Subs	Develop study plan/work plan by RMP workgroup; new subcontract or increased effort by SFEI.	substantial
3i Test seasonality of RMP data		SFEI; Subs	Develop study plan/work plan by RMP workgroup; increased effort by SFEI and subcontractors.	substantial
3j Determine rates of particle burial	2b	SFEI; Subs	Develop work plan by RMP workgroup; subcontract or increased effort by SFEI.	substantial

Implementing the recommendations summarized in Tables 2.2 and 2.3 will require considerable effort from all parties to the RMP. They will involve additional committee and workgroup meetings for planning, discussion, and negotiation. Just as important, the studies listed in Table 2.2 will demand additional financial resources to support new subcontracts, or to enable SFEI to hire additional personnel to maintain their day-to-day scientific, administrative, and management activities, as these additional studies are performed by the senior scientific staff. *The Review Panel believes that such additional funding should be made available to initiate implementation of these suggested studies in order of their prioritization (Table 2.2).*

The Review Panel also perceives different parties to the RMP as having primary responsibility for implementation of these recommendations. However, each will require collaboration among and between the Regional Board, the Steering Committee, and SFEI. Most will require that work plans be formulated, and that workgroups with representatives of the Technical Review Committee be convened to evaluate the topic and recommend actions to the Steering Committee.

Finally, it is important to note that the full suite of recommendations for gradual implementation (Tables 2.2 and 2.3) are interrelated. The Review Panel suggests that the first step in implementing these recommendations should be a critical path analysis that shows which actions must necessarily precede others. This will assist the parties to the RMP in analyzing the overall implications of each recommendation and in placing them in a logical sequence for implementation and for development of the new five-year plan.

Table 2.3. Recommendations in the Five-Year Review report that suggest more fundamental activities to be undertaken by the RMP. Recommendations that overlap with those in other chapters are cross-referenced.

Recommendation	Cross-Listing	Responsible Parties	Implementation Approach	Financial Impact
3b Document aims of RMP	2c, 3a, 4a, 5c	All	Agreement on roles and responsibilities of parties; definition of data needs/usage by parties.	?
3c Expand core objectives/questions	2b, 2c	All	Agreement on scope and direction of RMP; develop five-year plan.	?
3a Evaluate design issues	3g, 3h, 3i, 3j, 3k, 3l	All	Definition of data needs/usage by parties; integration with other studies; statistical analyses.	?

Review Panel

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Review Coordinators

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Review Implementation: Progress and Future Steps

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The Five-Year Review of the RMP generated a lengthy list of recommendations for improvement. Many of these recommendations were technical in nature and are being readily implemented by SFEI staff. Two in particular, however, required more direct and sustained involvement from the Steering and Technical Review committees. The Review Panel recommended that the RMP reconsider its objectives and focus its efforts more carefully on management needs. It suggested that the RMP could accomplish this more effectively if it improved its decision-making processes and clarified the roles, authorities, and responsibilities of the various parties. Beginning in the fall of 1997, the main parties involved in the RMP (Regional Board staff, Program Participants on the Steering Committee, Technical Review Committee, and SFEI staff) participated in a number of facilitated meetings to respond to these two recommendations.

The group found that they shared most of the goals articulated by each of the parties involved in the RMP and clarified each party's role in guiding the direction of the Program. This recognition increased the confidence that the group could resolve any disagreements without risking working relationships and/or the operation of the RMP itself.

As the next step, the parties to the RMP jointly developed more formal procedures for identifying and evaluating new study ideas against environmental management needs, technical criteria, and fiscal implications; designing a long-term planning template; and clarifying data interpretation and synthesis approaches. The Regional Board stressed their desire throughout this and later discussions for the RMP to put greater emphasis on interpretation and synthesis and challenged SFEI to make it happen. Discussion of how to best prioritize and select special and pilot studies resulted in a more informed realization of the complexity of the RMP's planning process and the need for a more tangible structure. The resulting *Pilot and Special Study Selection Policy* describes in some detail how the efforts of all the parties to the RMP should be coordinated throughout the lengthy study selection and approval process. The documents describing the pilot and special study selection procedure and the *Data Interpretation Policy* are available at SFEI's website at http://www.sfei.org.

RMP Objectives

The RMP's overall goal is to provide data and interpretation that helps to address certain information needs of the Regional Board. In general, these efforts fall under five major objectives which provide a framework for efforts to respond to more specific management questions.

1. Describe patterns and trends in contaminant concentration and distribution.
2. Describe general sources and loading of contamination to the Estuary.
3. Measure contaminant effect on selected parts of the Estuary ecosystem.
4. Compare monitoring information to relevant water quality objectives and other guidelines.
5. Synthesize and distribute information from a range of sources to present a more complete picture of the sources, distribution, fates, and effects of contaminants in the Estuary ecosystem.

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[4] Brock Bernstein is no longer with EcoAnalysis.

To help guide discussions about what should be monitored and where, and what kinds of questions might be addressed by special studies, the Regional Board prepared a written statement with focusing questions (see boxes). It is important to note that these questions need to be asked within the context of the current knowledge upon which the RMP needs to build to refine answers and to increase the confidence in management actions. As a result, the technical and scientific questions that motivate the RMP now focus directly on providing information needed to address specific issues named by the primary information user (the Regional Board). This also gives Program Participants some reassurance that RMP data can now be transformed into information that will have relevance and purpose, and that the data will be used to continually adjust management priorities at the Regional Board.

The resulting document, and the understanding among the parties it reflects, fulfill the charge from the Review Panel to focus more carefully on management needs. It was achieved only because of the parties' good-faith efforts to improve their communication, clarify their roles, and respect their differences.

Regional Board's Information Needs

This is the set of questions that are asked on a continuing basis at the Regional Board. As a representation of the Regional Board's information needs and its overall perspective, it does include items that are not the purview of the RMP (e.g., to determine pollutants of concern or define what is and is not controllable). RMP activities should be designed to fulfill one or more of these information needs.

Focusing Questions

1. What are the pollutants and pollutant groups of concern?
    - 1a. of the national priority pollutants, which ones are found in the Estuary system and of those, which ones are at levels that may be causing effects?
    - 1b. of pollutants identified through local (as opposed to national) monitoring, which ones have been identified through TIE analyses or are found at levels above those known to cause effects in estuarine ecosystems?
2. What are the overall loadings and mass-balance budgets for pollutants of concern?
    - 2a. what is the implication of historic discharges for mass budgets and fluxes?
    - 2b. what is the relative contribution of point source outfalls, storm drains, large and small tributaries, harbor activities (including dredging), atmospheric deposition, historic deposits, and natural sources?
3. Of the pollutants of concern with ongoing inputs,
    - 3a. what are the sources to the point of discharge?
    - 3b. are these sources controllable? and if so, under what existing regulatory framework and at what level of government?
4. What is the general pattern of levels, fate, and transport of pollutants of concern within embayments?
    - 4a. do the general patterns suggest different levels of risk/concern within embayments (i.e., are mid-Estuary conditions generally good but shallow areas closer to shore more problematic?)
    - 4b. how are these patterns changing in response to natural processes and progressive management actions?
5. Of the pollutants of concern for which ongoing, controllable inputs still exist, which of the controllable source reductions provide the greatest benefit in terms of preventing further degradation and restoring ecosystem function and human health?
6. How effective are management actions?
    - 6a. how have past management actions affected the overall patterns of levels, fate, and transport of pollutants of concern?
    - 6b. are current management actions achieving effective control of ongoing, controllable sources?

Specific Management Questions

Current issues of concern for the RMP are grouped below in relation to each proposed RMP objective.

1. Compare monitoring data
    - 1a. Which contaminants should be monitored?
    - 1b. How do RMP data compare with relevant water, sediment, and tissue quality guidelines?
    - 1c. How do the various Estuary reaches compare to each other, in time and space, relative to water, sediment and tissue guidelines?
2. Describe patterns and trends
    - 2a. How do contaminant levels change over the long-term?
    - 2b. Can those changes be linked to changes in inputs to the Estuary?
    - 2c. What is the relationship between pollutant trends and patterns seen in the "spine" of the Estuary and those in the shallower margins?
    - 2d. How are spatial patterns and long-term trends in contaminants affected by estuarine processes?
3. Describe general sources and loadings
    - 3a. What proportion of the contaminants in each Estuary reach are contributed by point source outfalls, storm drains, large and small tributaries, harbor activities including dredging, atmospheric deposition, and historic deposits?
    - 3b. How do contaminants move and transform after they enter the Estuary?
    - 3c. At what spatial and temporal resolution should loadings to the Estuary and changes in upstream contaminant inputs due to pollution prevention efforts be monitored?
    - 3d. What are the background concentrations of contaminants in the Estuary from natural sources?
4. Measure contaminant effects
    - 4a. Which contaminants bioaccumulate in estuarine organisms to levels of concern?
    - 4b. What is the spatial and temporal extent of toxicity in the Estuary?
    - 4c. Which contaminants cause effects in the Estuary?
5. Synthesize information
    - 5a. Provide periodic interpretation and synthesis on selected contaminant-related topics.
    - 5b. Describe and distribute key RMP findings to a variety of audiences.
    - 5c. Assess the use of RMP data and information in decision-making.

These facilitated sessions represented the important first steps of the complex task of re-designing the RMP to meet the revised objectives and the first "edition" of management questions. The involved parties recognized that the objectives and management questions will have to be adjusted periodically as the information base grows.

Beginning in spring of 1998, SFEI initiated a detailed assessment of how the RMP's design should and could be modified to better address the management questions. Workgroups including experts from outside the region have been assisting the parties involved in the RMP to summarize the current understanding about chlorinated hydrocarbons, metals, pesticides, sediment as a pollutant reservoir, and characterization of sources and loadings to the Estuary. These deliberations will result in recommendations for collecting needed information and revising the RMP Base Program. The workgroup addressing chlorinated hydrocarbons completed their deliberations in late 1998, while the other workgroups will submit their recommendations in early 1999. These individual recommendations will then be integrated, evaluated from a statistical design perspective, incorporated into the Five-Year Plan, and phased in as financial resources allow. While the re-design is proceeding, the RMP is not remaining entirely static.

CHAPTER 3

Water Monitoring

Water Monitoring

Background

This chapter presents a graphical and narrative summary of the Regional Monitoring Program (RMP) water monitoring results for 1997. This chapter also includes articles contributed by RMP investigators that provide interpretive summaries of specific water monitoring activities.

Water quality was monitored at twenty-two RMP Base Program stations. Parameters measured included conventional water quality parameters (salinity, temperature, total suspended solids, and others; Figures 3.1–3.3), trace elements, trace organic contaminants, and toxicity. Water was also sampled at two stations in the southern end of the Estuary in cooperation with the cities of San Jose (station C-3-0) and Sunnyvale (station C-1-3). In addition, the U.S. Geological Survey monitored water quality at shorter time scales to complement RMP monitoring activities.

Station locations are shown on the inside of the front cover. Water samples were collected in January, April, and August. Sampling dates and parameters measured at each station are shown in Table 1.2 in *Chapter One: Introduction*. For trace elements, dissolved (0.45 µm filtered) and total (arsenic, chromium, mercury, and selenium) or near-total (cadmium, copper, lead, nickel, silver, and zinc) concentrations are presented in Figures 3.4–3.23. Dissolved (1 µm filtered) and total concentrations of trace organic contaminants are also presented in Figures 3.24–3.39. In addition, long-term trends in trace element and trace organics for each Estuary reach are provided in Figures 3.41 and 3.42. Data for silver were not available. Detailed methods of collection and analysis are included in *Appendix A*.

In order to compare water monitoring results among the major reaches of the Estuary, the RMP stations are separated into five groups based on

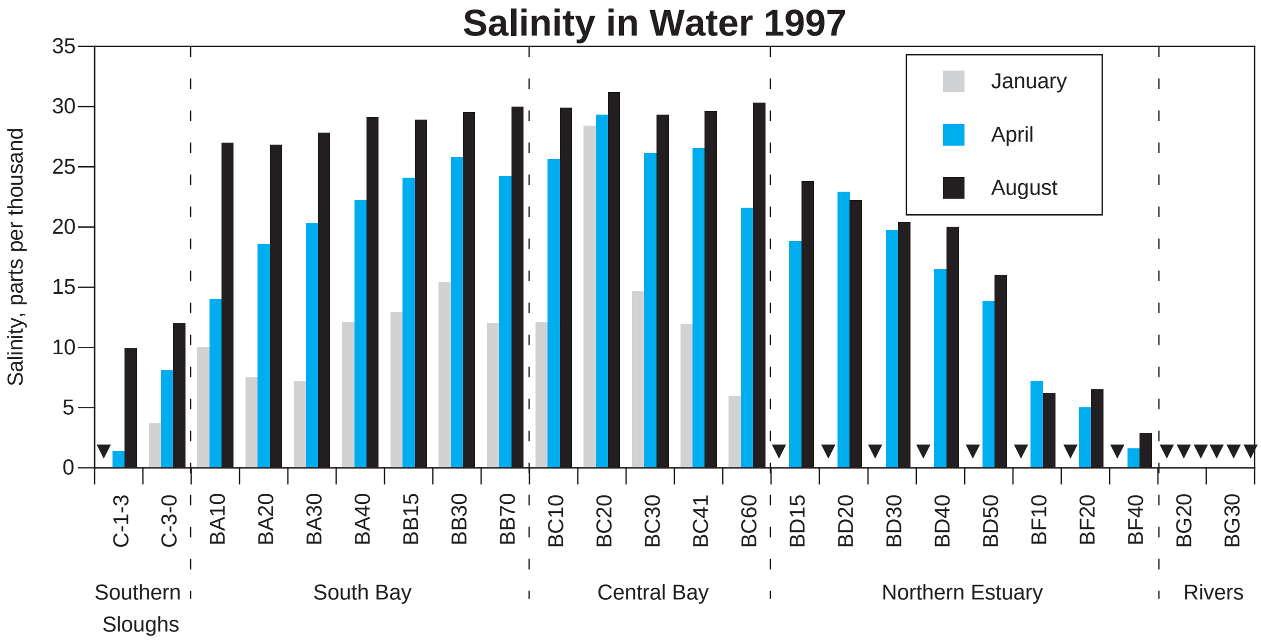


Figure 3.1. Salinity in parts per thousand (‰) at each RMP water station in January, April, and August 1997. ▼ indicates salinity was < 1 ‰. Salinities ranged from below detection (1 ‰) to 31 ‰. The highest salinity was detected at Golden Gate (BC20) in August. Salinities were lowest in January. Salinities below 5 ‰ are considered freshwater for application of water quality standards.

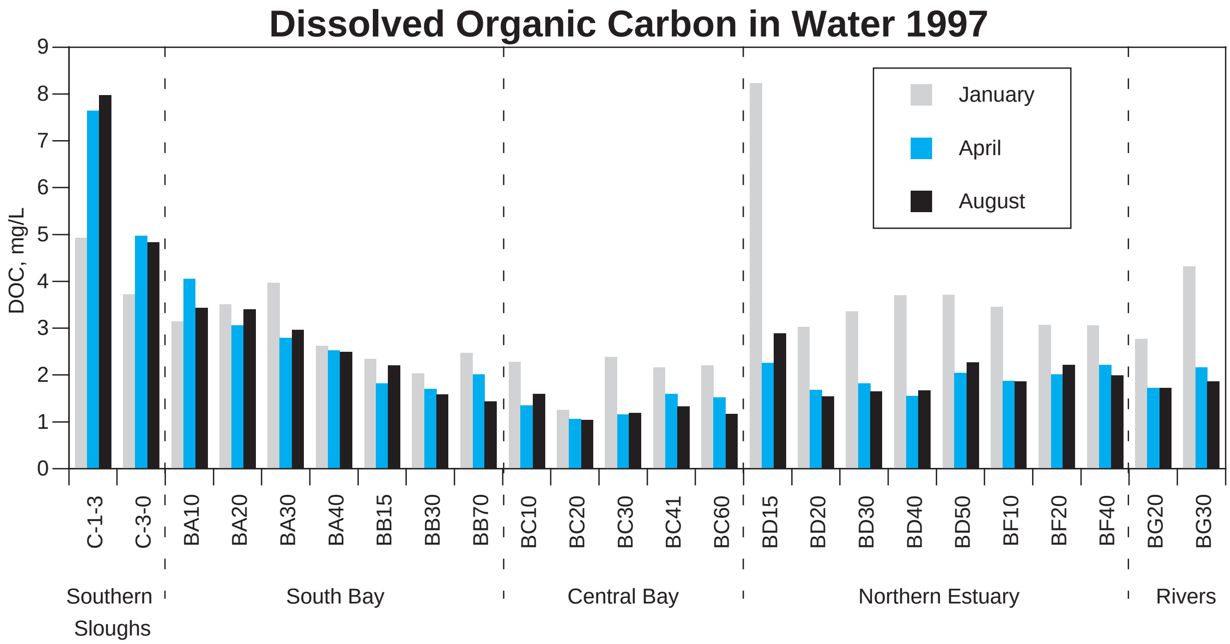


Figure 3.2. Dissolved organic carbon (DOC) in milligrams per liter (mg/L) at each RMP water station in January, April, and August of 1997. DOC ranged from 1.05 mg/L to 8.2 mg/L. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest concentration was sampled at Golden Gate (BC20) in August.

similarities in geography, water chemistry, and hydrodynamics: the Southern Sloughs (C-1-3 and C-3-0), South Bay (seven stations, BA10 through BB70), Central Bay (five stations, BC10 through BC60), Northern Estuary (eight stations, BD15 through BF40), and the Rivers (BG20 and BG30).

Water Quality Objectives and Criteria

In this report, comparisons to water quality objectives and criteria are made to provide a context for evaluating the condition of the Estuary in terms of contamination, and not for any regulatory purpose. Water quality objectives and criteria used for these comparisons (Tables 3.7) were selected based on guidance from the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Kim Taylor, personal communication). Most of the criteria used were taken from the U.S. Environmental Protection Agency's proposed California Toxics Rule (U.S. EPA, 1997; CTR). U.S. EPA is scheduled to issue a final rule formalizing these California Toxics Rule criteria in the near future. Objectives for total (dissolved + particulate) trace elements were obtained from the San Francisco Bay Basin Plan (SFBRWQCB, 1995). Selenium criteria are region-specific criteria for total recoverable selenium that apply to the entire Estuary (National Toxics Rule, U.S. EPA, 1995). A criterion for diazinon was not included in the proposed CTR, but a guideline developed by the California Department of Fish and Game (Menconi and Cox, 1994) is used in this report to evaluate the degree of contamination in the Estuary.

Different objectives and criteria apply to saltwater, estuarine, and freshwater portions of the Estuary. As defined by the Basin Plan (SFBRWQCB, 1995), estuary locations are
1) freshwater when their salinity is below 5 parts per thousand (ppt) more than 75% of the time;
2) saltwater when their salinity is greater than 5 ppt more than 75% of the time; and 3) estuarine if salinity is intermediate, if estuarine organisms are present for significant periods, or based on an evaluation by the SFBRWQCB (1995).

For estuarine locations, the Basin Plan specifies that the lower of the freshwater and saltwater objectives apply. For this report, RMP stations were classified as freshwater, estuarine, or saltwater based on an evaluation by the SFBRWQCB (Kim Taylor, personal communication) of long-term data at RMP stations, and the characteristic benthic assemblages observed in the RMP Benthic Pilot Study (Lowe and Thompson, in *Chapter 4* of this report). The following stations are classified as estuarine in this report: Sunnyvale (C-1-3), San Jose (C-3-0), South Bay (BA20), Petaluma River (BD15), San Pablo Bay (BD20), Pinole Point (BD30), Davis Point (BD40), Napa River (BD50), Pacheco Creek (BF10), Grizzly Bay (BF20), Honker Bay (BF40), Sacramento River (BG20), and San Joaquin River (BG30).

For some contaminants multiple criteria exist that apply to different target organisms (aquatic life or humans) or different lengths or routes of exposure (e.g., 1 hour or 4 days). For this report, RMP contaminant data are compared to the lowest criterion for each contaminant. In general, trace element concentrations were compared to 4-day average criteria for aquatic life, which are lower than the 1-hour average criteria. This is considered appropriate by the SFBRWQCB (Kim Taylor, personal communication) since RMP data are probably indicative of conditions that persist longer than one day. Trace organic contaminant concentrations were compared to human health criteria based on consumption of organisms only, since RMP stations are all seaward of drinking water intakes in the Delta.

Water quality guidelines for six trace elements measured at freshwater stations are related to water hardness. In the RMP, hardness data are only collected at stations where the salinity is less than 5‰. For these trace elements, freshwater guidelines at estuarine stations where hardness data were not collected were calculated assuming a hardness of 100 mg/L.

Aquatic Bioassays

Laboratory bioassays using Estuary water were conducted at ten RMP stations (Figure 3.40) during the wet-season sampling (January–February) and again in the dry-season sampling (July–August). Two laboratory bioassays were conducted.

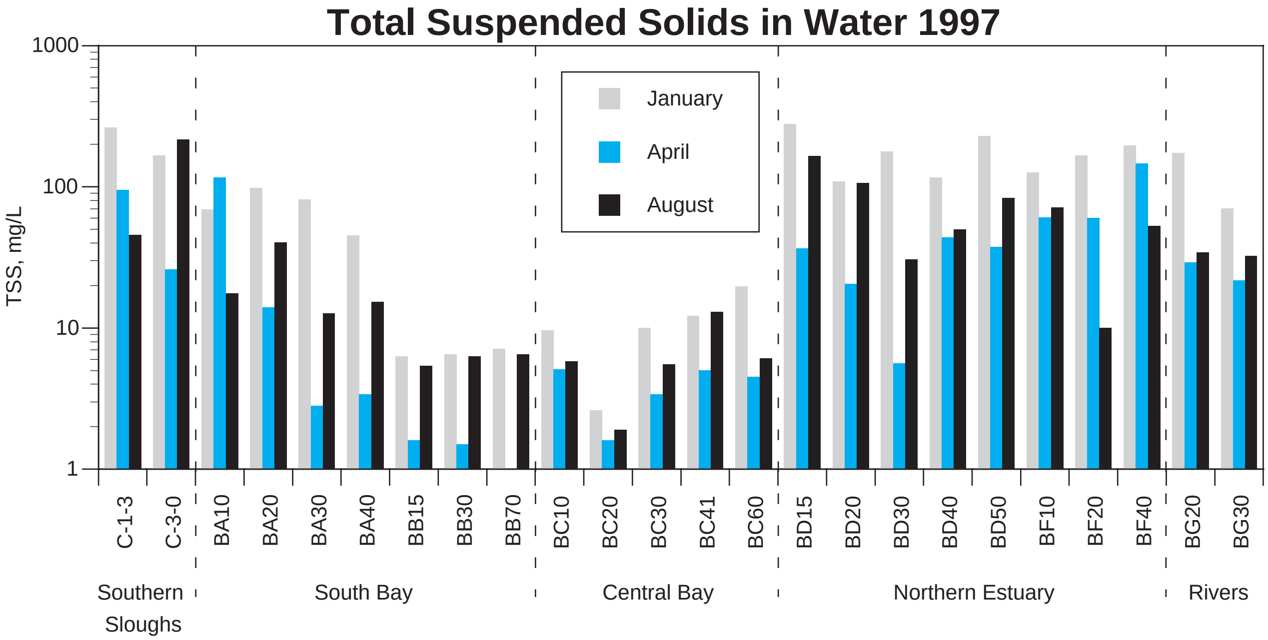


Figure 3.3. Total suspended solids (TSS) in milligrams per liter (mg/L) at each RMP water station in January, April, and August of 1997. Note logarithmic scale. TSS concentrations ranged from 1.0 mg/L to 279 mg/L. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Alameda (BB70) in April. Average TSS concentrations were higher in the Northern Estuary stations than other Estuary reaches.

Mysids (*Mysidopsis bahia*) were exposed to Estuary water for seven days where percent survival was the endpoint. Larval mussels (*Mytilus* sp.) were exposed to Estuary water for 48 hours where percent normal development was the endpoint. Detailed methods are included in *Appendix A*. Significant toxicity was determined by statistical comparison (t-tests) of field samples with controls.

References

Menconi, M. and C. Cox. 1994. Hazard assessment of the insecticide diazinon to aquatic organisms in the Sacramento-San Joaquin river system. Administrative Report 94-2, California Department of Fish and Game, Rancho Cordova, CA.

SFBRWQCB. 1995. 1995 Basin Plan. San Francisco Bay Regional Water Quality Control Board. Oakland, CA.

U.S. EPA. 1995. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance Final Rule. Federal Register Vol. 62, No. 150, Dec. 22, 1992.

U.S. EPA. 1997. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Proposed Rule. Federal Register Vol. 62, No. 150, August 5, 1997.

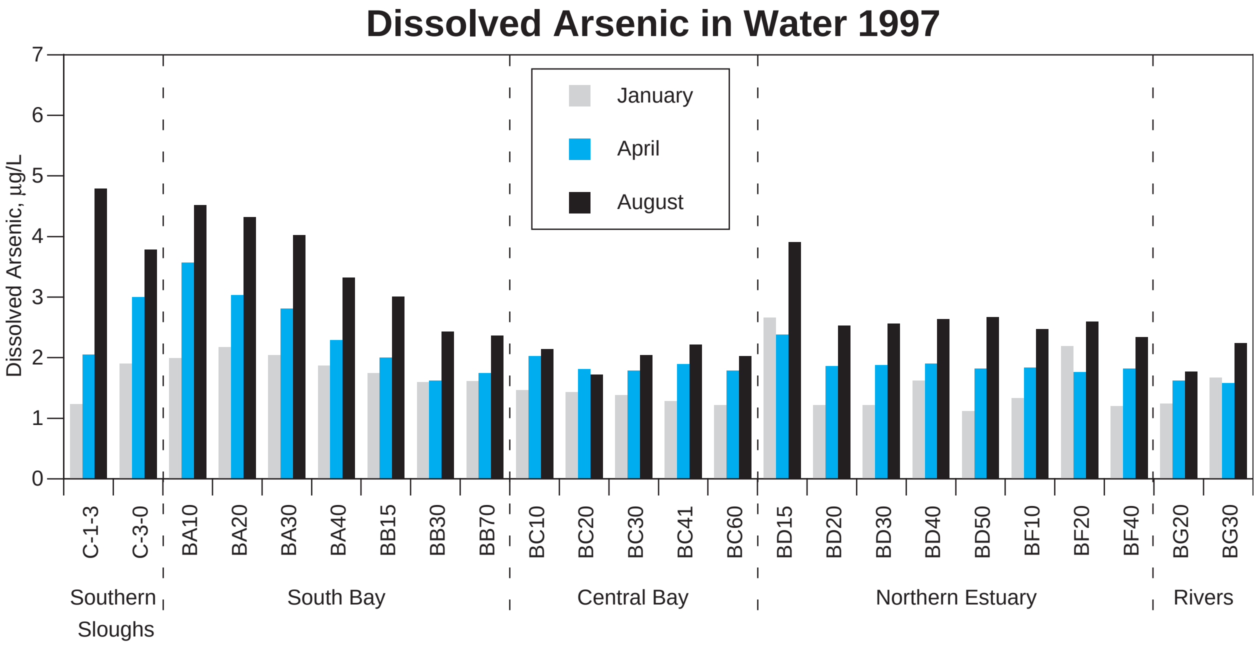


Figure 3.4. Dissolved arsenic (As) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August. Concentrations ranged from 1.12 to 4.79 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) in August and the lowest at Napa River (BD50) in January. Average concentrations were highest (4.29 ppb) in the Southern Sloughs in August and lowest (1.36 ppb) in the Central Bay in January. All samples were below the 4-day average WQC for dissolved arsenic (saltwater 36 ppb, freshwater 150 ppb).

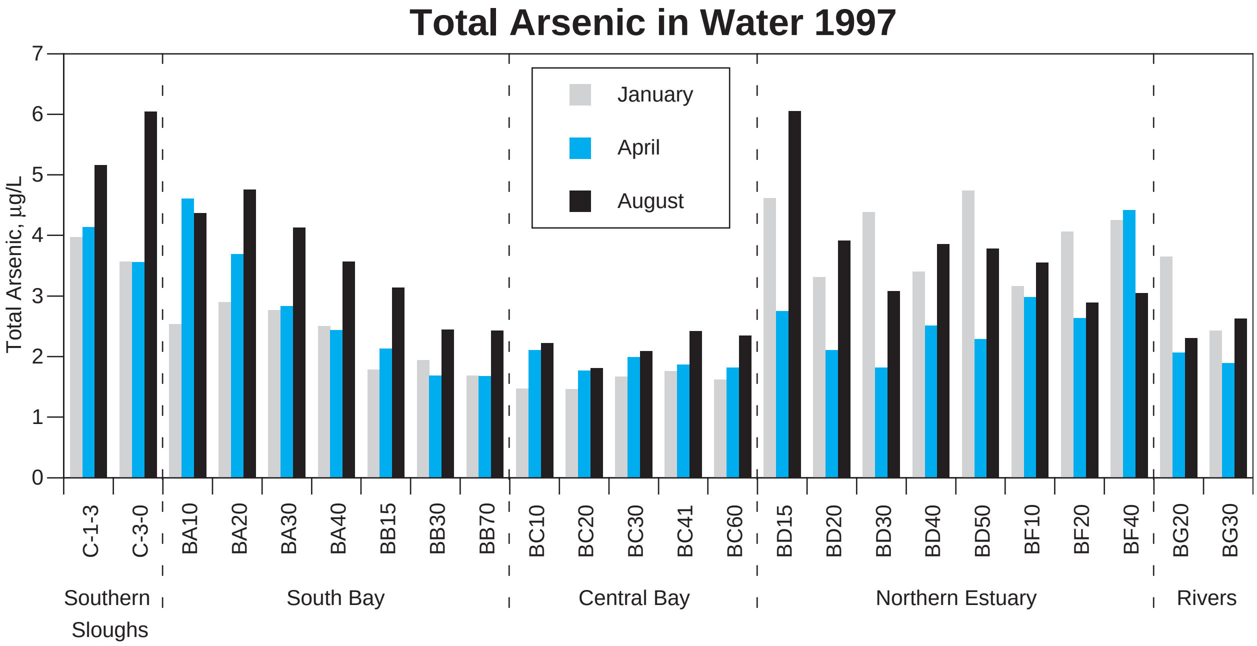


Figure 3.5. Total arsenic (As) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 1.46 to 6.05 ppb. The highest concentration was sampled at Petaluma River (BD15) in August, and the lowest at Golden Gate (BC20) in January. Average concentrations were highest (5.60 ppb) in the Southern Sloughs in August and lowest (1.60 ppb) in the Central Bay in January. All samples were below the 4-day average WQO for total arsenic (saltwater 36 ppb, freshwater 190 ppb).

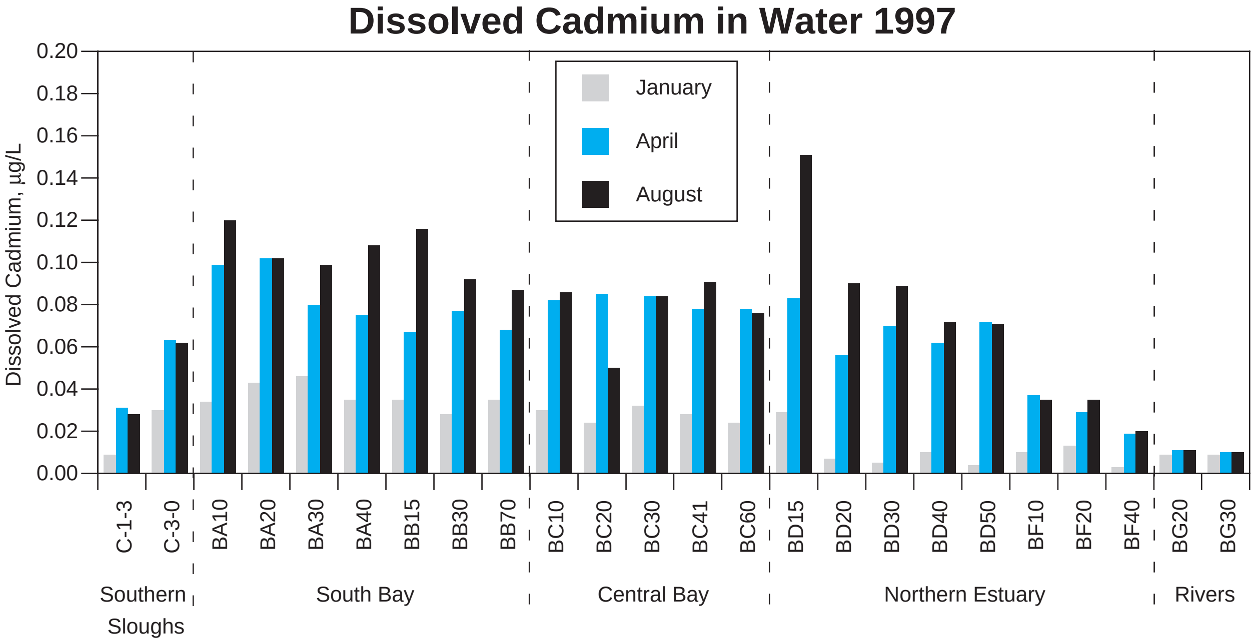


Figure 3.6. Dissolved cadmium (Cd) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.003 to 0.15 ppb. The highest concentration was sampled at Petaluma River (BD15) in August and the lowest at Honker Bay (BF40) in January. Average concentrations were highest (0.10 ppb) in the South Bay in August and lowest (0.01 ppb) in the Rivers in January. All samples were below the 4-day average WQC for dissolved cadmium (saltwater 9.3 ppb, freshwater—hardness dependent).

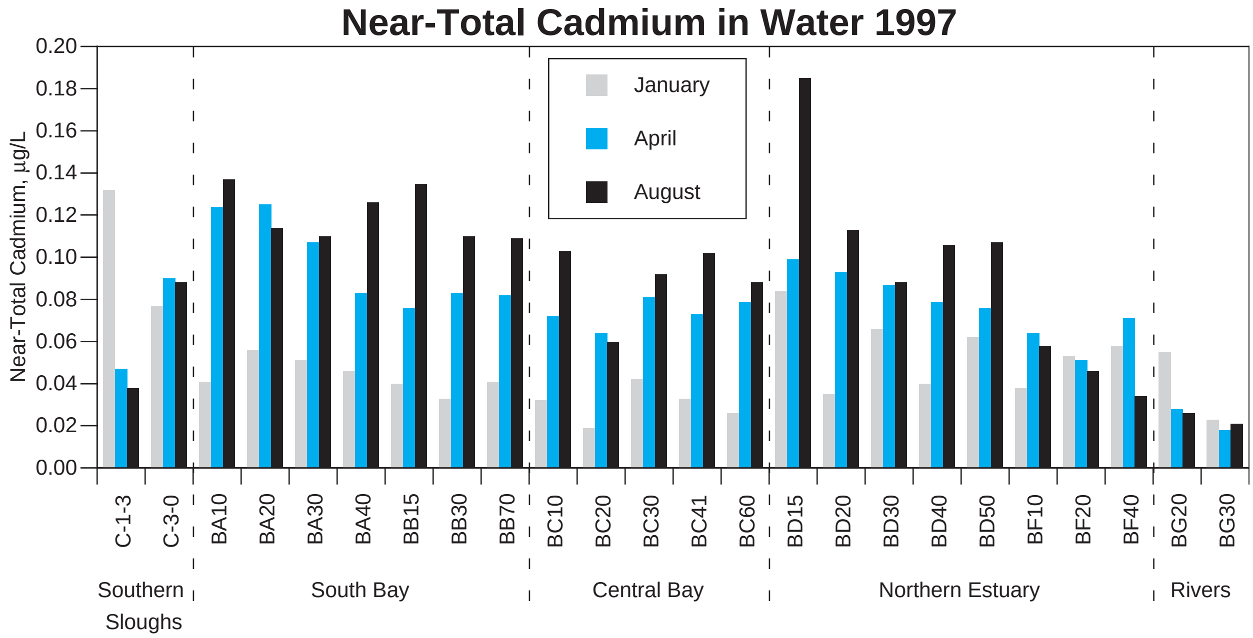


Figure 3.7. Near-total cadmium (Cd) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.02 to 0.19 ppb. The highest concentration was sampled at Petaluma River (BD15) in August and the lowest at San Joaquin River (BG30) in April. Average concentrations were highest (0.12 ppb) in the South Bay in August and lowest (0.02 ppb) in the Rivers in April. All samples were below the 4-day average WQO for total cadmium (saltwater 9.3 ppb, freshwater—hardness dependent).

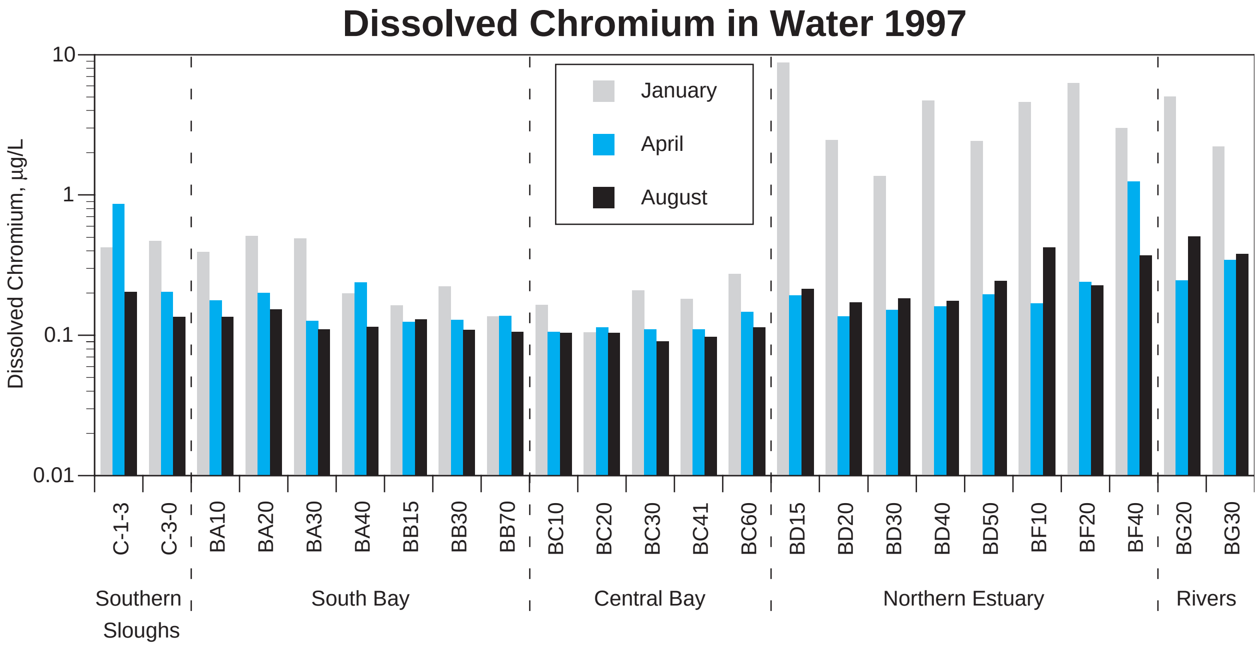


Figure 3.8. Dissolved chromium (Cr) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. Concentrations ranged from 0.1 to 8.8 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Richardson Bay (BC30) in August. Average concentrations were highest (4.2 ppb) in the Northern Estuary in January and lowest (0.1 ppb) in the Central Bay in August. All samples were below the 4-day average WQC for dissolved chromium (saltwater 50 ppb, freshwater 11 ppb).

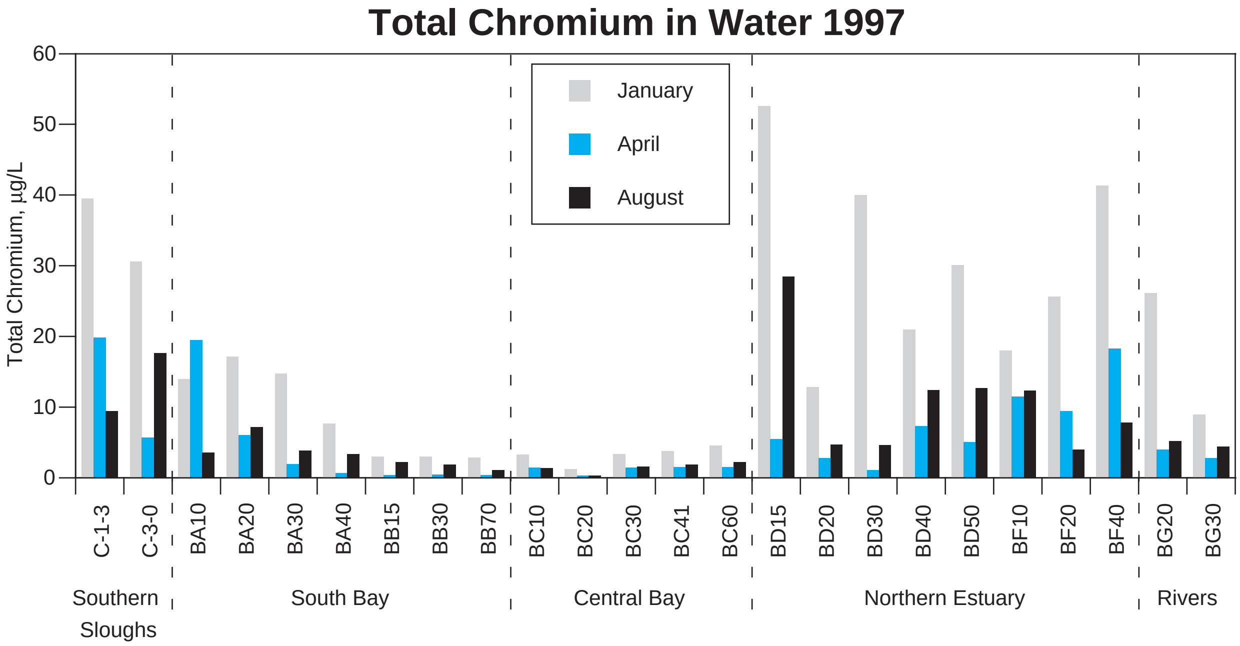


Figure 3.9. Total chromium (Cr) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.30 to 52.55 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Golden Gate (BC20) in April. Average concentrations were highest (35.03 ppb) in the Southern Sloughs in January and lowest (1.22 ppb) in the Central Bay in April. Twenty samples were above the 4-day average WQO for total chromium (saltwater 50 ppb, freshwater 11 ppb).

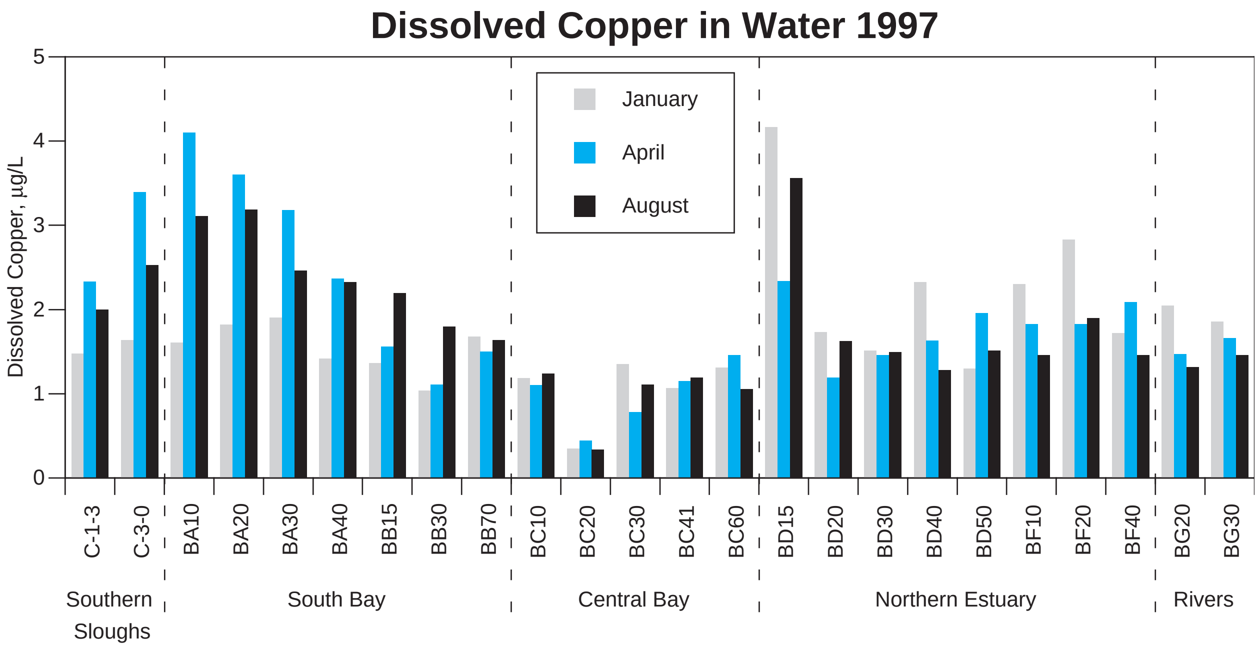


Figure 3.10. Dissolved copper (Cu) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.34 to 4.16 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (2.86 ppb) in the Southern Sloughs in April and lowest (0.99 ppb) in the Central Bay in August. Eight samples were above the WQC for dissolved copper (saltwater 3.1 ppb, freshwater—hardness dependent).

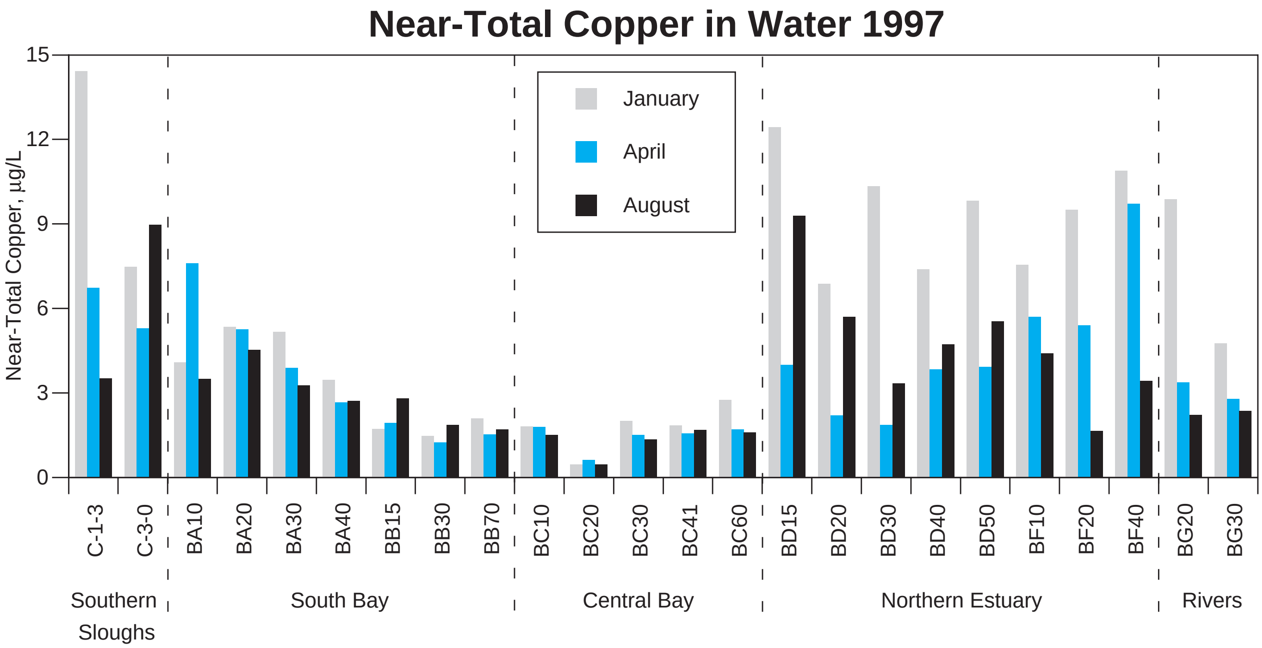


Figure 3.11. Near-total copper (Cu) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.46 to 14.4 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) in January and the lowest at Golden Gate (BC20) in January. Average concentrations were highest (10.9 ppb) in the Southern Sloughs in January and lowest (1.32 ppb) in the Central Bay in August. Copper is compared to guidelines only on a dissolved basis.

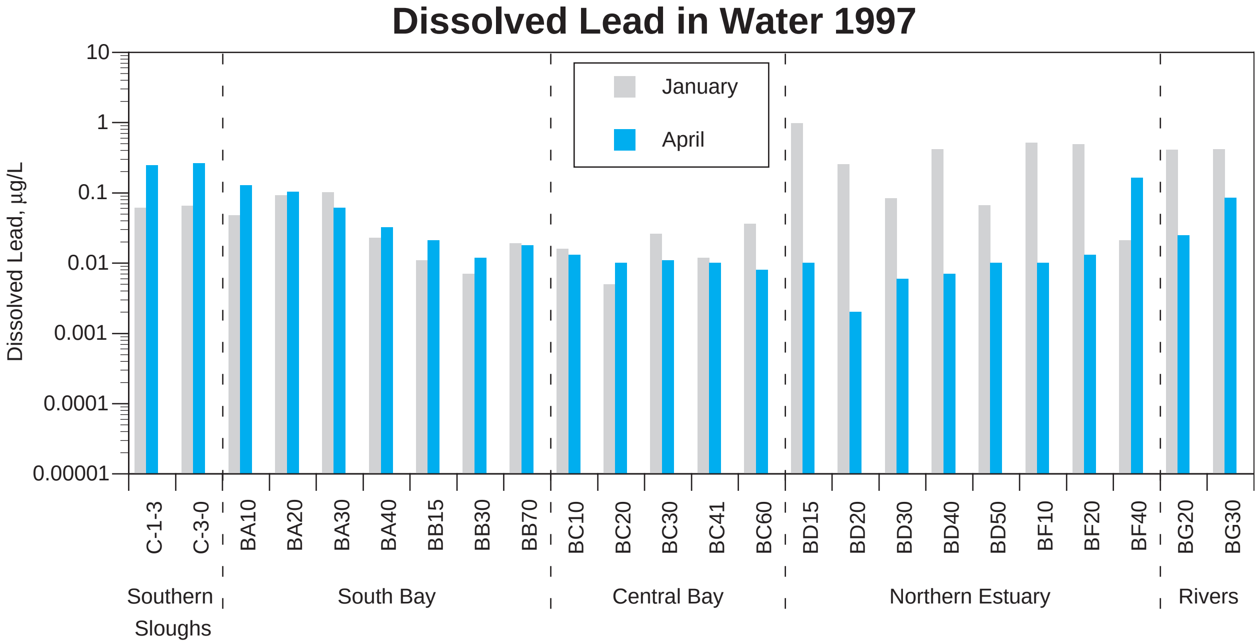


Figure 3.12. Dissolved lead (Pb) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January and April 1997. Data for August 1997 were not available at the time of report production. Note logarithmic scale. Concentrations for January and April 1997 ranged from 0.002 to 0.98 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest was sampled at San Pablo Bay (BD20) in April. Average concentrations were highest (0.41 ppb) in the Rivers in January and lowest (0.01 ppb) in the Central Bay in April. All samples were below the 4-day average WQC for dissolved lead (saltwater 8.1 ppb, freshwater—hardness dependent).

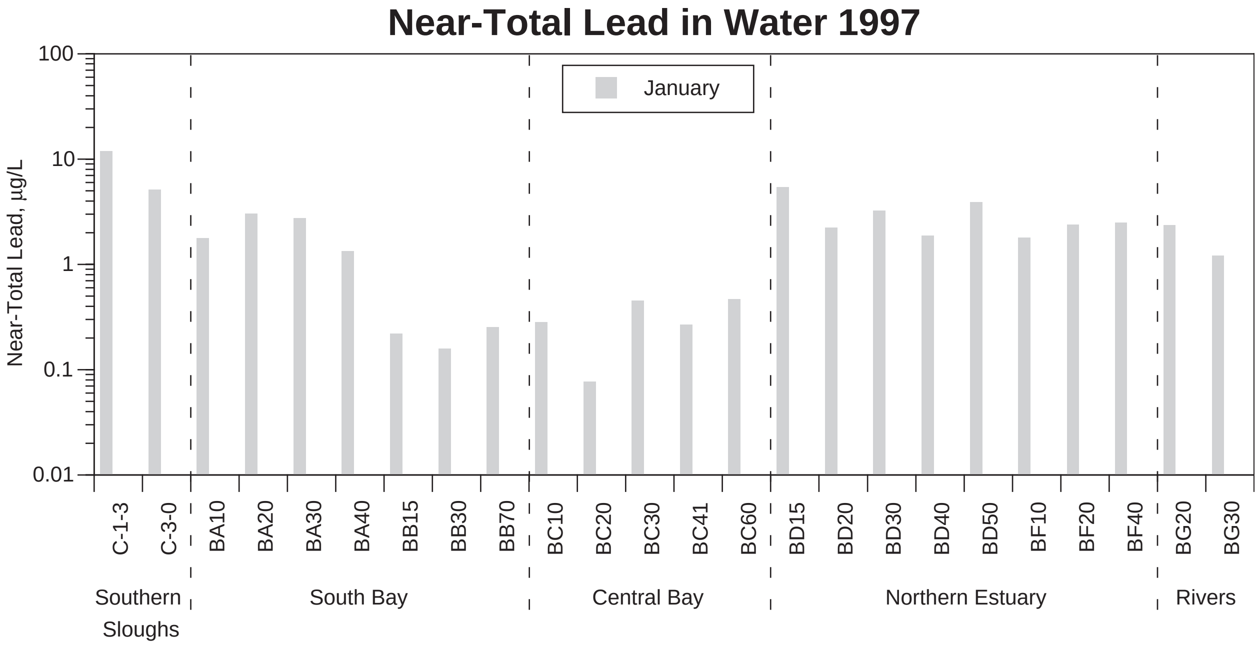


Figure 3.13. Near-total lead (Pb) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January 1997. Data for April and August 1997 were not available at the time of report production. Note logarithmic scale. Concentrations for January ranged from 0.08 to 11.91 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) and the lowest at Golden Gate (BC20). Average concentrations were highest (8.51 ppb) in the Southern Sloughs and lowest (0.31 ppb) in the Central Bay. Ten samples were above the 4-day average WQO for total lead (saltwater 5.6 ppb, freshwater—hardness dependent).

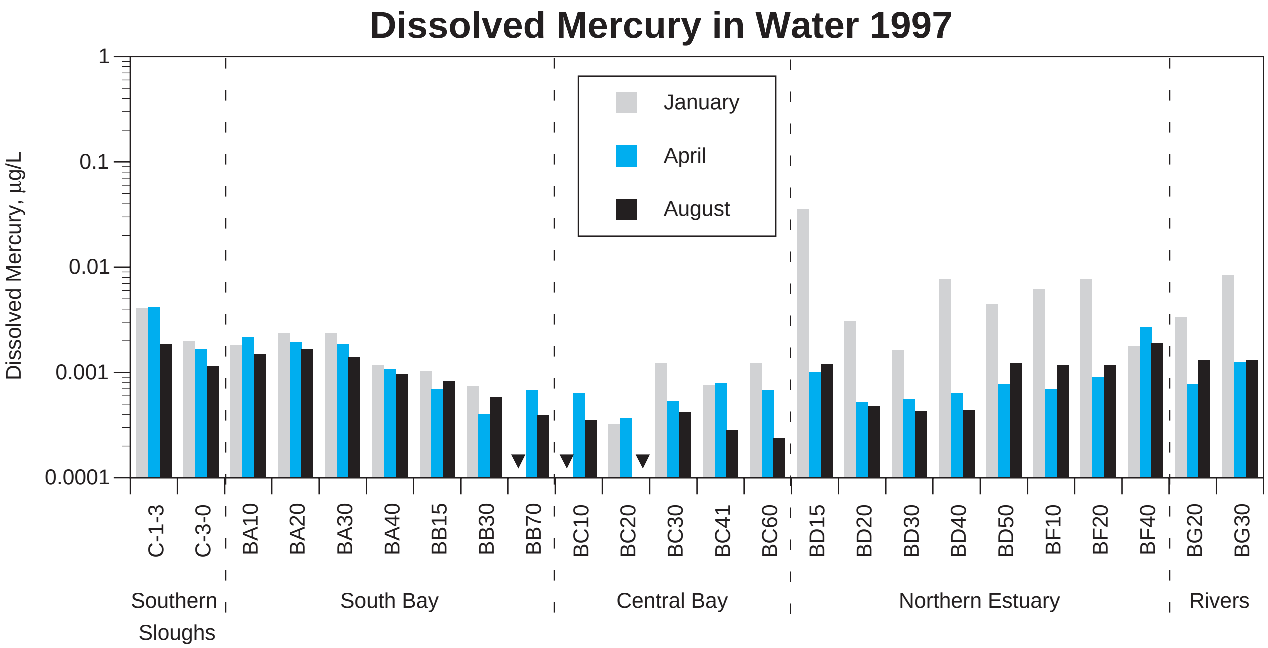


Figure 3.14. Dissolved mercury (Hg) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. ▼ = not detected. Concentrations ranged from not detected to 0.035 ppb. The highest concentration was at Petaluma River (BD15) in January. Average concentrations were highest (0.0085 ppb) in the Northern Estuary in January and lowest (0.00026 ppb) in the Central Bay in August. Mercury is compared to guidelines only on a total basis.

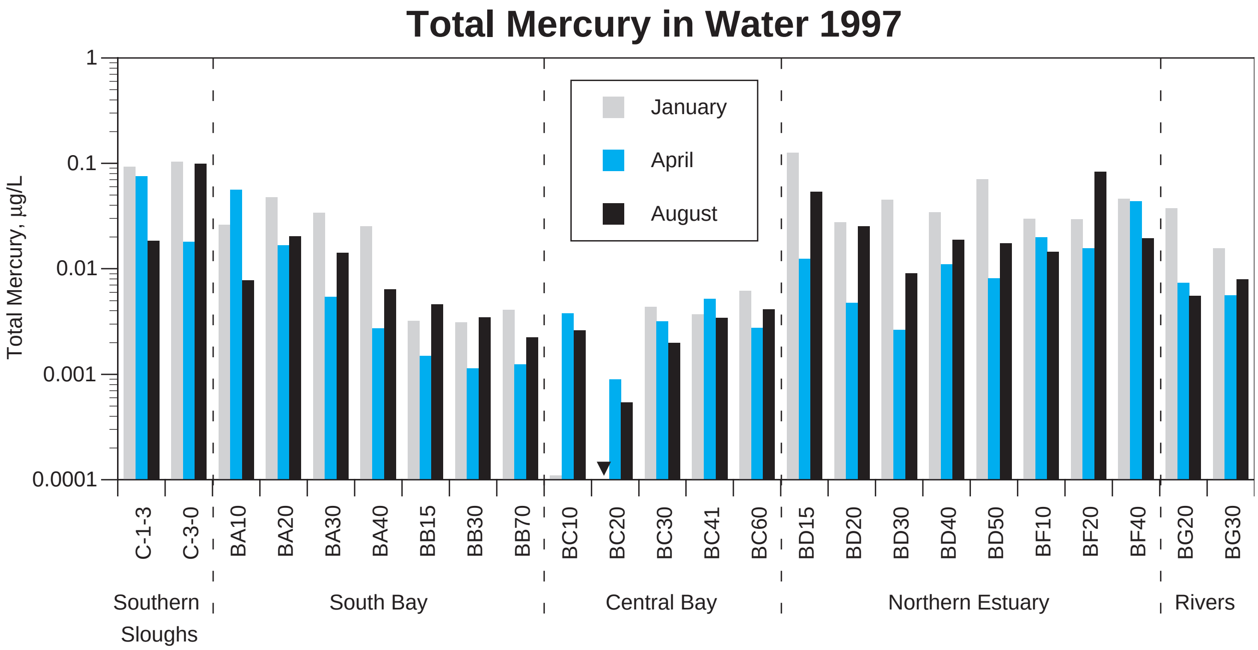


Figure 3.15. Total mercury (Hg) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. ▼ = not detected. Concentrations ranged from not detected to 0.13 ppb. The highest concentration was at Petaluma River (BD15) in January. Average concentrations were highest (0.098 ppb) in the Southern Sloughs in January and lowest (0.003 ppb) in the Central Bay in August. Twenty-two samples were above the 4-day average WQO for total mercury (saltwater 0.025 ppb, freshwater 0.025 ppb).

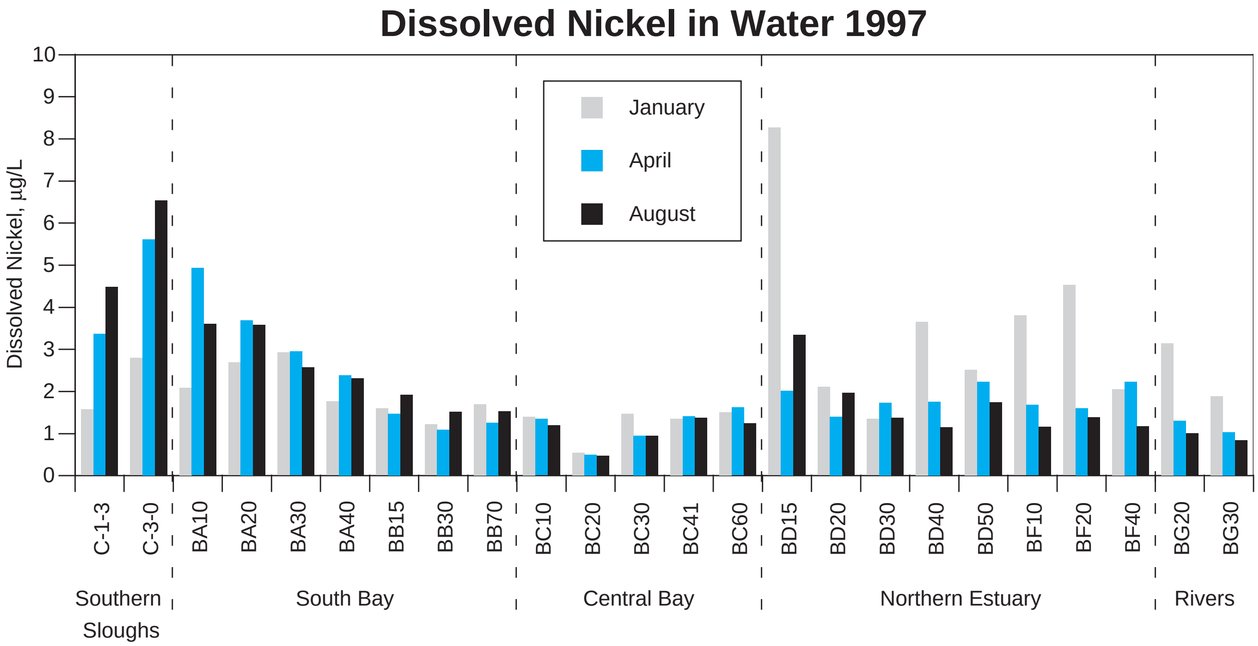


Figure 3.16. Dissolved nickel (Ni) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.48 to 8.27 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (5.51 ppb) in the Southern Sloughs in August and lowest (0.92 ppb) in the Rivers in August. One sample was above the 4-day average WQC for dissolved nickel (saltwater 8.2 ppb, freshwater—hardness dependent).

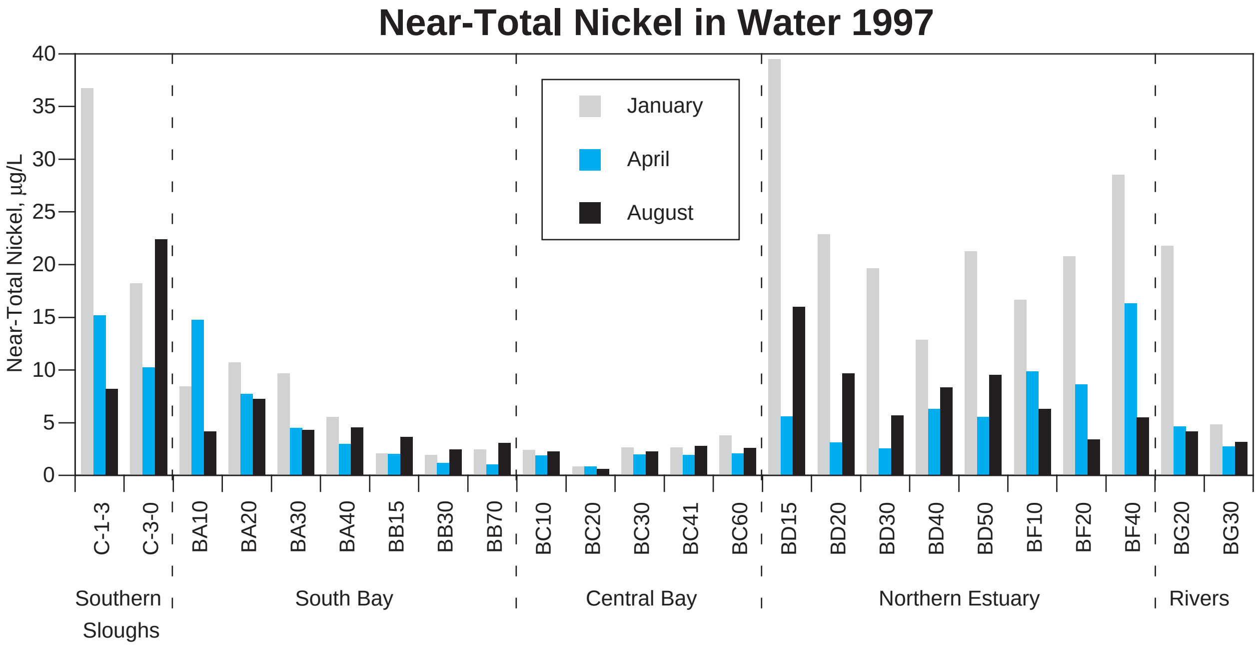


Figure 3.17. Near-total nickel (Ni) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 0.61 to 39.48 ppb. The highest concentration was sampled at Petaluma River (BD15) in January and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (27.48 ppb) in the Southern Sloughs in January and lowest (1.74 ppb) in the Central Bay in April. Twenty-eight samples were above 24-hour average WQO for total nickel (saltwater 7.1 ppb, freshwater—hardness dependent).

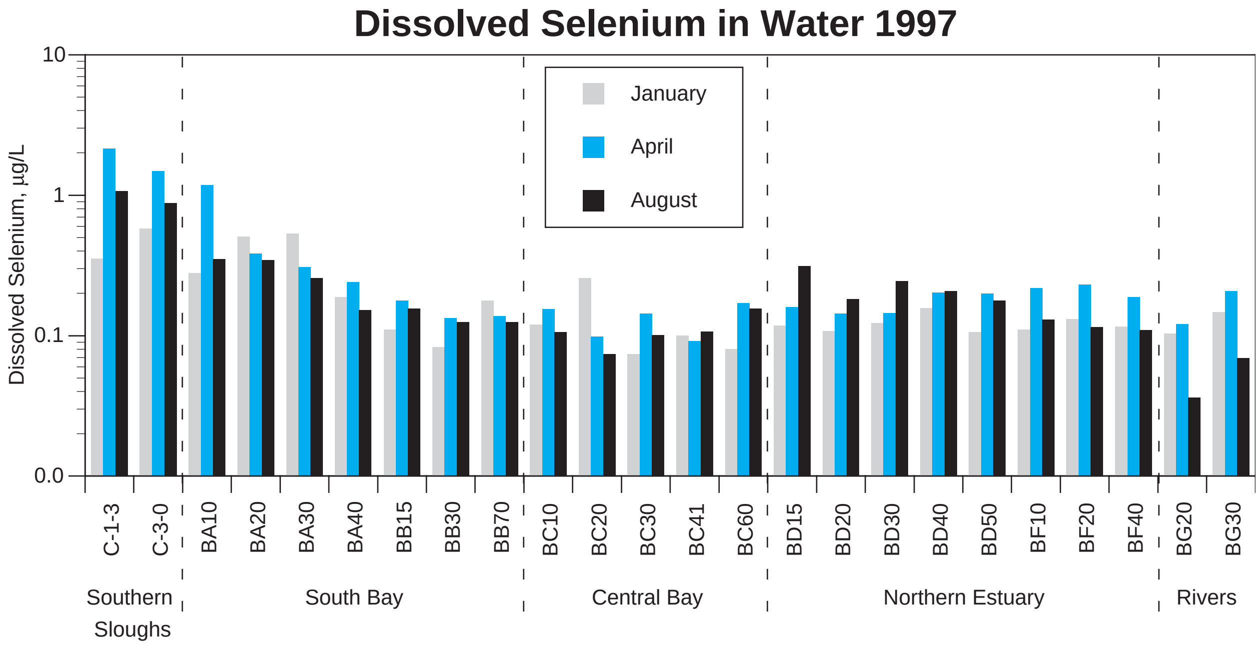


Figure 3.18. Dissolved selenium (Se) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. Concentrations ranged from 0.04 to 2.14 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) in April, and the lowest was sampled at Sacramento River (BG20) in August. Average concentrations were highest (1.82 ppb) in the Southern Sloughs in April and lowest (0.05 ppb) in the Rivers in August. Selenium is compared to guidelines only on a total basis.

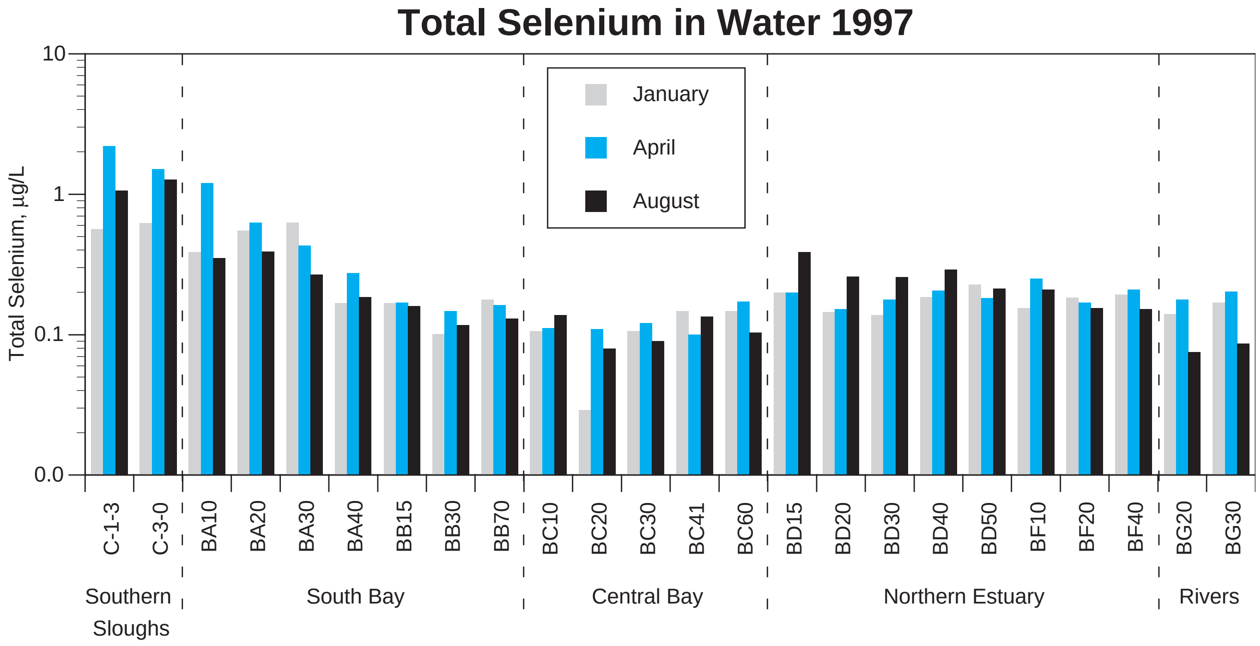


Figure 3.19. Total selenium (Se) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. Concentrations ranged from 0.03 ppb to 2.20 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) in April and the lowest at Golden Gate (BC20) in January. Average concentrations were highest (1.85 ppb) in the Southern Sloughs in April and lowest (0.08 ppb) in the Rivers in August. There are no Basin Plan WQOs for selenium. All samples were below the National Toxics Rule WQC for total selenium (saltwater 5 ppb and freshwater 5 ppb).

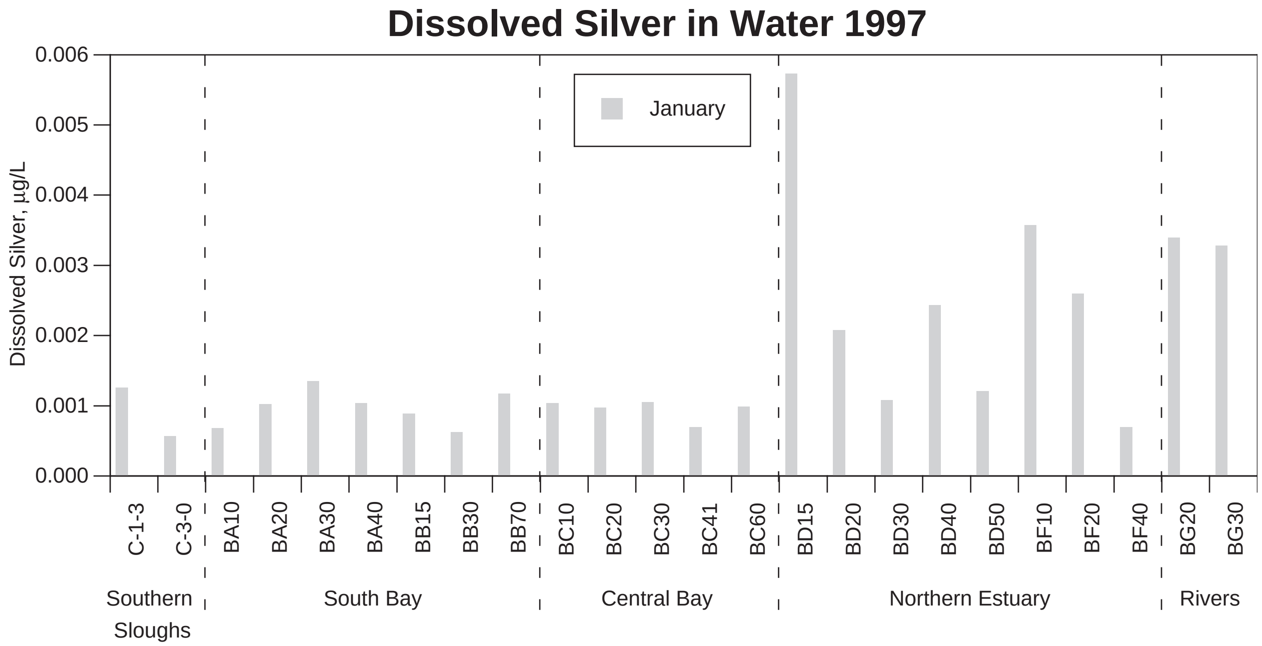


Figure 3.20. Dissolved silver (Ag) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January 1997. Samples for April and August were lost due to methodological problems. Concentrations for January 1997 ranged from 0.0006 to 0.0057 ppb. The highest concentration was sampled at Petaluma River (BD15) and the lowest at San Jose (C-3-0). Average concentrations were highest (0.0033 ppb) in the Rivers and lowest (0.0009 ppb) in the Southern Sloughs. All samples were below the 1-hour maximum WQC for dissolved silver (saltwater 1.9 ppb, freshwater—hardness dependent).

Total Silver in Water 1997

Samples lost due to methodological problems.

Figure 3.21. Total silver (Ag) concentrations in water. All 1997 samples were lost due to methodological problems.

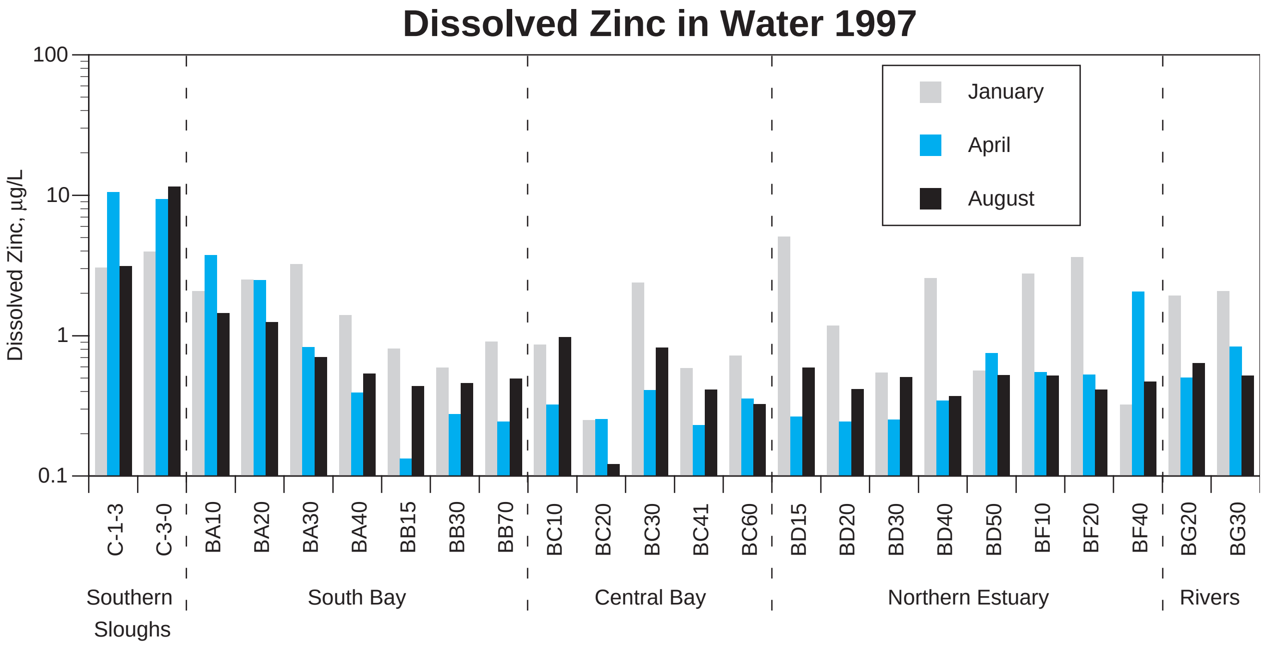


Figure 3.22. Dissolved zinc (Zn) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. Concentrations ranged from 0.12 to 11.52 ppb. The highest concentration was sampled at San Jose (C-3-0) and the lowest at Golden Gate (BC20), both in August. Average concentrations were highest (9.94 ppb) in the Southern Sloughs and lowest (0.32 ppb) in the Central Bay, both in April. All samples were below the 4-day average WQC for dissolved zinc (saltwater 81 ppb, freshwater—hardness dependent).

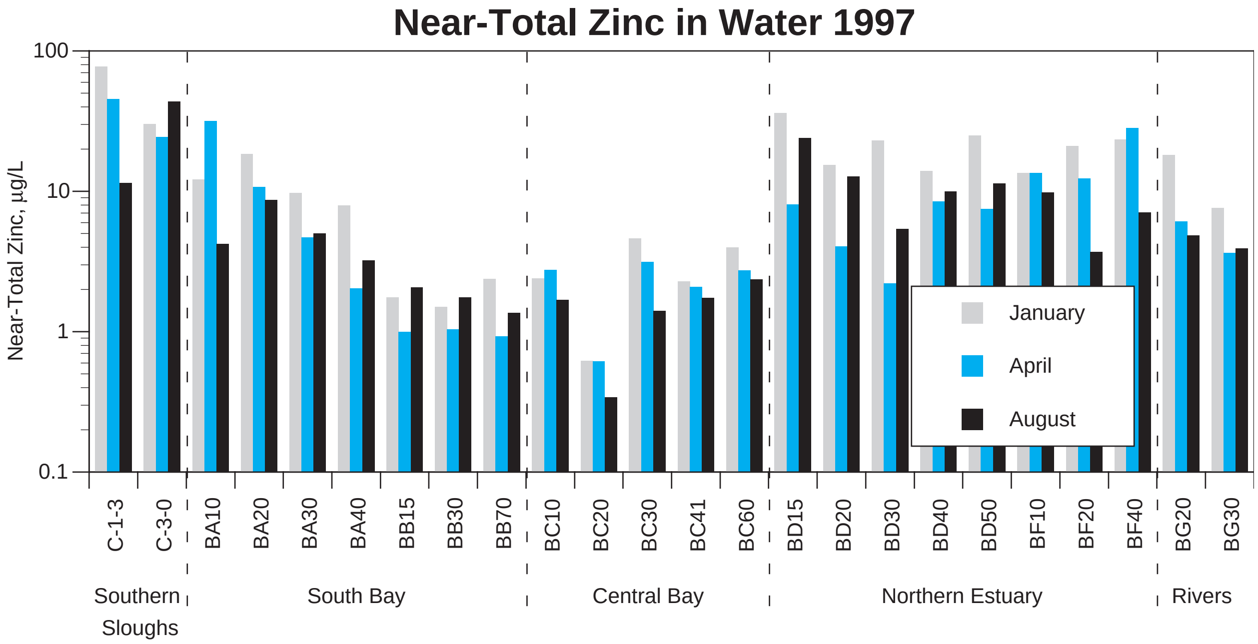


Figure 3.23. Near-total zinc (Zn) concentrations in water in parts per billion (ppb) at 24 RMP stations sampled in January, April, and August 1997. Note logarithmic scale. Concentrations ranged from 0.34 to 77.57 ppb. The highest concentration was sampled at Sunnyvale (C-1-3) in January and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (53.90 ppb) in the Southern Sloughs in January and lowest (1.51 ppb) in the Central Bay in August. Twelve samples were above the 24-hour average WQO for total zinc (saltwater 58 ppb, freshwater—hardness dependent).

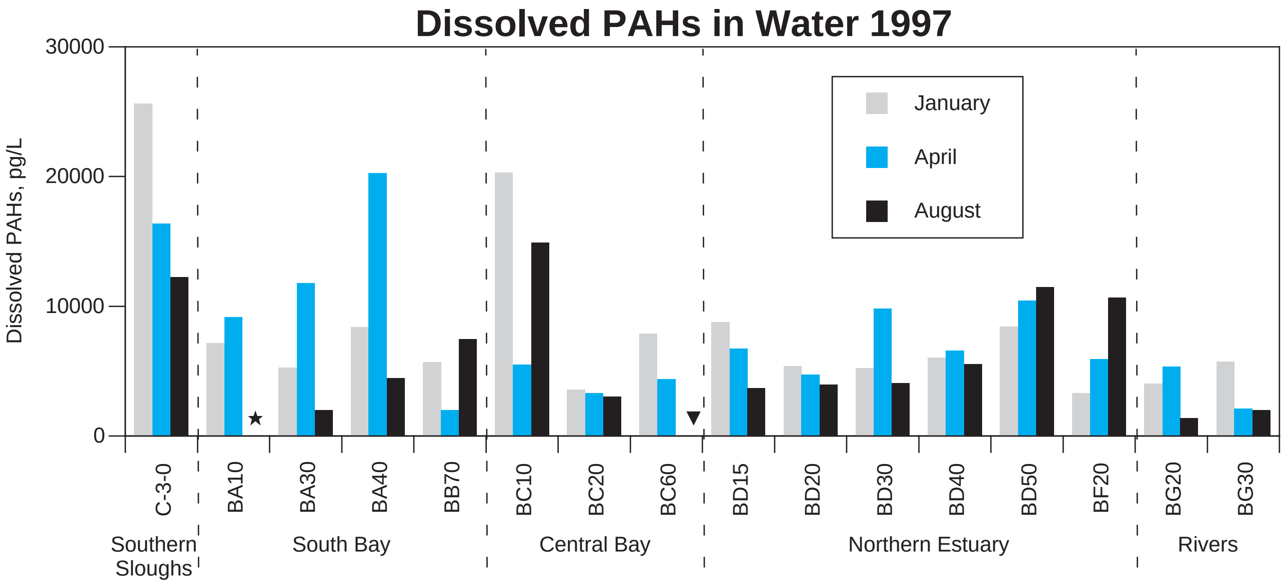


Figure 3.24. Dissolved PAH concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, ▼ = below detection. Concentrations ranged from below detection to 25,605 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in January. Average concentrations were highest (10,805 ppq) in the South Bay in April and lowest (1,680 ppq) in the Rivers in August. There are no water quality guidelines for dissolved PAHs.

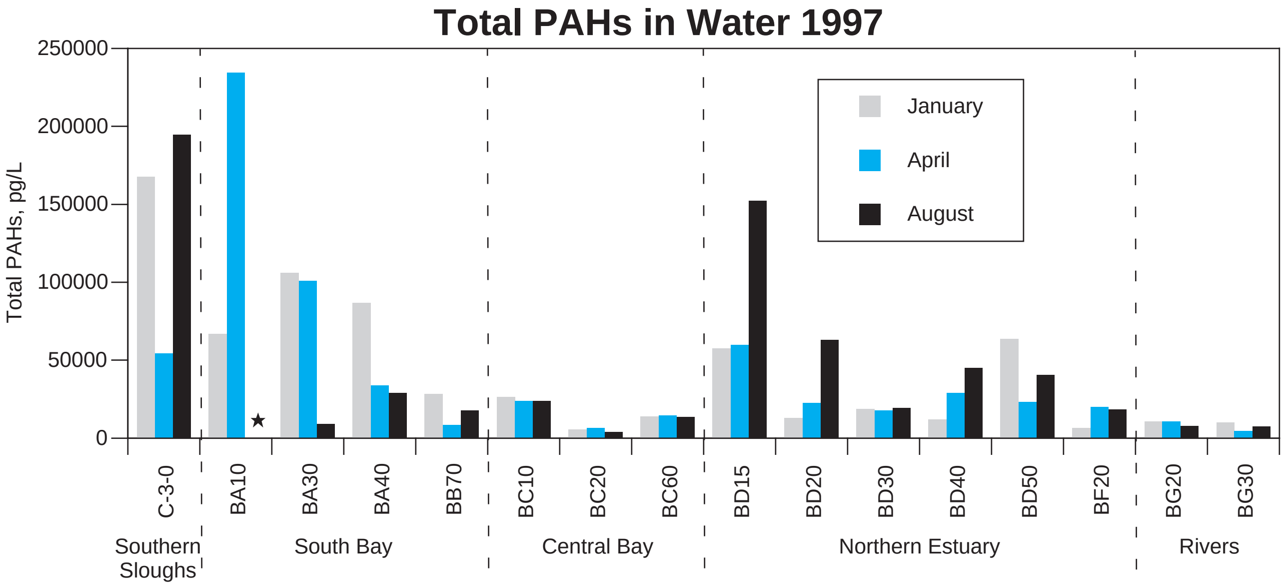


Figure 3.25. Total PAH concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed. Concentrations ranged from 4,100 to 234,390 ppq (see*Appendix B* for MDLs). The highest concentration was sampled at Coyote Creek (BA10) in April and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (94,430 ppq) in the South Bay in April and lowest (7,565 ppq) in the Rivers in August. Six stations were above the water quality criterion for total PAHs from the US EPA National Toxics Rule of 31,000 ppq in January, five in April, and five in August.

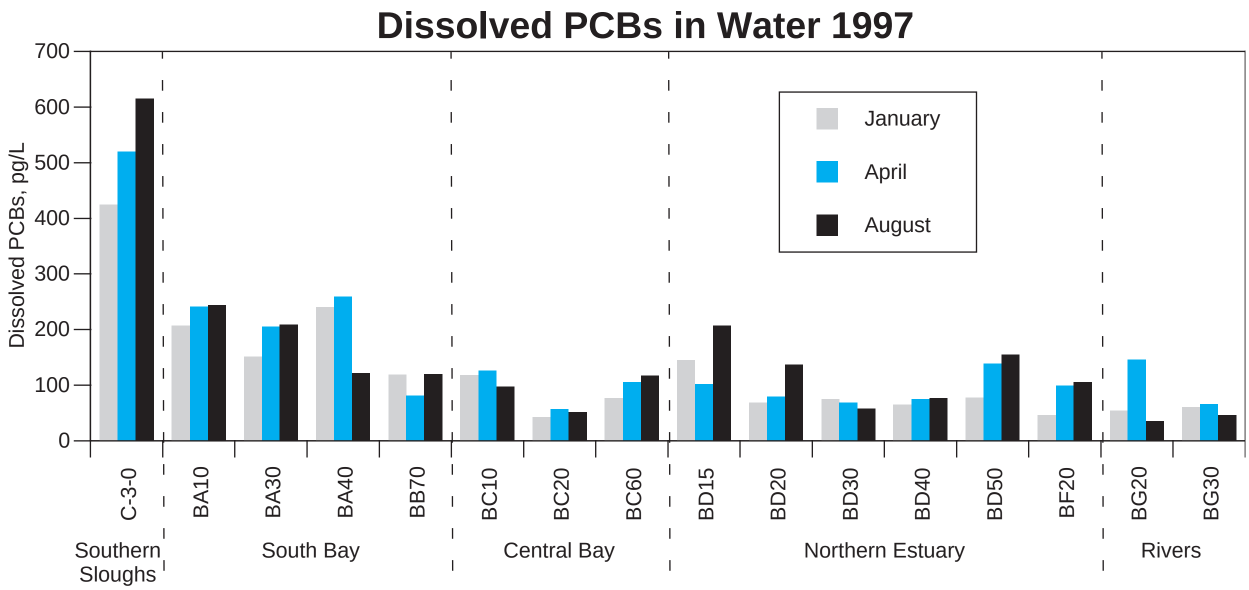


Figure 3.26. Dissolved PCB concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 35 to 615 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) and the lowest at Sacramento River (BG20), both in August. Average concentrations were highest (197 ppq) in the South Bay in April and lowest (41 ppq) in the Rivers in August. There are no water quality guidelines for dissolved PCBs.

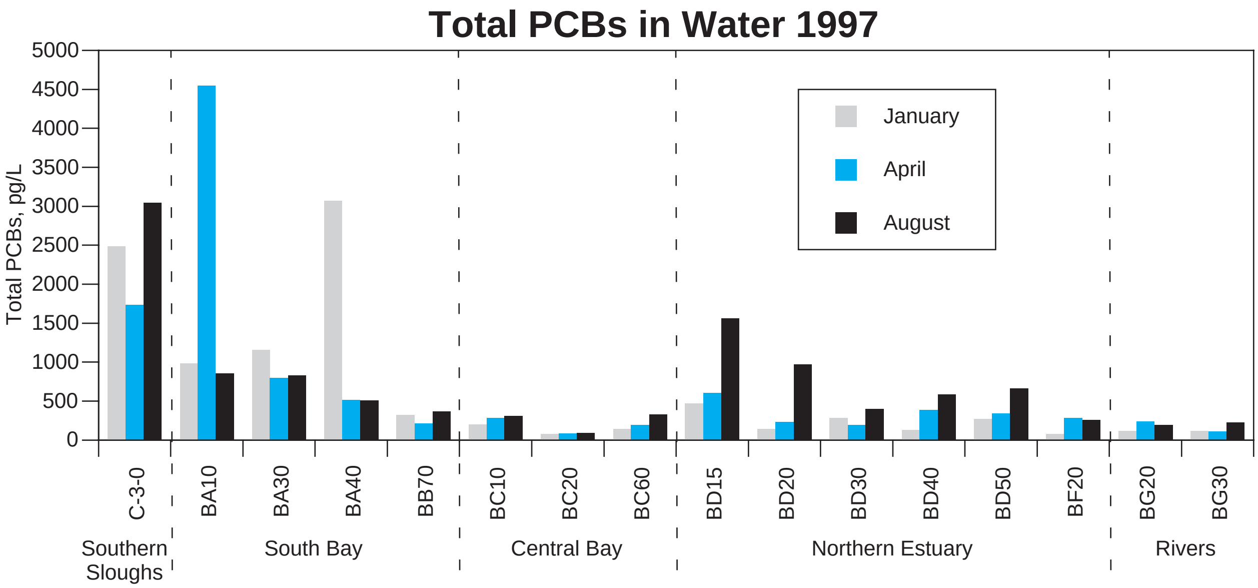


Figure 3.27. Total PCB concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 77 to 4,547 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Coyote Creek (BA10) in April and the lowest at Golden Gate (BC20) in January. Average concentrations were highest (1,518 ppq) in the South Bay in April and lowest (118 ppq) in the Rivers in January. US EPA-NTR PCB (Aroclor-based) criteria are 14,000 ppq for freshwater aquatic life, 30,000 ppq for saltwater aquatic life, and 170 ppq for human health (consumption of organisms only). Nine stations in January were above the human health criterion, fourteen stations in April, and fifteen stations in August.

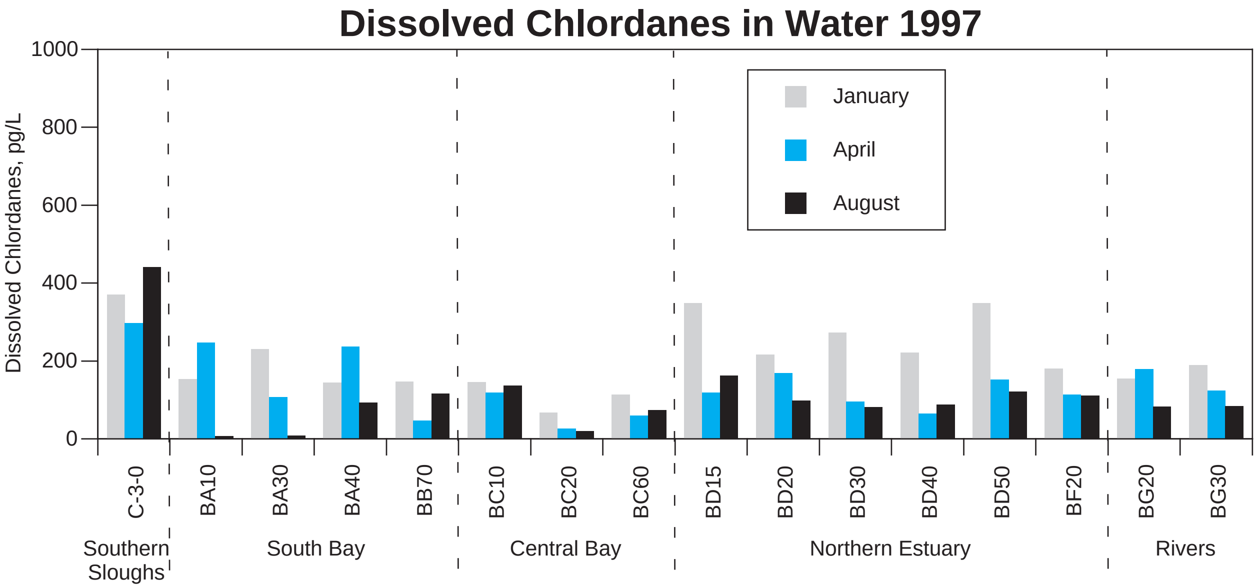


Figure 3.28. Dissolved chlordane concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 7 to 440 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) and the lowest at Coyote Creek (BA10), both in August. Average concentrations were highest (265 ppq) in the Northern Estuary in January and lowest (56 ppq) in the South Bay in August. There are no criteria for dissolved chlordane.

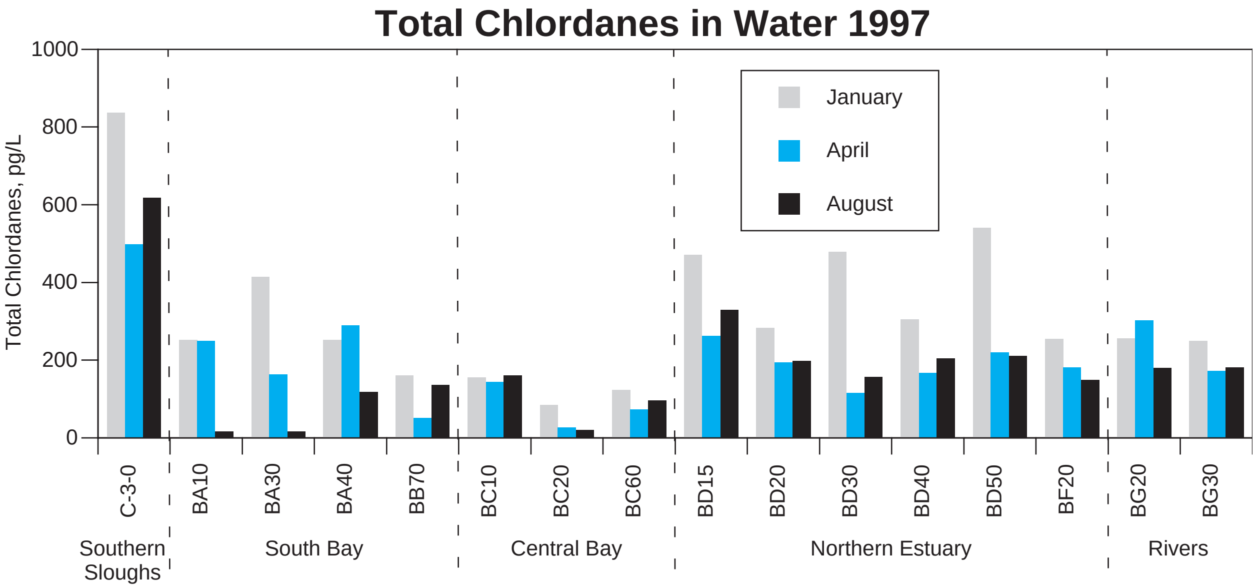


Figure 3.29. Total chlordane concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 16 to 836 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in January and the lowest at Dumbarton Bridge (BA30) in August. Average concentrations were highest (388 ppq) in the Northern Estuary in January and lowest (71 ppq) in the South Bay in August. All stations were below the water quality objectives for total chlordane of 4,300 ppq for freshwater and 4,000 ppq for saltwater.

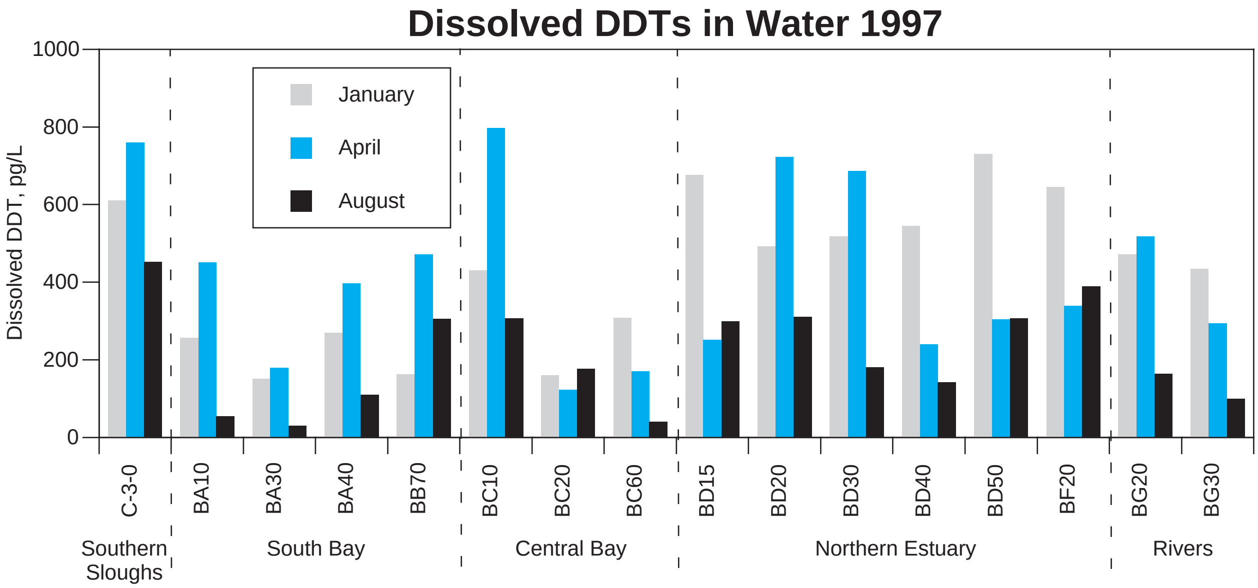


Figure 3.30. Dissolved DDT concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Concentrations ranged from 29 to 797 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Yerba Buena Island (BC10) in April and the lowest at Dumbarton Bridge (BA30) in August. Average concentrations were highest (601 ppq) in the Northern Estuary in January and lowest (124 ppq) in the South Bay in August. There are no water quality objectives for dissolved DDTs.

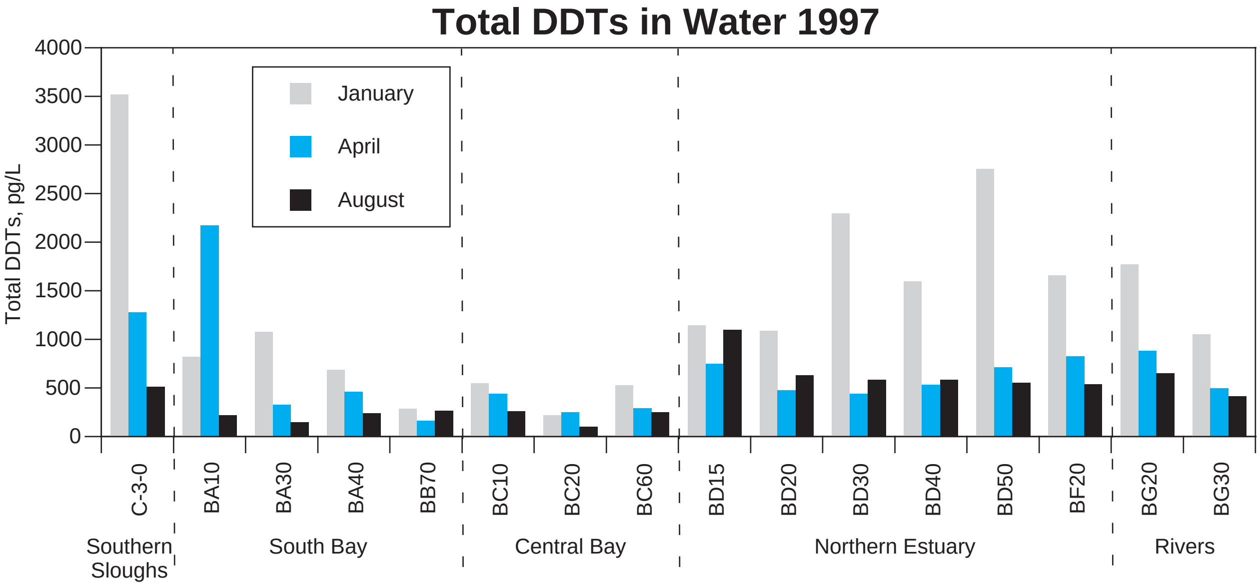


Figure 3.31. Total DDT concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August, 1997. Concentrations ranged from 100 to 3,519 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in January and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (1,755 ppq) in the Northern Estuary in January and lowest (204 ppq) in the Central Bay in August. Water quality objectives do not exist for total DDTs although individual compounds have criteria.

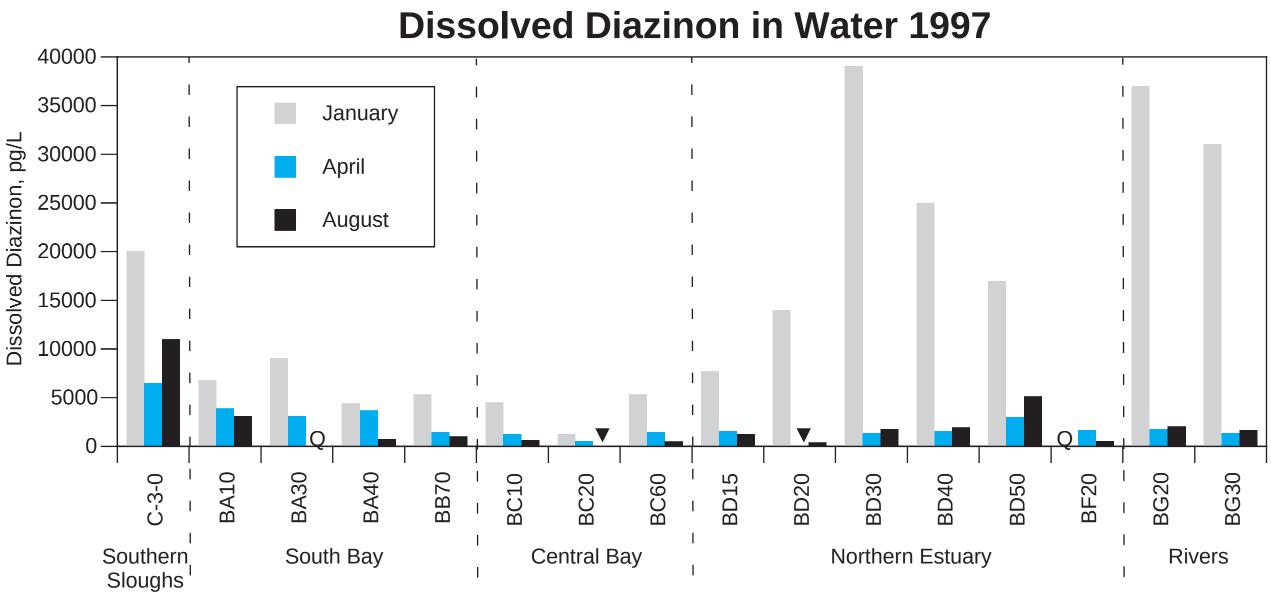


Figure 3.32. Dissolved diazinon concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Q = outside the QA limit, ▼ = below detection. Concentrations ranged from below detection to 39,000 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Pinole Point (BD30) in January. Average concentrations were highest (34,000 ppq) in the Rivers in January and lowest (377 ppq) in the Central Bay in August. There are no water quality guidelines for dissolved diazinon.

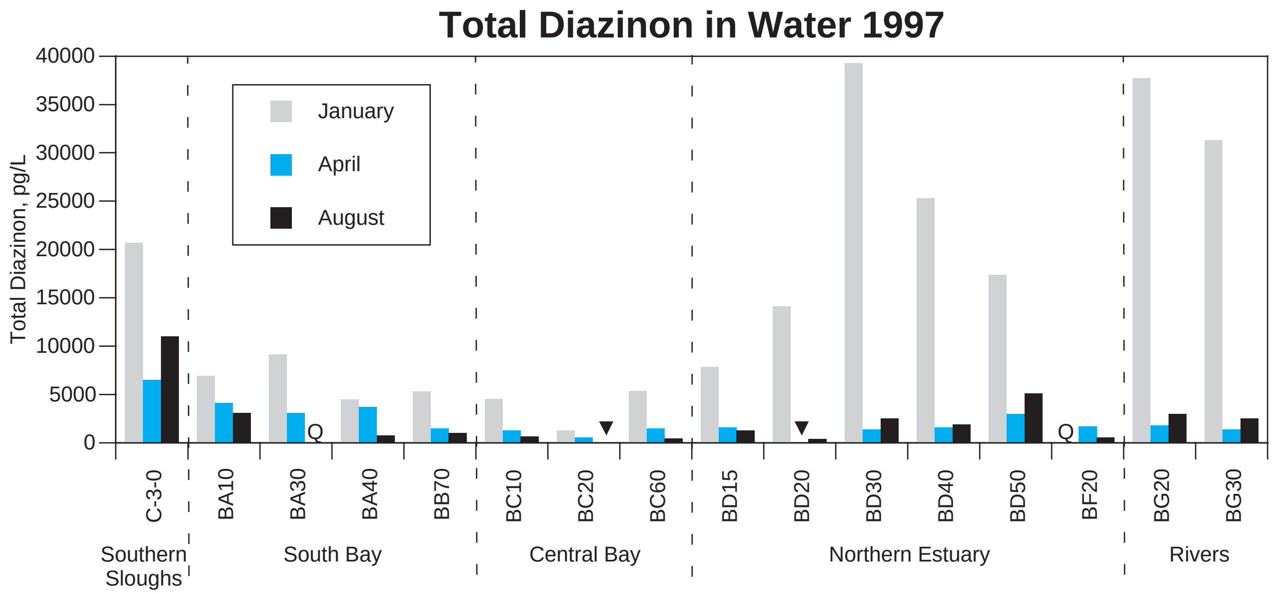


Figure 3.33. Total diazinon concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. Q = outside the QA limit, ▼ = below detection. Concentrations ranged from below detection to 39,270 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Pinole Point (BD30) in January. Average concentrations were highest (34,505 ppq) in the Rivers in January and lowest (377 ppq) in the Central Bay in August. All stations were below the California Department of Fish and Game guideline of 40,000 ppq.

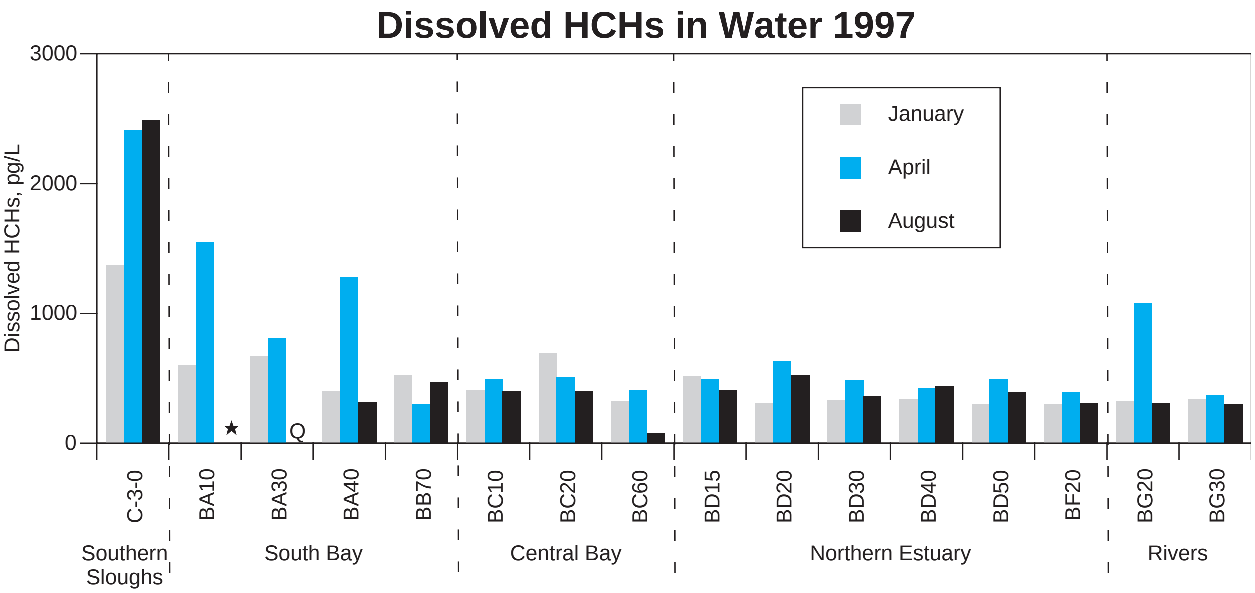


Figure 3.34. Dissolved HCH concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, Q = outside the QA limit. Concentrations ranged from 80 to 2,490 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in August and the lowest at Red Rock (BC60) in August. Average concentrations were highest (985 ppq) in the South Bay in April and lowest (292 ppq) in the Central Bay in August. There are no water quality criteria for dissolved HCHs.

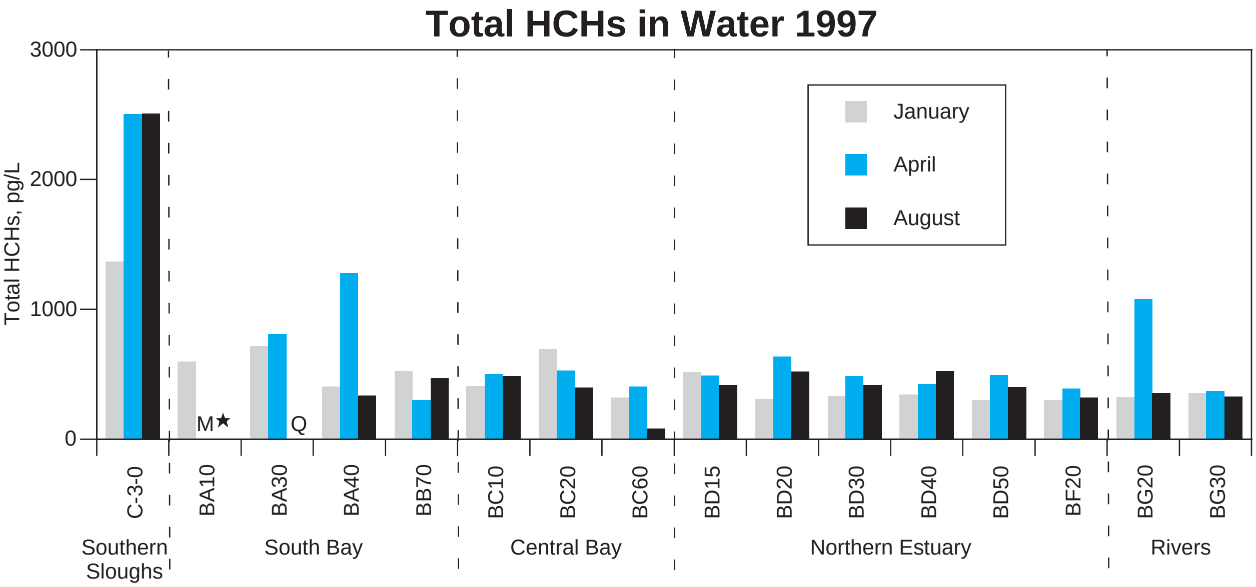


Figure 3.35. Total HCH concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, M = matrix interference, Q = outside the QA limit. Concentrations ranged from 80 to 2,508 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in April and the lowest at Coyote Creek (BA10) in August. Average concentrations were highest (797 ppq) in the South Bay in April and lowest (320 ppq) in the Central Bay in August. Water quality criteria do not exist for total HCHs although individual compounds have criteria.

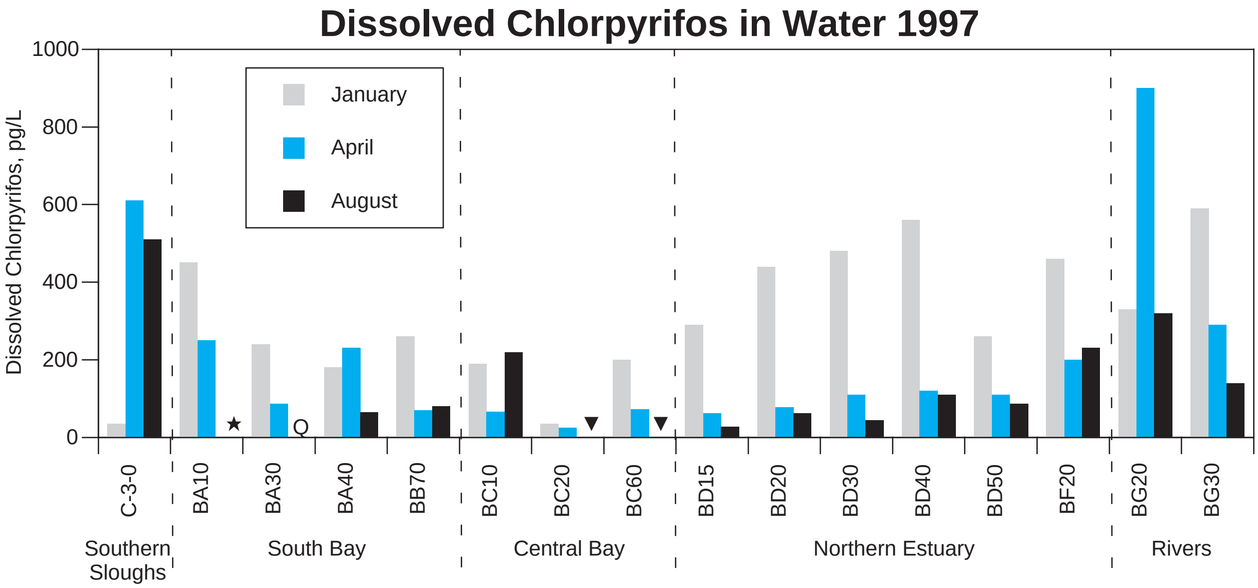


Figure 3.36. Dissolved chlorpyrifos concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, ▼ = below detection, and Q = outside the QA limit. Concentrations ranged from below detection to 900 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Sacramento River (BG20) in April. Average concentrations were highest (595 ppq) in the Southern Sloughs in August and lowest (54 ppq) in the Southern Sloughs in January. There are no water quality criteria for dissolved chlorpyrifos.

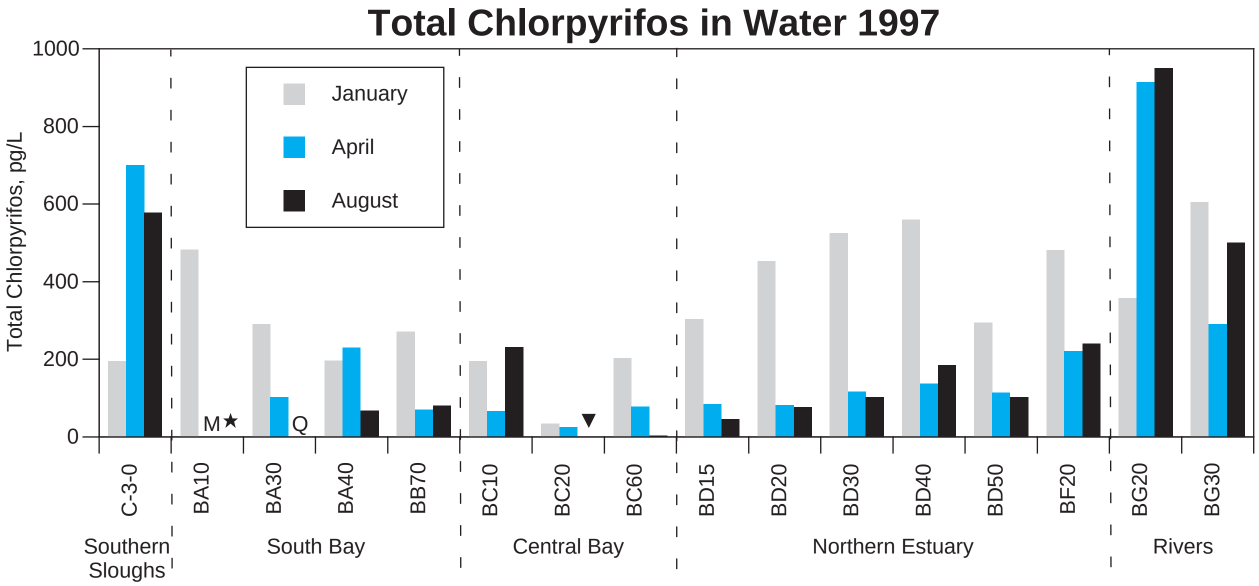


Figure 3.37. Total chlorpyrifos concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, ▼ = below detection, M = matrix intereference, Q = outside the QA limit. Concentrations ranged from below detection to 950 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Sacramento River (BG20) in August. Average concentrations were highest (725 ppq) in the Rivers in August and lowest (56 ppq) in the Central Bay in April. All stations were below the EPA 4-day criteria of 41,000 ppq for freshwater and 5,600 ppq for saltwater.

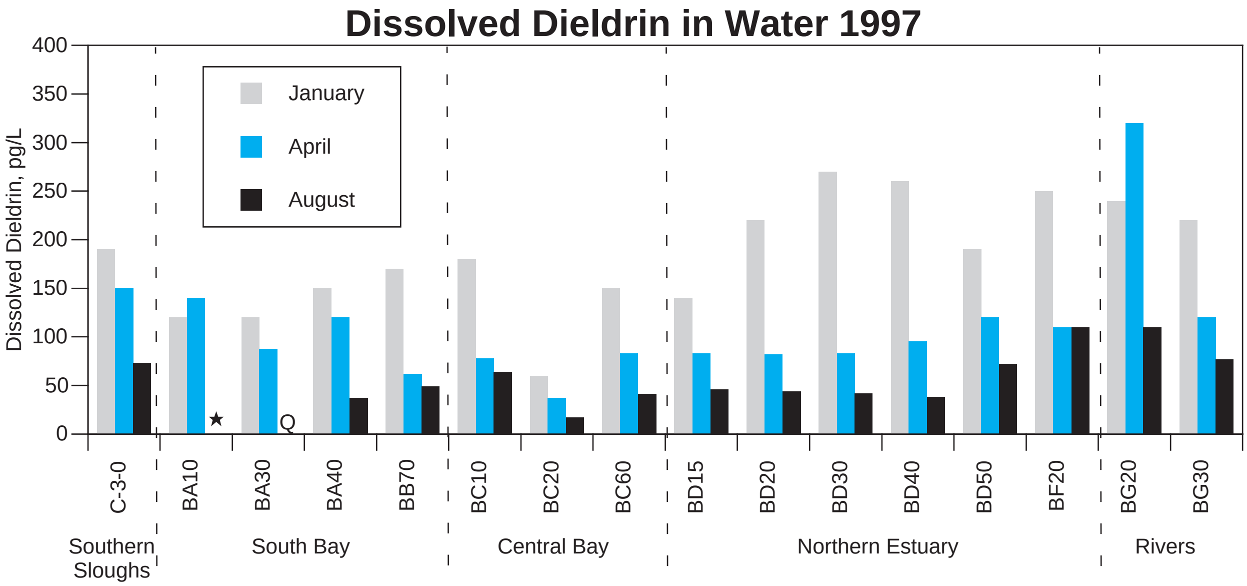


Figure 3.38. Dissolved dieldrin concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, Q = outside the QA limit. Concentrations ranged from 17 to 320 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Sacramento River (BG20) in April and the lowest at Golden Gate (BC20) in August. Average concentrations were highest (230 ppq) in the Rivers in January and lowest (41 ppq) in the Central Bay in August. There are no water quality guidelines for dissolved dieldrin.

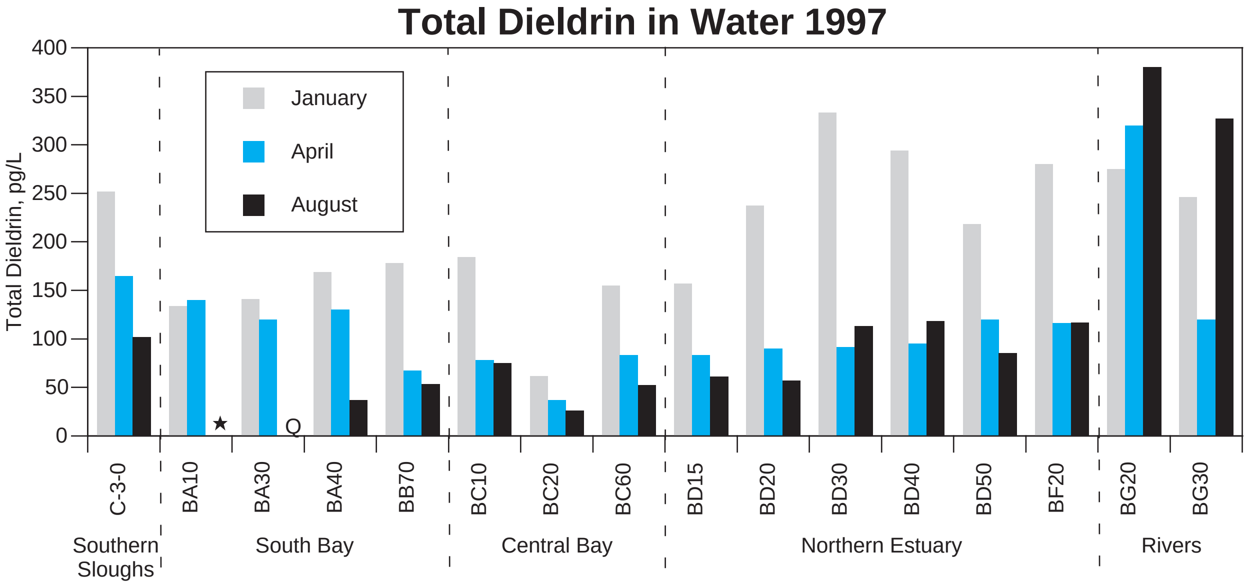


Figure 3.39. Total dieldrin concentrations in water (ppq) at 16 RMP stations sampled in January, April, and August 1997. ★ = not analyzed, Q = outside the QA limit. Concentrations ranged from 26 to 380 ppq (see *Appendix B* for MDLs). The highest concentration was sampled at Sacramento River (BG20) and the lowest at Golden Gate (BC20), both in August. Average concentrations were highest (354 ppq) in the Rivers and lowest (45 ppq) in the South Bay, both in August. All stations were below the 4-day water quality criteria of 56,000 ppq for freshwater and 1,900 ppq for saltwater.

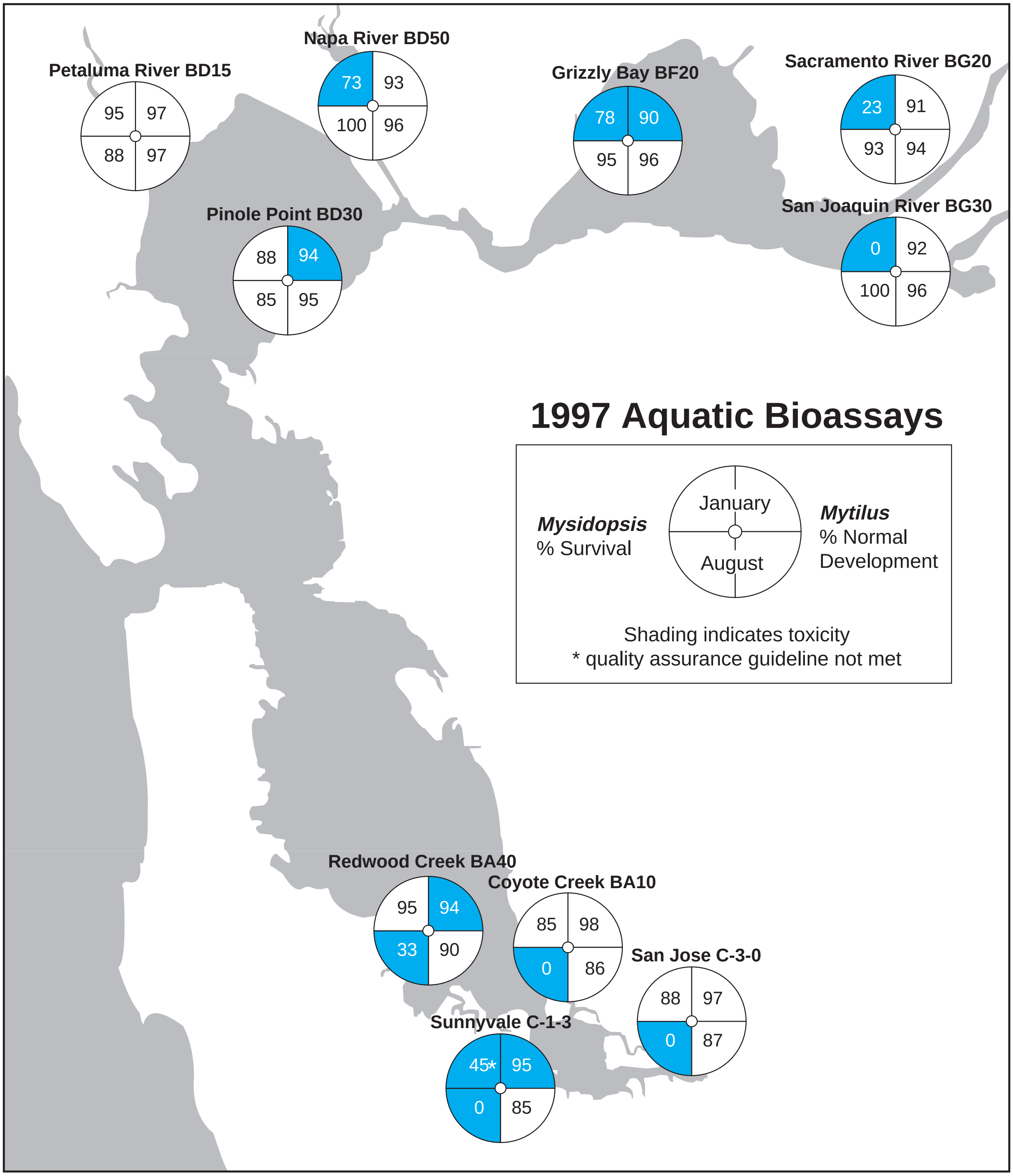


Figure 3.40. Aquatic bioassay results for 1997. Clean artificial seawater was used for control samples. See *Appendix A* for a description of the methods used. Toxicity was determined by statistical comparison to controls. Toxicity in the seven-day *Mysidopsis* test was observed in both January and August at Sunnyvale (C-1-3). However, in the January mysid test at Sunnyvale (denoted by *), toxicity was likely caused by hypoxic test conditions. Mysid toxicity was also observed in January at Napa River (BD50), Sacramento River (BG20), San Joaquin River (BG30), and Grizzly Bay (BF20) and in August at Redwood Creek (BA40), San Jose (C-3-0), and Coyote Creek (BA10). The 48-hour tests using *Mytilus* larvae indicated statistically significant embryo toxicity in January at Sunnyvale (C-1-3), Redwood Creek (BA40), Pinole Point (BD30), and Grizzly Bay (BF20). However, percent normal development at these stations was relatively high. The statistical test was significant because of low variability in the control treatment and probably does not indicate toxicity in the samples.

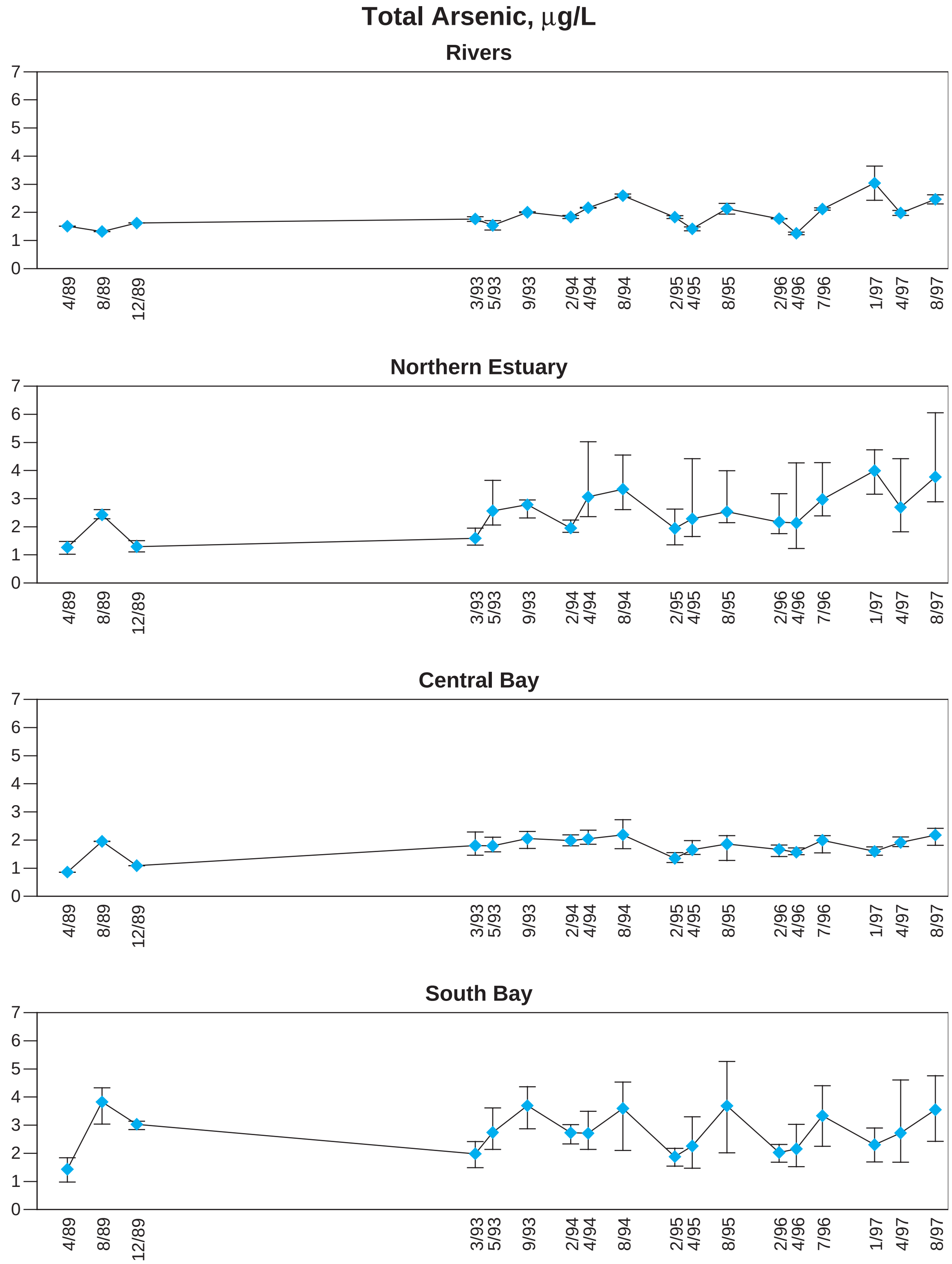


Figure 3.41. Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. The vertical bars represent range of values. The sample size varies between sites and between seasons.

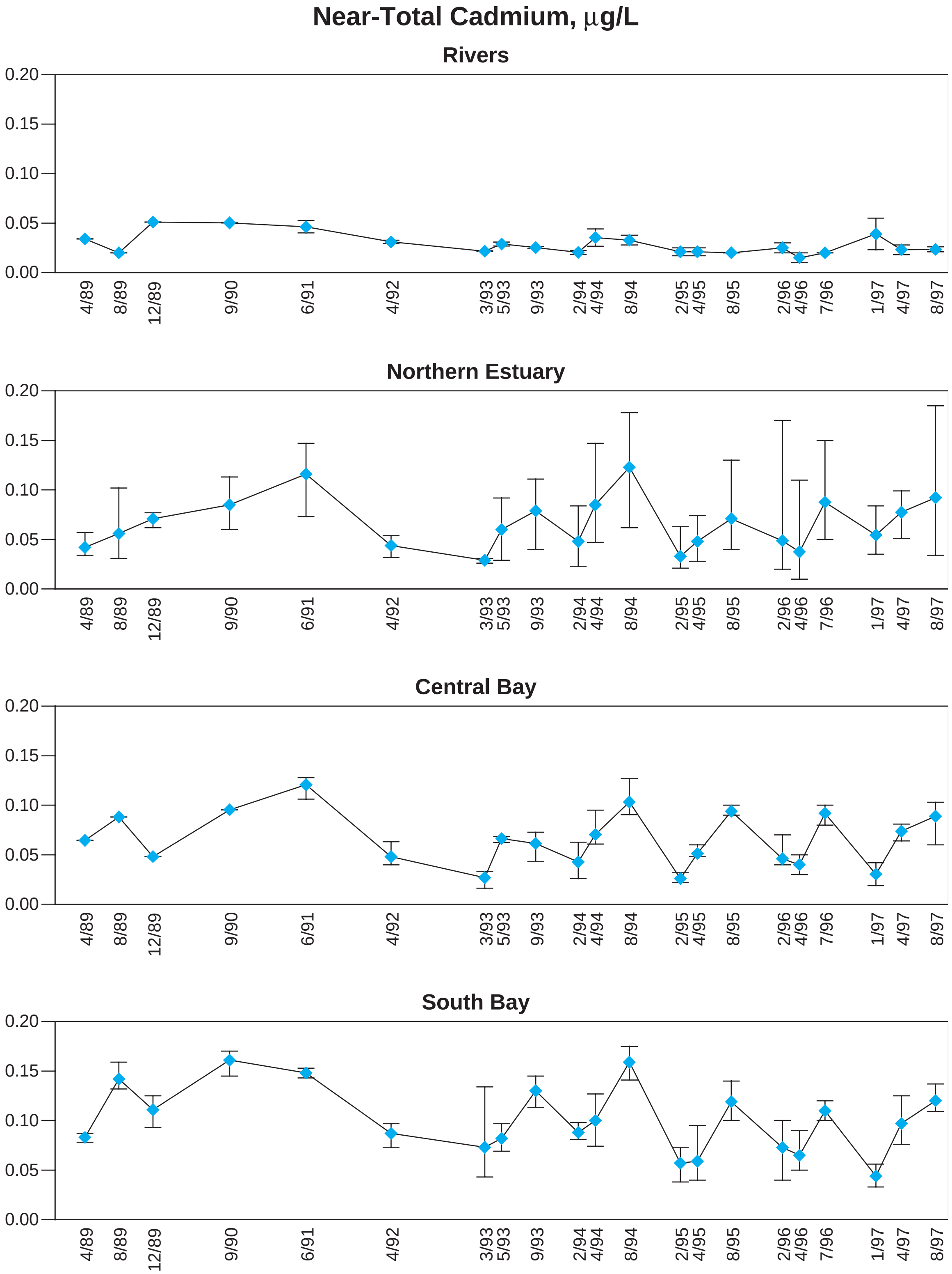


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. The vertical bars represent range of values.

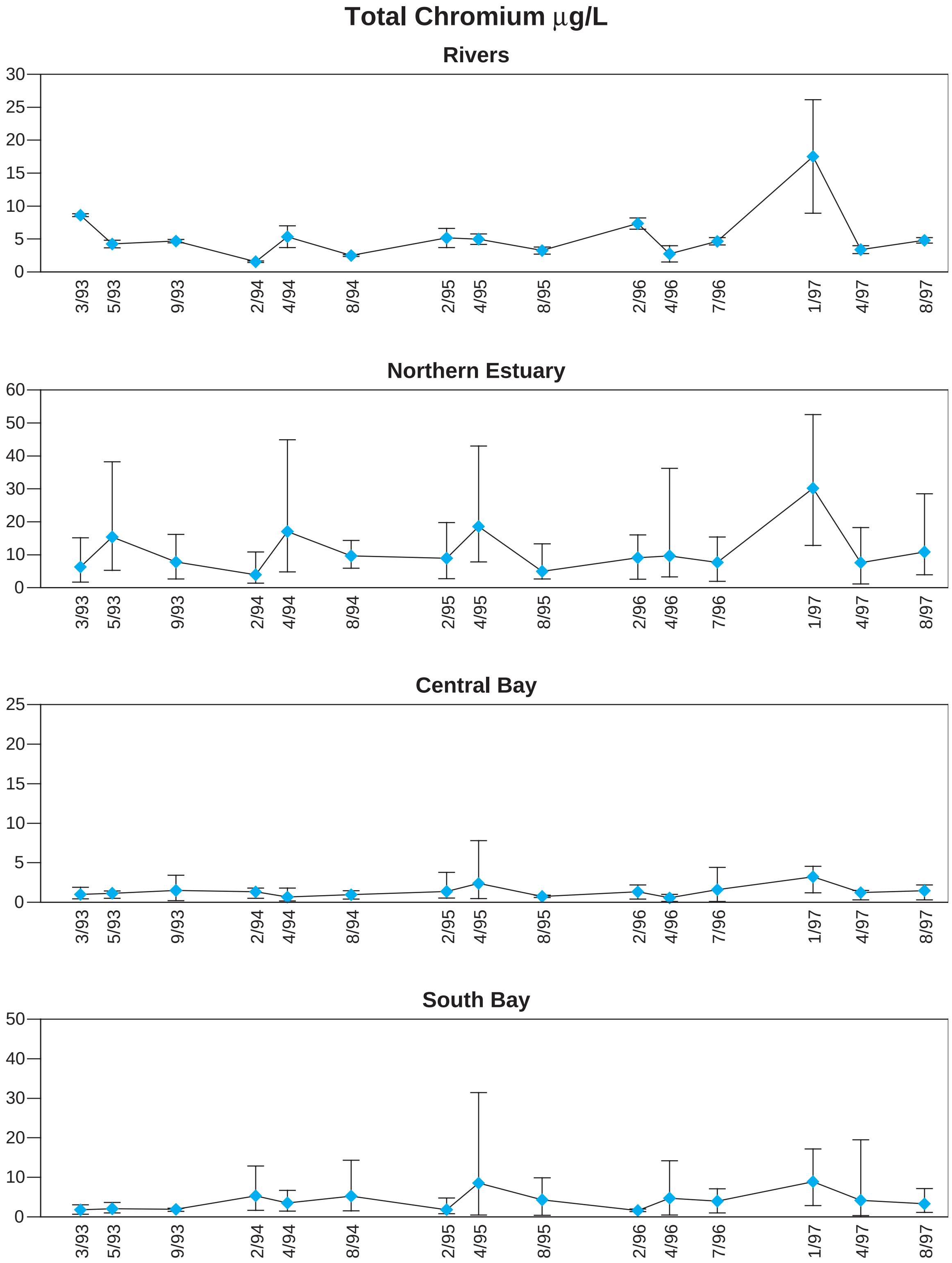
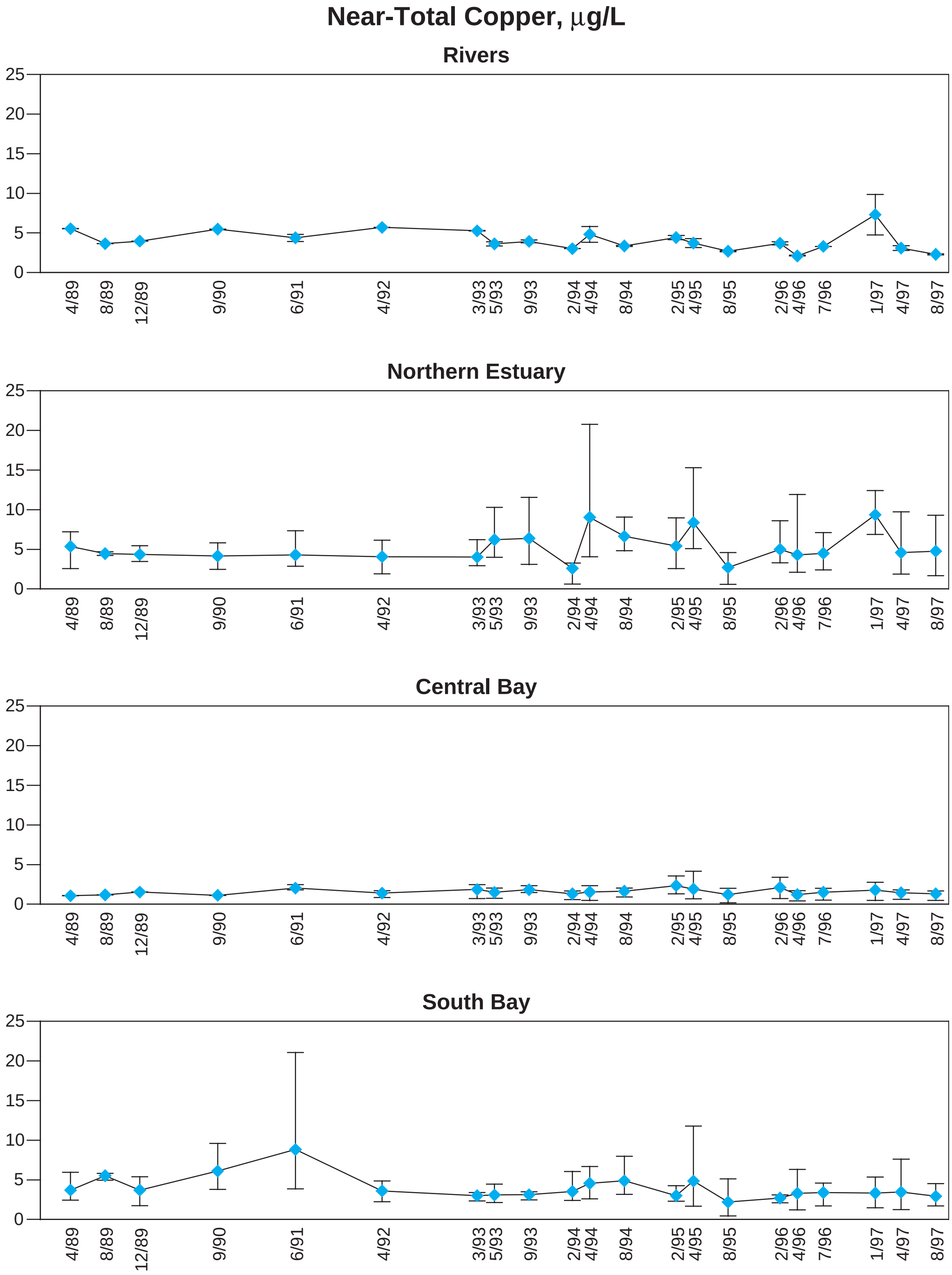


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1993–1997. Note different y-axis scales.The vertical bars represent range of values.



Near-Total Copper, µg/L

Rivers

Northern Estuary

Central Bay

South Bay

Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. The vertical bars represent range of values.

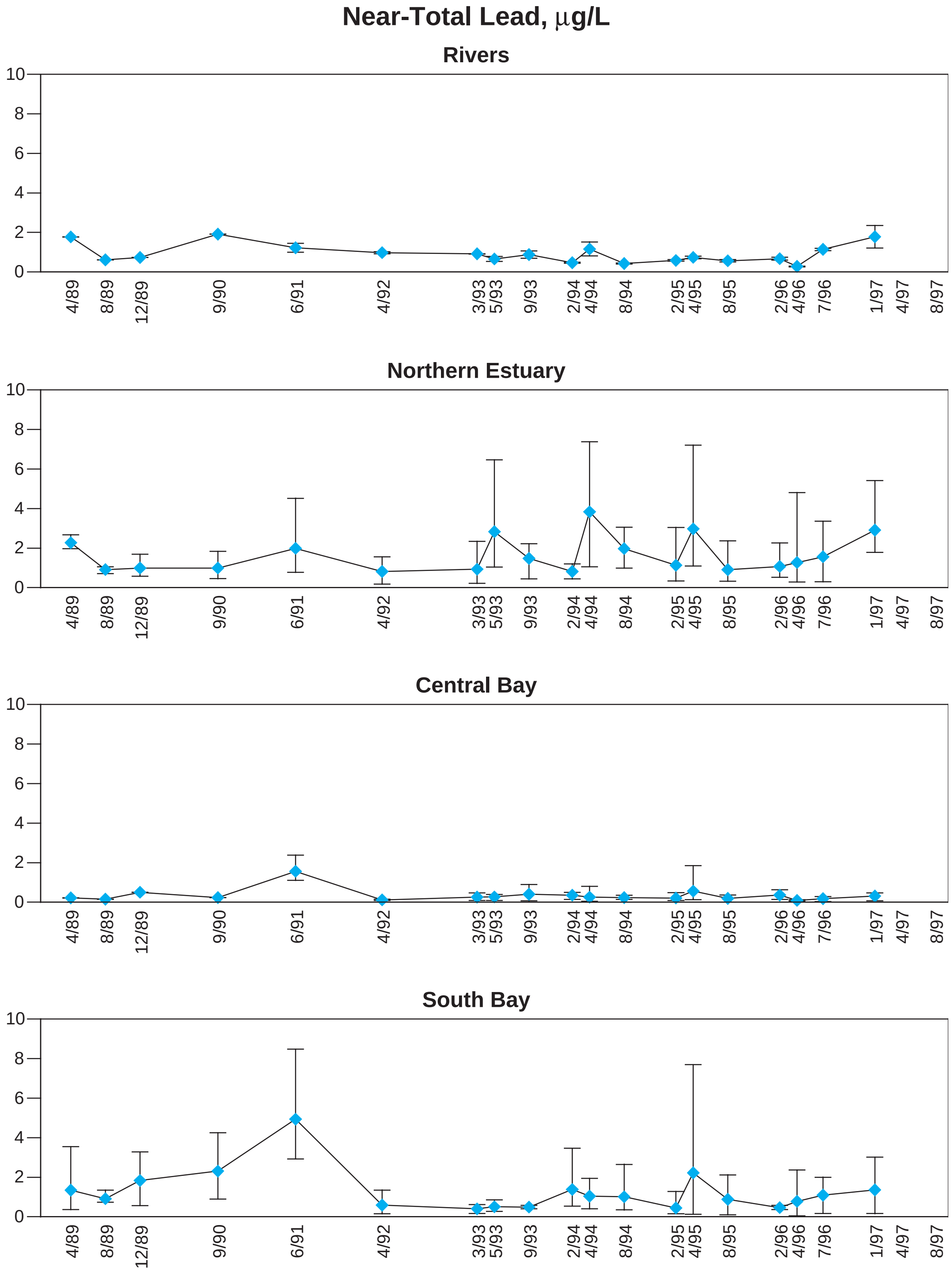


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. The vertical bars represent range of values. Note: Data for lead in April 1997 and August 1997 were not available at the time of report production.

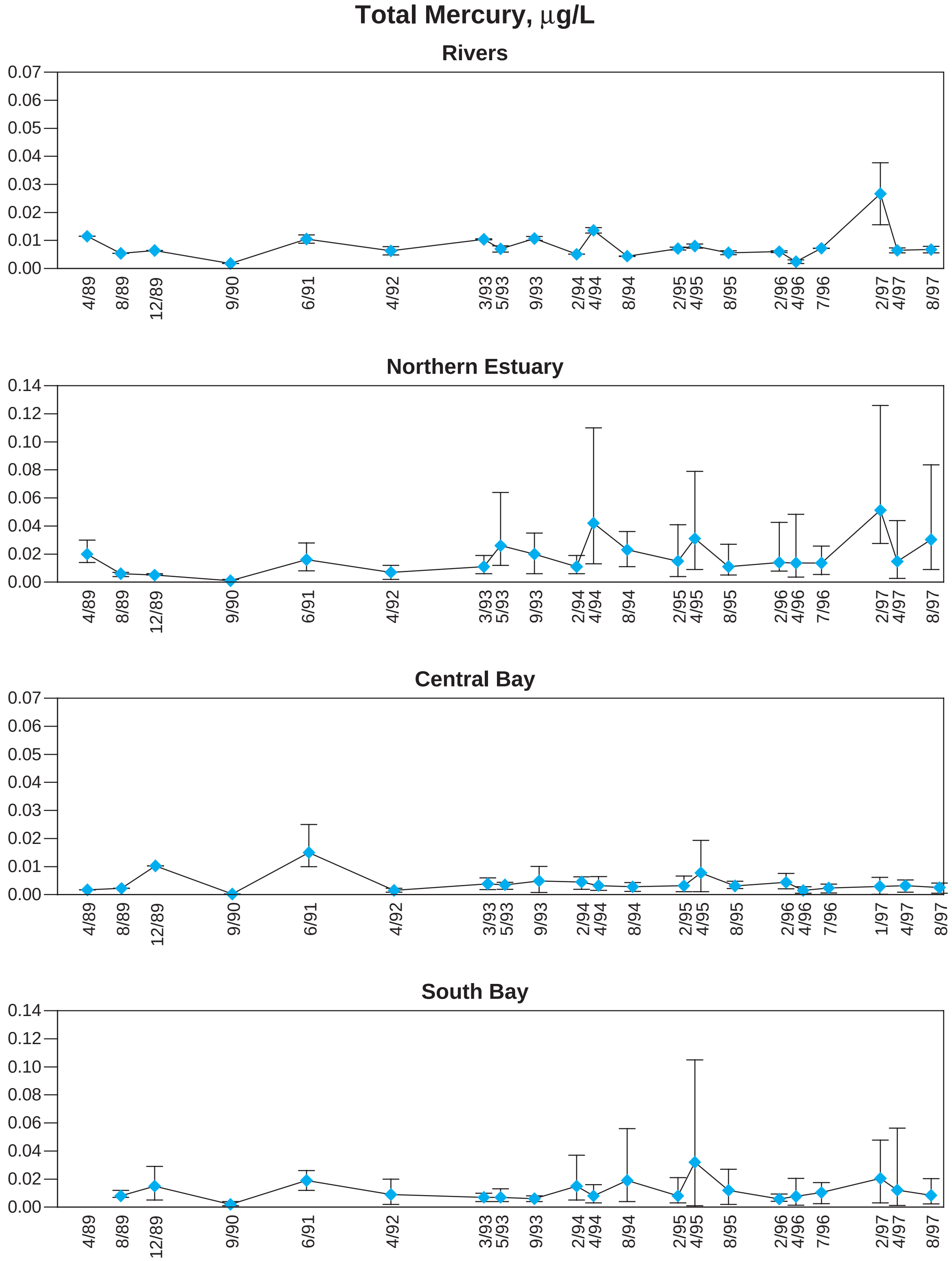


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. Note different y-axis scales. The vertical bars represent range of values.

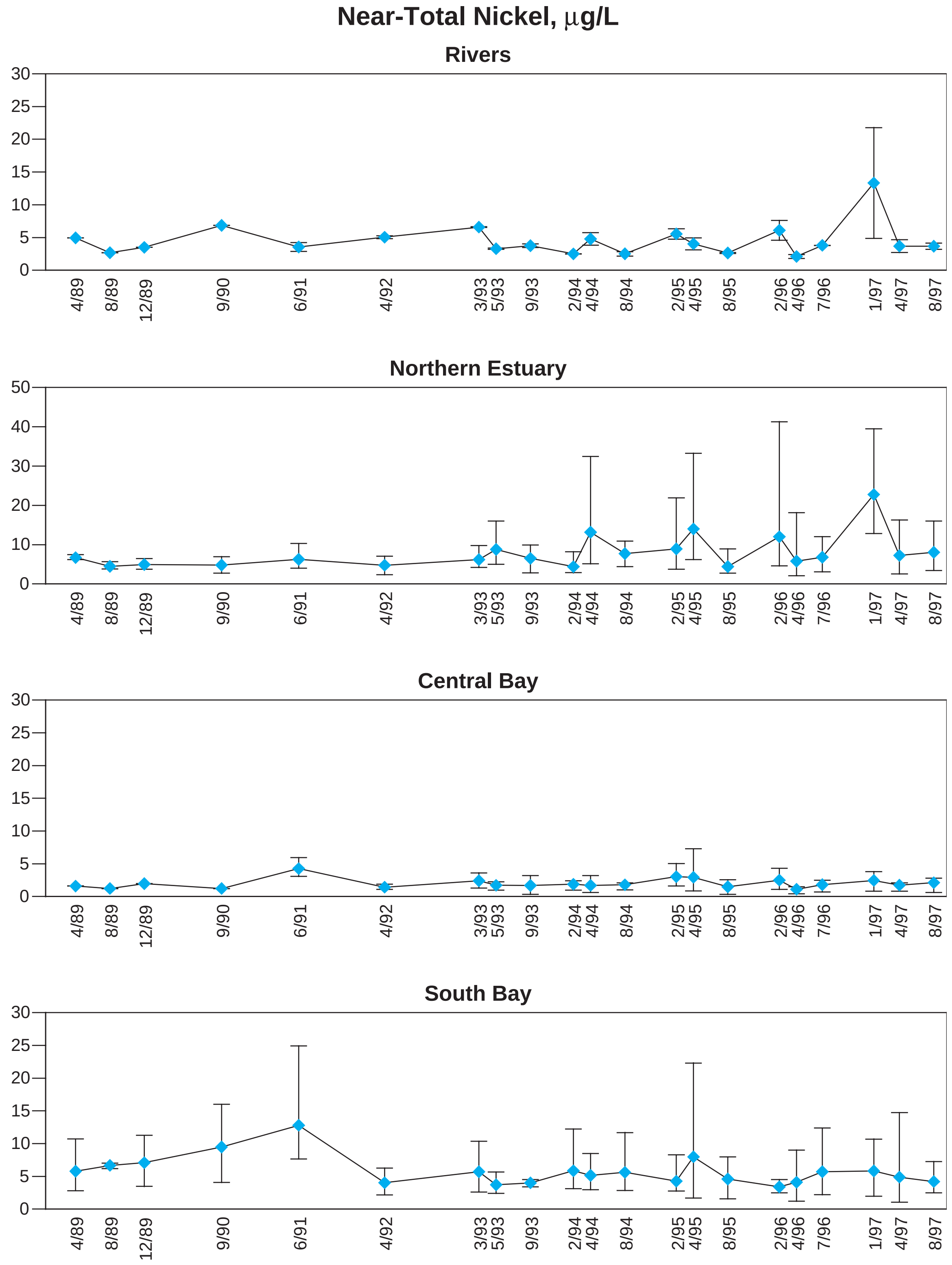


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. Note different y-axis scales. The vertical bars represent range of values.

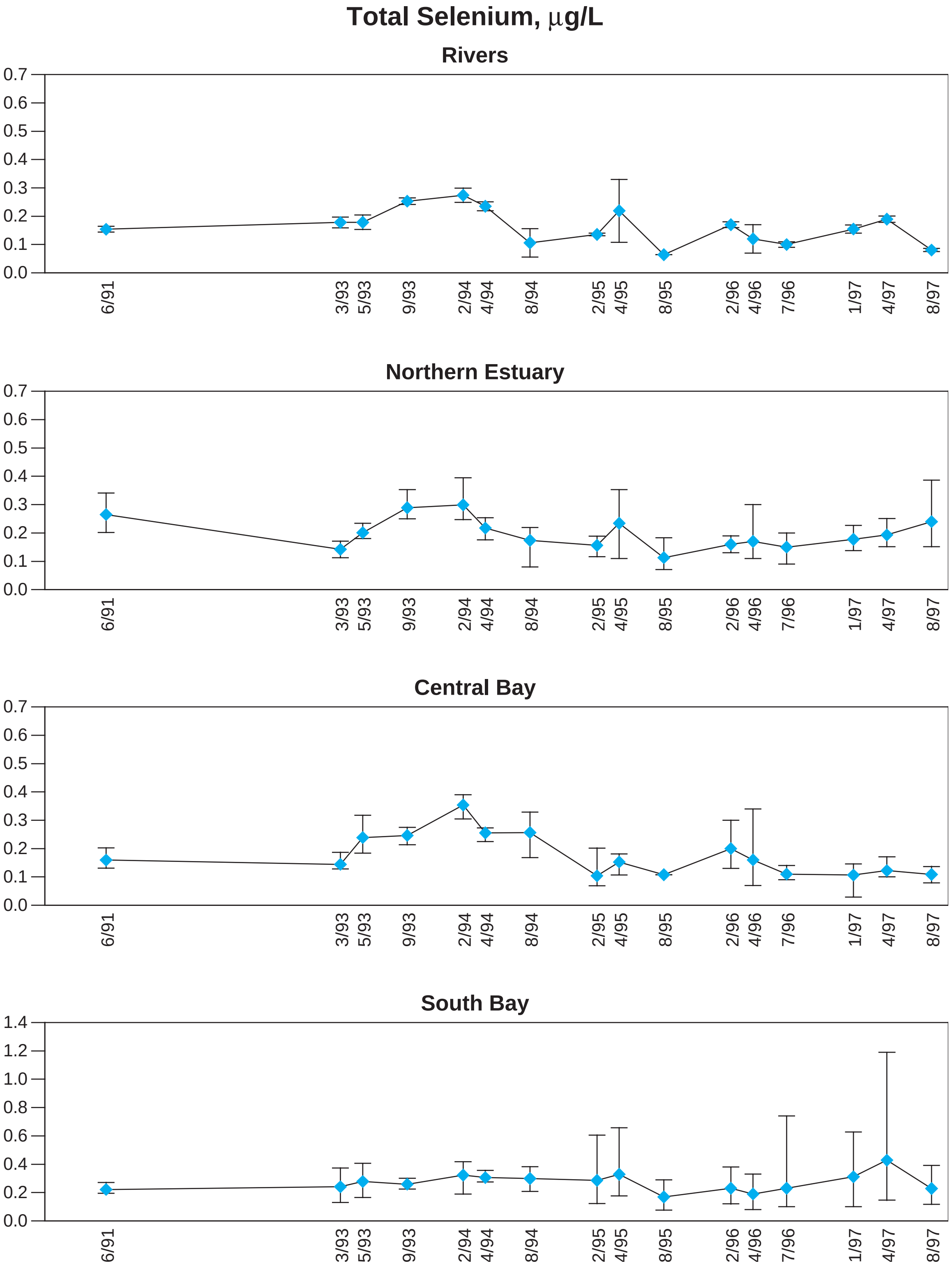


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1991–1997. The vertical bars represent range of values.

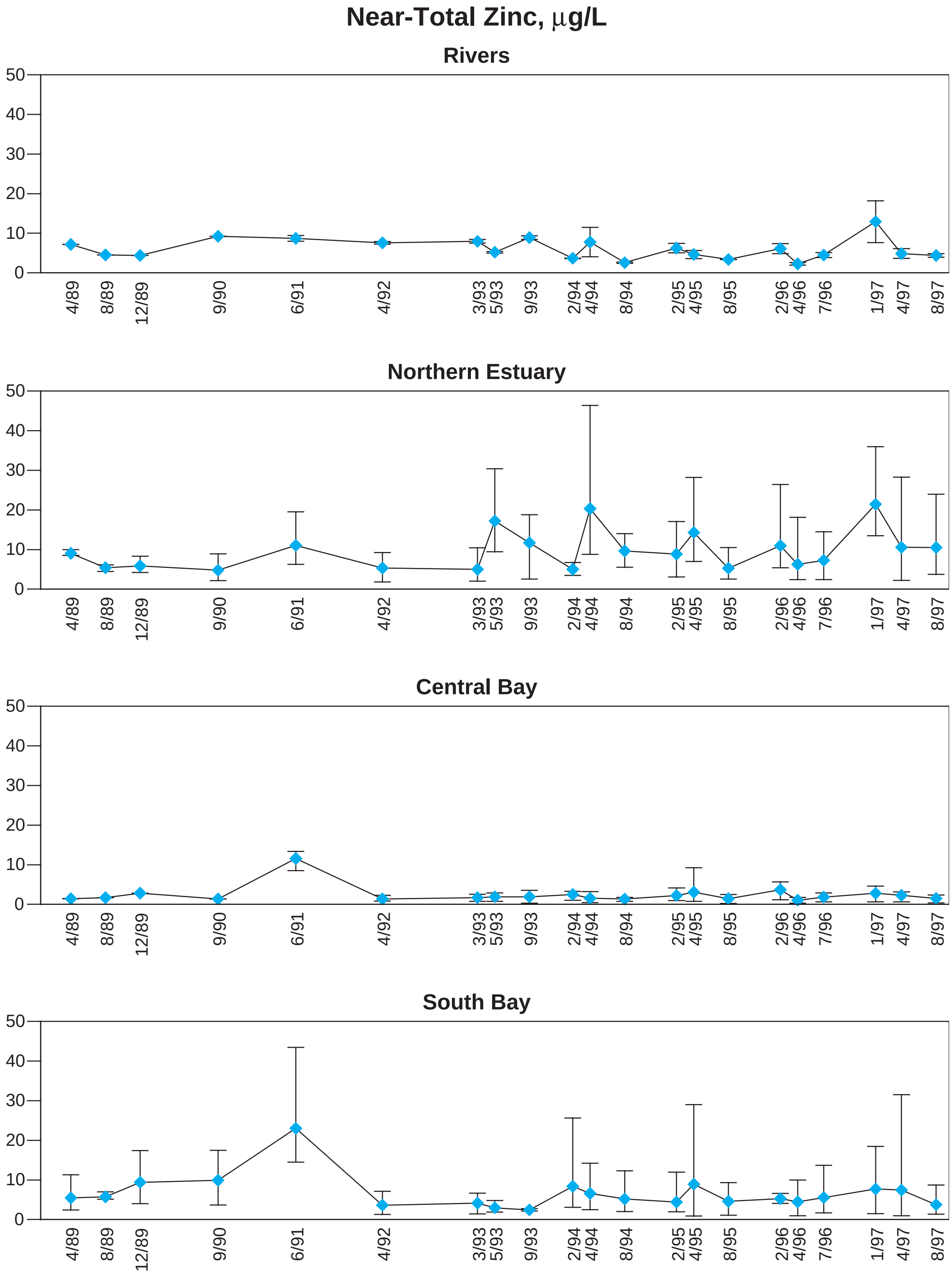


Figure 3.41 (continued). Average trace element concentrations (parts per billion, ppb) in water in each Estuary reach from 1989–1997. The vertical bars represent range of values.

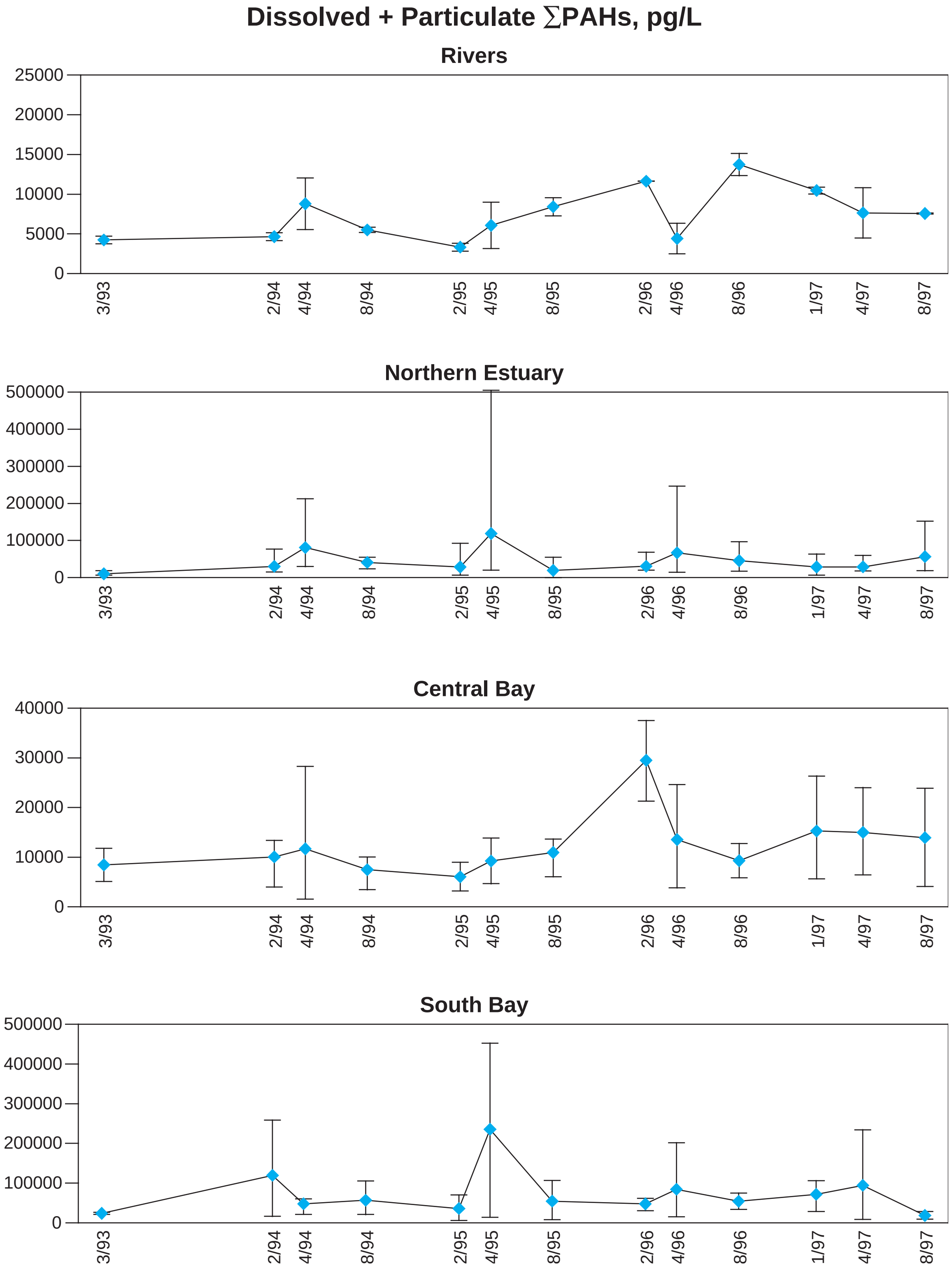


Figure 3.42. Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1993–1997. Note different y-axis scales. The vertical bars represent the range of values. Sample sizes varies between reaches and seasons.

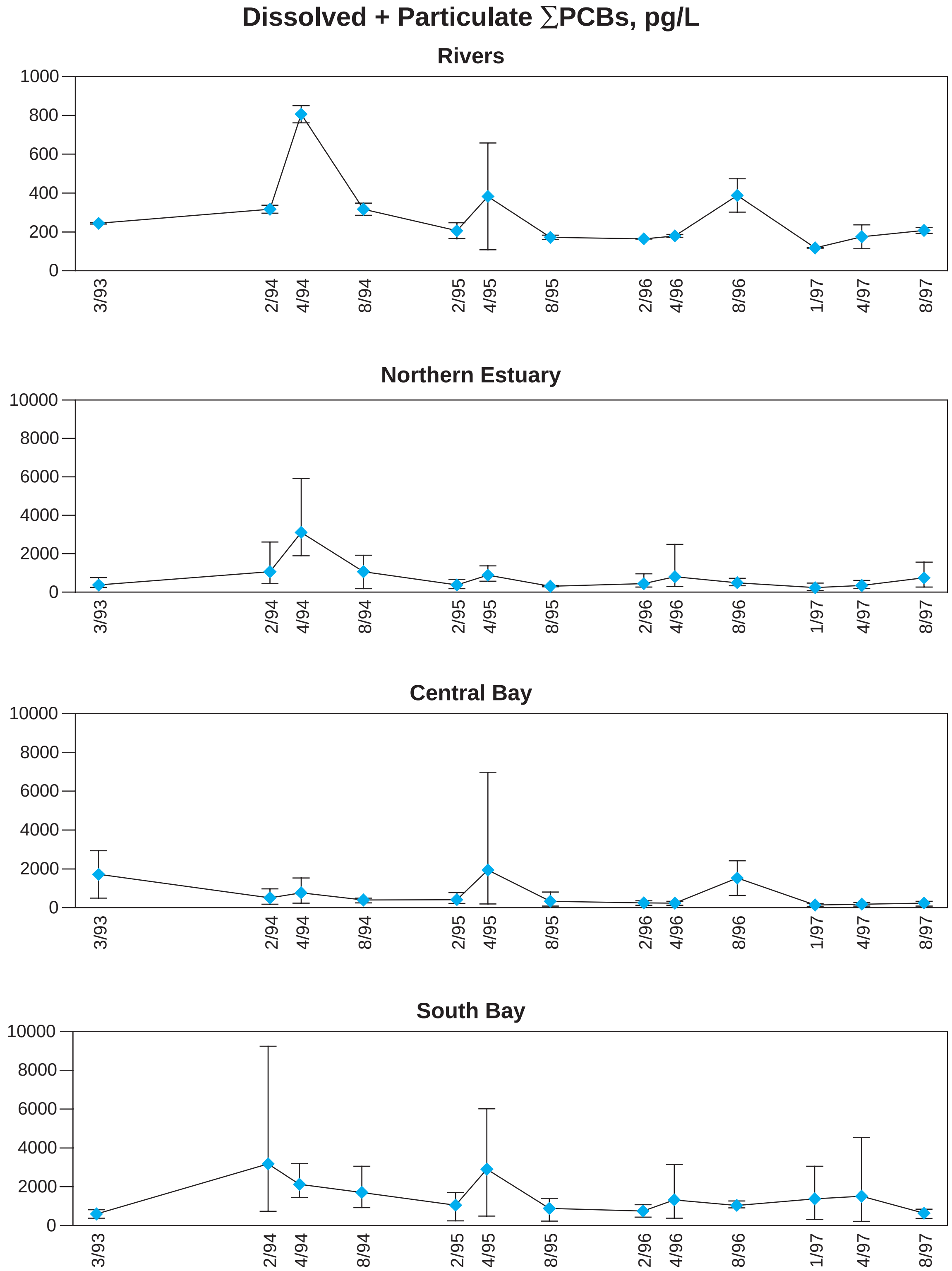


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1993–1997. Note different y-axis scales. The vertical bars represent the range of values.

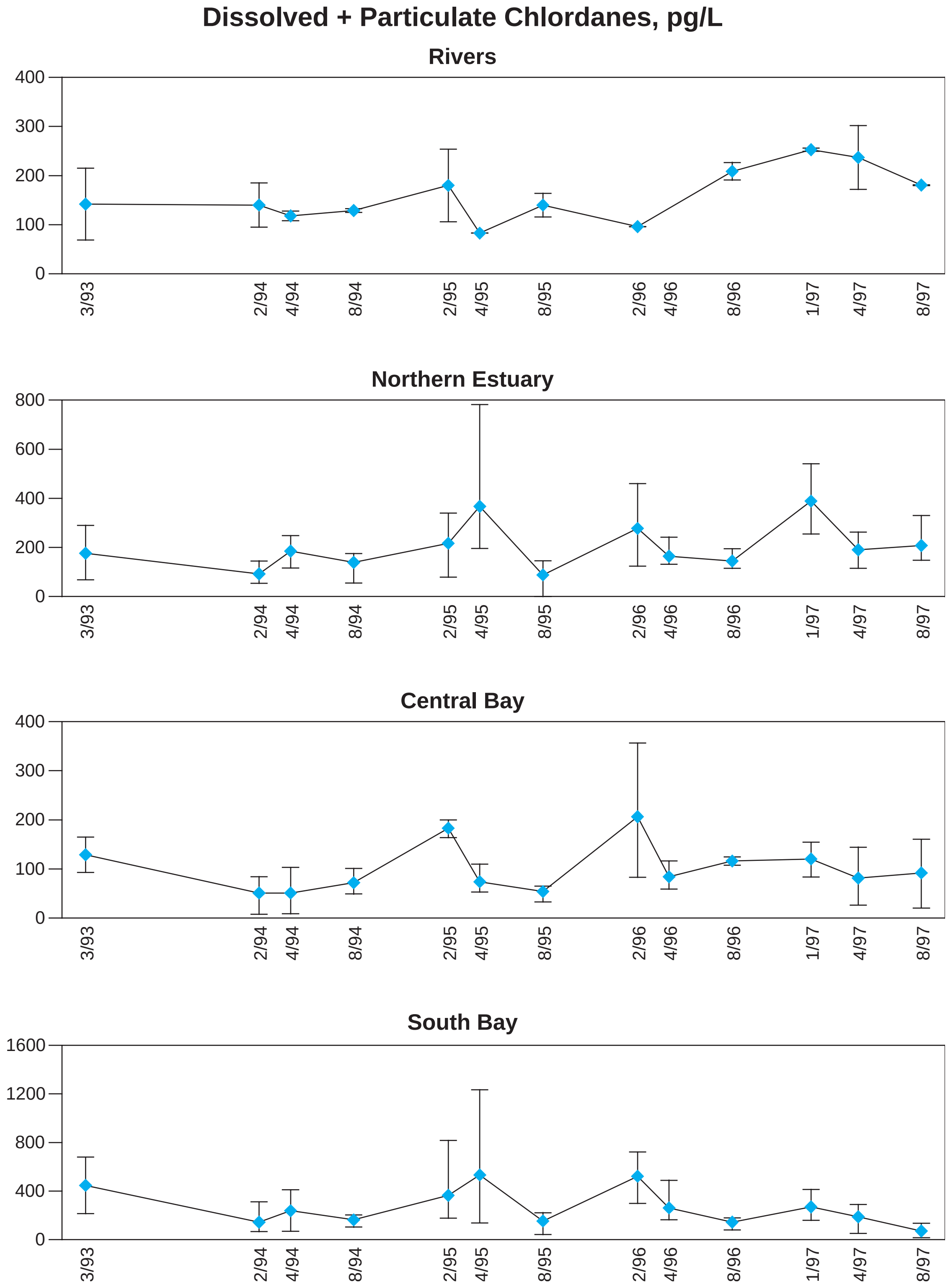


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1993–1997. Note different y-axis scales. The vertical bars represent the range of values.

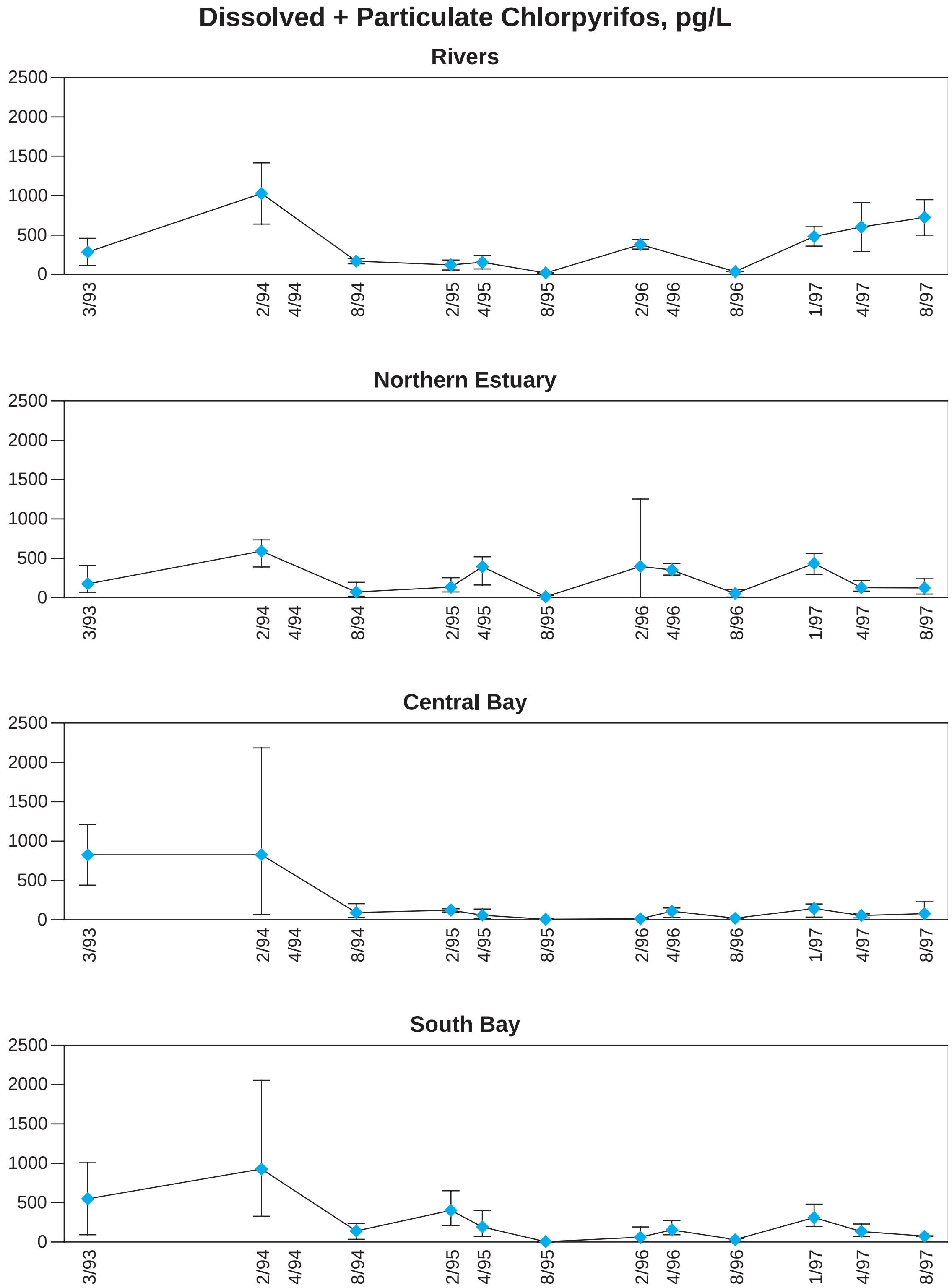
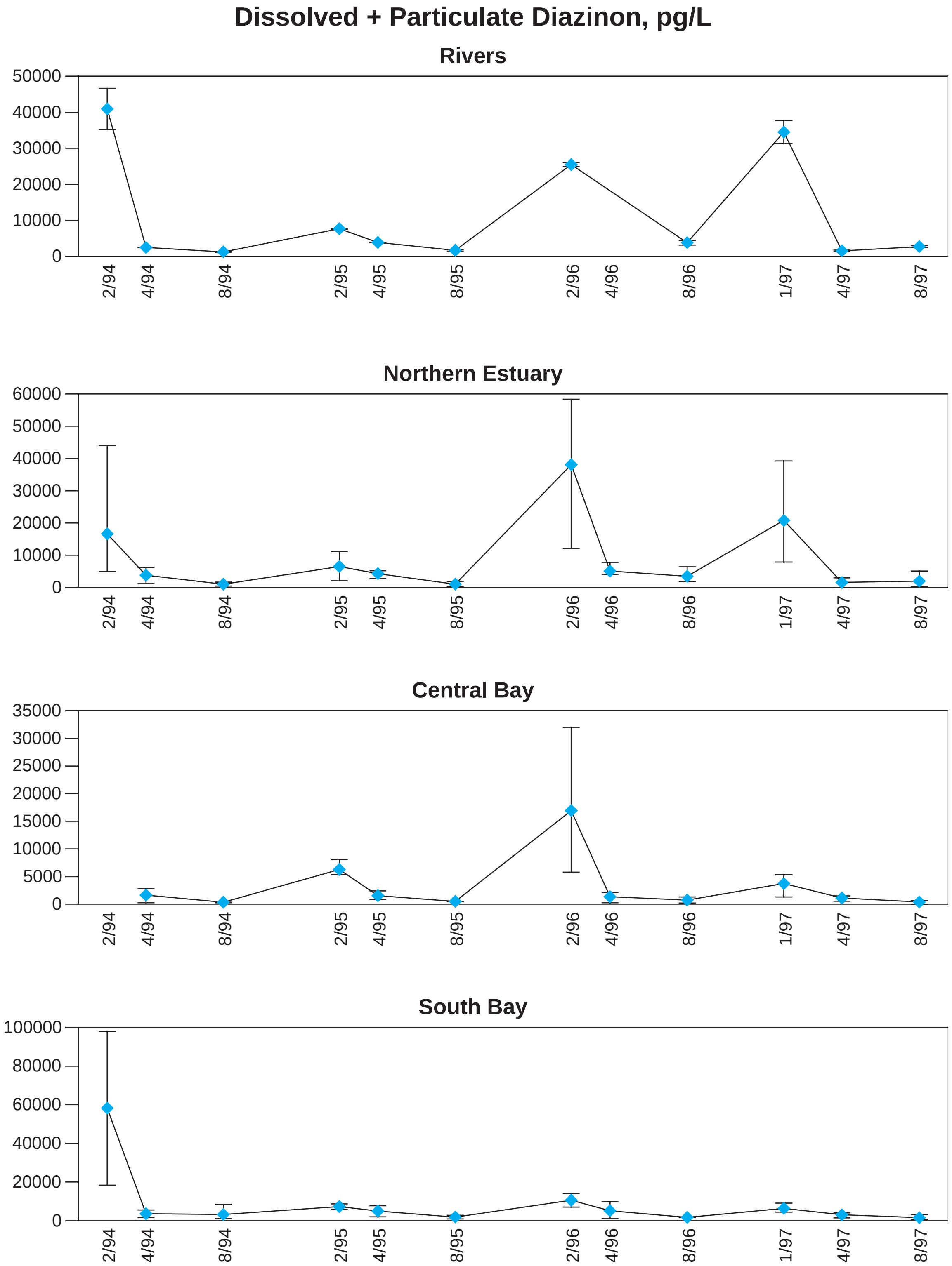


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1993–1997. The vertical bars represent the range of values.



Dissolved + Particulate Diazinon, pg/L

Rivers

Northern Estuary

Central Bay

South Bay

Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1994–1997. Note different y-axis scales. The vertical bars represent the range of values.

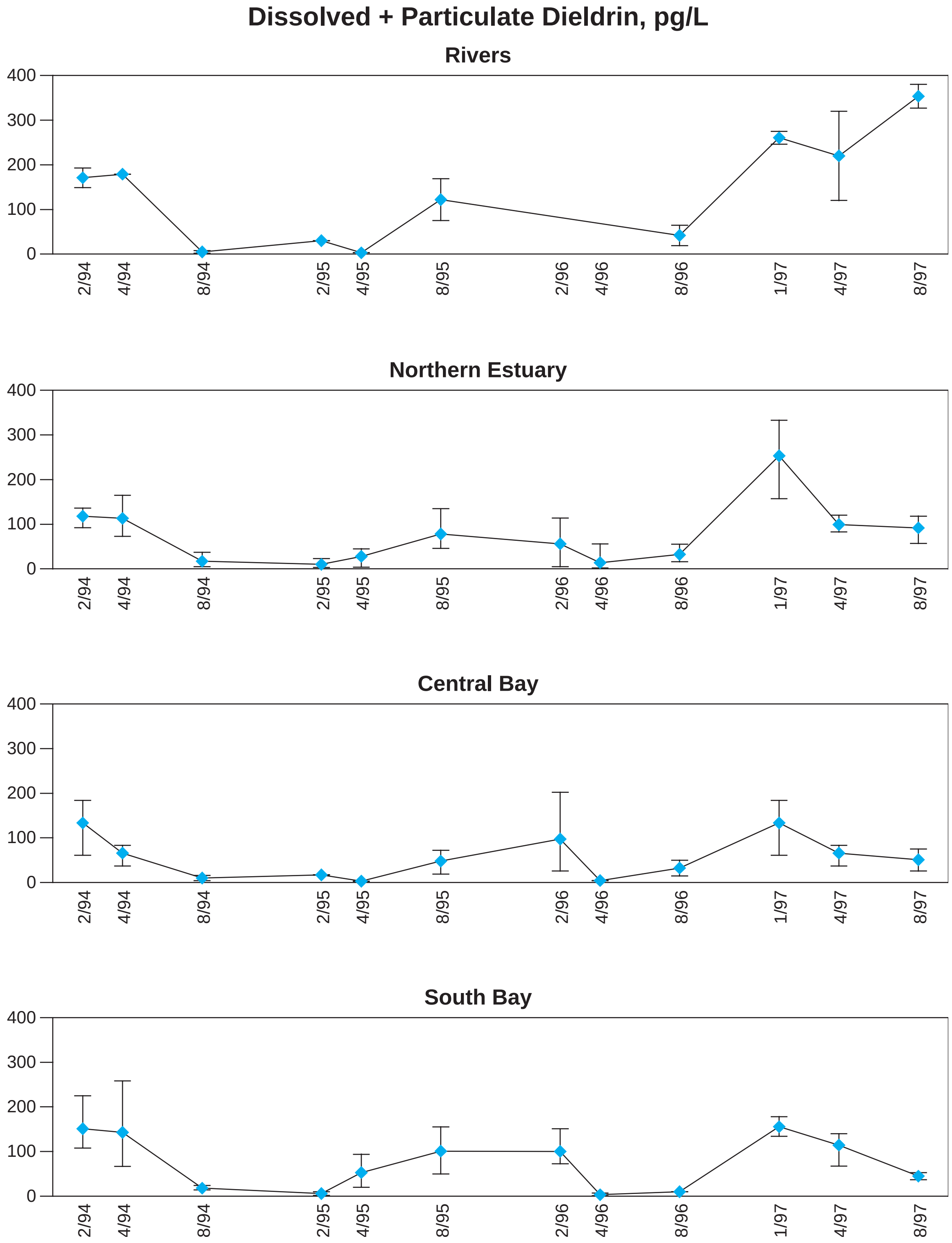


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1994–1997. The vertical bars represent the range of values.

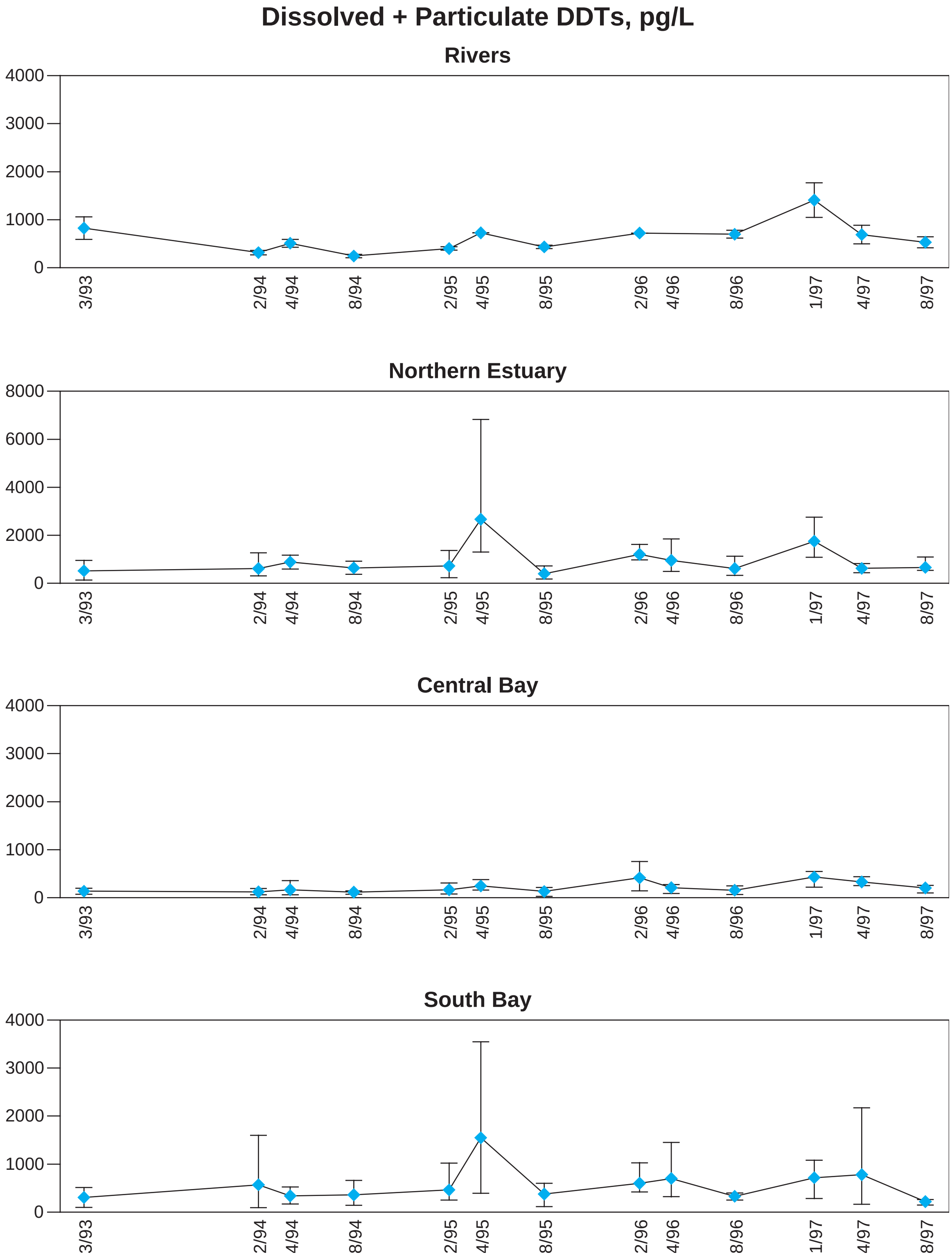


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1993–1997. Note different y-axis scales. The vertical bars represent the range of values.

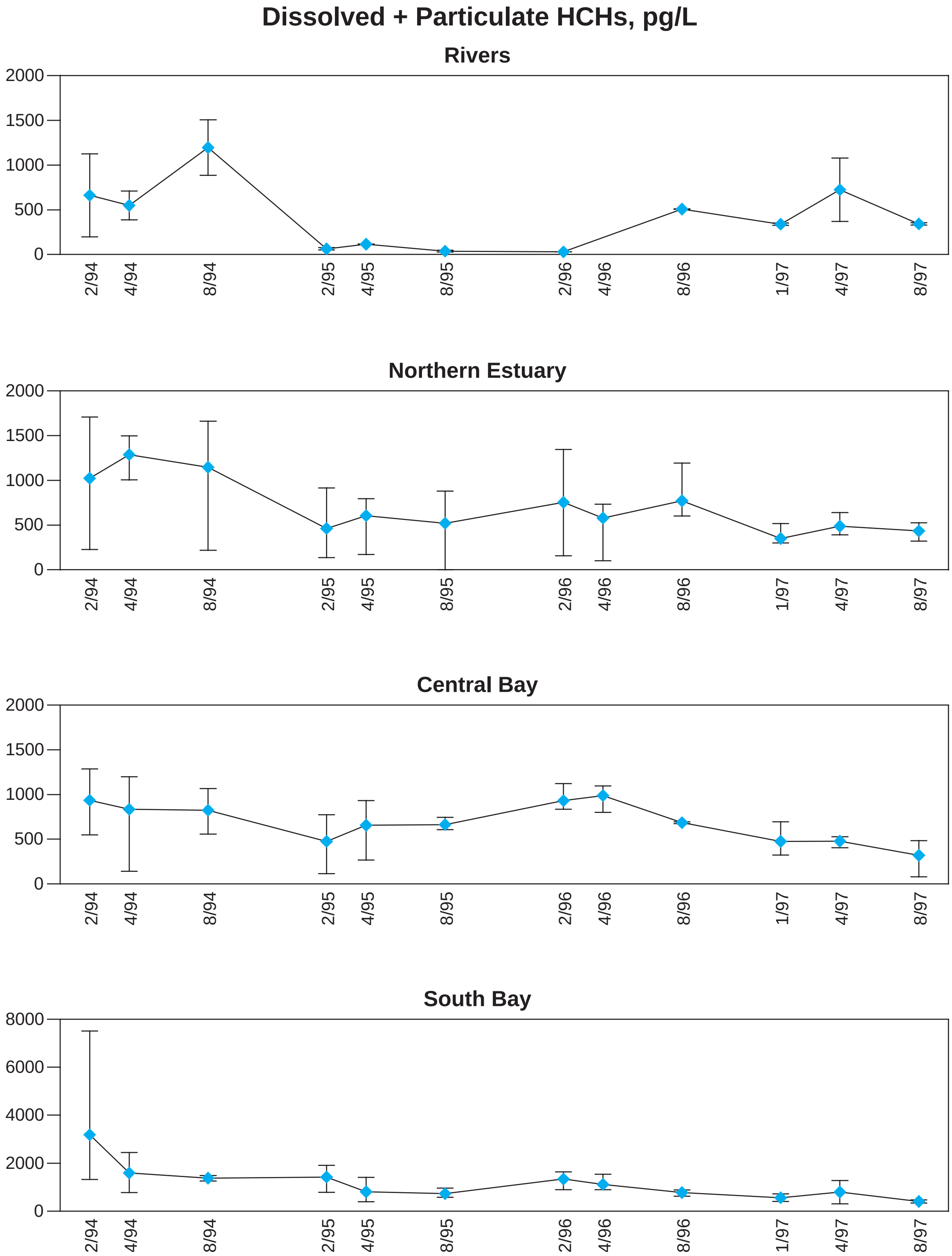


Figure 3.42 (continued). Average dissolved + particulate organic concentrations (parts per quadrillion, ppq) in water for each Estuary reach from 1994–1997. Note different y-axis scales. The vertical bars represent the range of values.

Episodic Toxicity in the San Francisco Bay System

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Background

Monitoring of ambient water toxicity in San Francisco Bay has been an integral component of the RMP since its inception. This monitoring includes collection of ambient waters from throughout the Bay system, exposing test organisms to these waters using a standardized test protocol (as per EPA guidelines, these ambient waters, along with the control water, are adjusted to uniform salinities via addition of artificial sea salts prior to use in testing), and observation of the response of these organisms to these waters. Tests and test species used in this monitoring have included algal growth tests with the diatom *Thallassiosira pseudonana*, bivalve embryo development tests with mussels (*Mytilus* sp.) and oysters (*Crassostrea gigas*), and crustacean survival and growth tests with *Mysidopsis bahia*. RMP ambient water toxicity testing is currently limited to testing with *Mysidopsis bahia*.

During the routine baseline monitoring cruise in the winter of 1995–1996, significant ambient water toxicity was observed throughout the northern San Francisco Bay system (Figure 3.43), with virtually complete mortality of *Mysidopsis bahia* taking place in waters at several of the RMP sampling sites. This was the first observation of significant ambient water toxicity since the inception of the RMP, indicating that, for the most part, the ambient waters in San Francisco Bay are

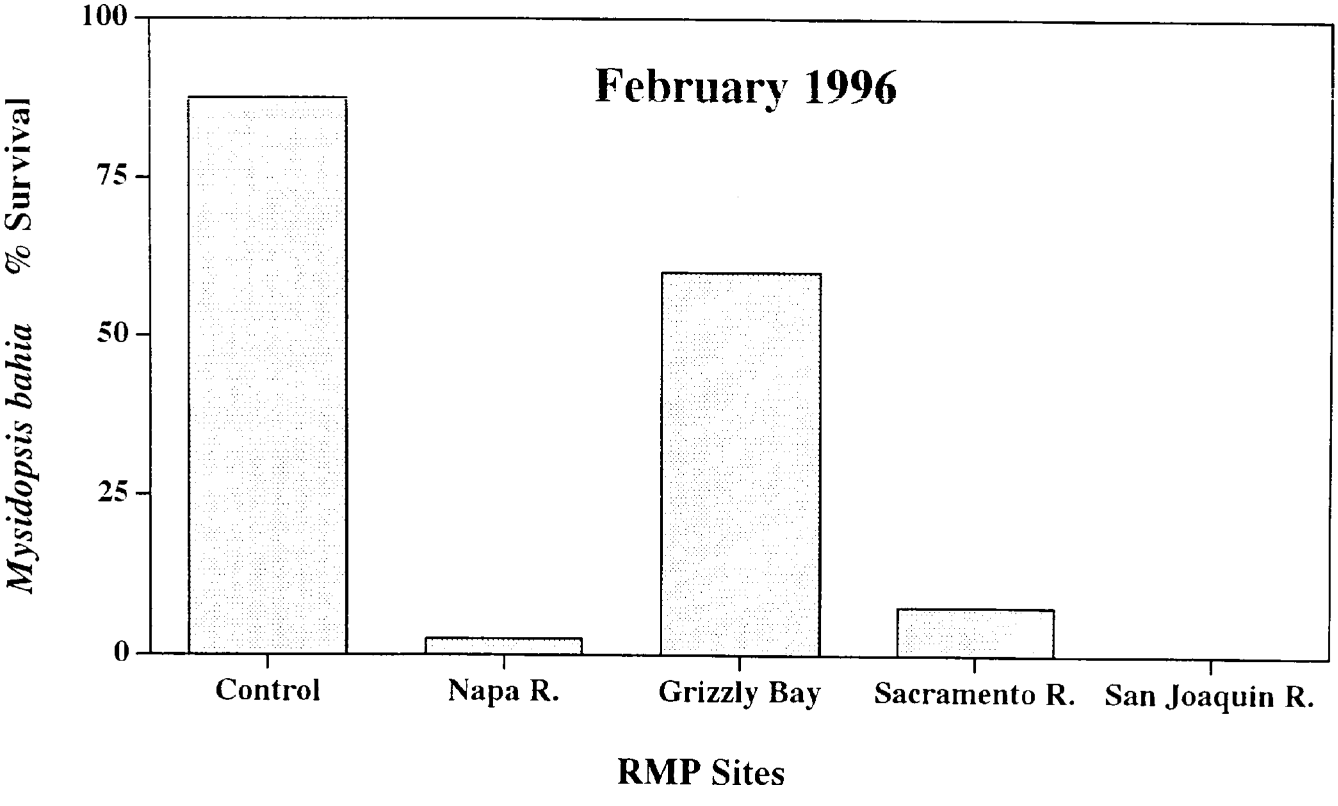

Figure 3.43. North Bay ambient water toxicity to *Mysidopsis bahia* in February 1996.

relatively free of toxicity. However, the fact that these toxic water samples were collected immediately following a major rainstorm event suggested that ambient water toxicity was occurring on small time scales, probably the result of stormwater runoff.

Year One: The Pilot Study

Based upon these observations and hypotheses, a Pilot Study was initiated the following winter to investigate episodic toxicity following rainstorm events. During this initial winter of 1996–1997, samples were collected at the mouths of Guadalupe and Alviso sloughs (Guadalupe River) in the South Bay, and in the Napa River and at Mallard Island in the North Bay. In addition, the baseline cruise sampling and testing in January again occurred on the heels of a major rainstorm event. The goal for the South Bay and Napa River sites was to sample stormwater runoff as it began to mix with estuarine water (as evidenced by elevated salinity). Mallard Island, located at the head of the Estuary near Chipps Island, is an ideal sampling site as it represents the influence of upstream waters (from the Sacramento and San Joaquin watersheds) that flow into the northern Bay system.

The results of the toxicity tests are summarized in Table 3.1.

The rainfall pattern in 1996–1997 was quite unusual, and this influenced the progress of the project. In South Bay samples, toxicity was observed during three storm events. This toxicity is apparently associated with elevated concentrations of the organophosphate pesticide chlorpyrifos.

Heavy rains early in the winter and major flooding on the Sacramento and San Joaquin rivers disrupted the planned sampling and testing at Mallard Island such that there was little opportunity to collect water samples that might be impacted by the upstream activities that take place during a normal water year. None of the few samples collected were toxic. However, the baseline cruise sampling, which occurred after a rainstorm event, revealed significant toxicity at northern Bay sites (Figure 3.44), suggesting that stormwater runoff was resulting in widespread ambient toxicity over a small time scale.

Changes in the Ambient Water Toxicity Monitoring Strategy

Considering the unusually heavy rains and flooding, the results of the Pilot Study were considered interesting enough to initiate a re-evaluation of the overall RMP strategy for monitoring ambient water toxicity. Exemplifying the “adaptive management” approach of the RMP, participants decided to modify the ambient water toxicity testing program. Sampling during the bi-annual baseline cruise was scaled back from thirteen stations to five to six stations in the South Bay and North Bay. The testing itself was reduced from two species to one species (*Mysidopsis*), from testing a partial dilution series to testing at the 100% ambient water concentration only, and from monitoring of survival and growth as test endpoints to monitoring of survival only. The resulting savings in resources was re-allocated to increase

Table 3.1. Summary of RMP episodic toxicity testing pilot project, 1996–1997.

	Napa River	**Guadalupe Slough and River**	**Mallard Island (Runoff[a])**
Number of Tests	2	16	4
Tests with Significant Toxicity to Mysid Shrimp	0	3	0

[a] Sampling was conducted in response to rainstorm events; additional sampling that was non-storm related is not reported here.

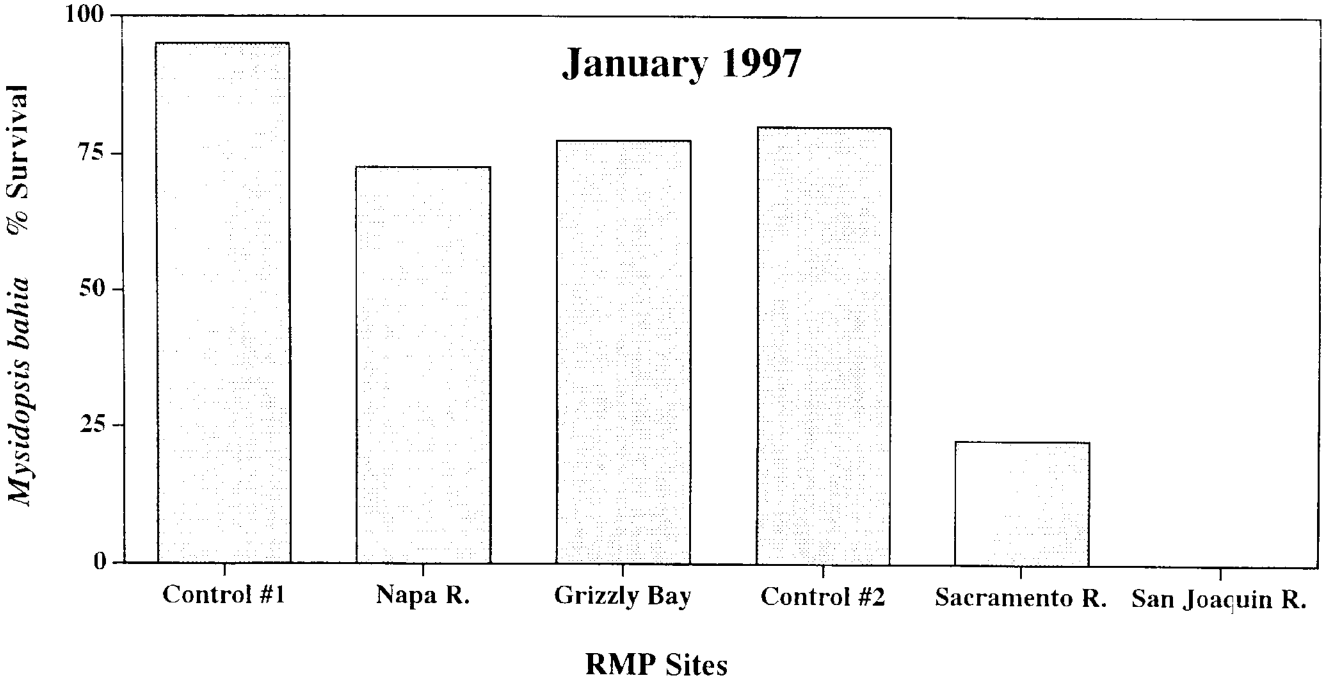

Figure 3.44. North Bay ambient water toxicity to *Mysidopsis bahia* in January 1997. Control #1 is for the Napa River and Grizzly Bay tests; Control #2 is for the Sacramento and San Joaquin River tests.

the level of episodic monitoring during the winter of 1997–1998 with the following objectives:

- Document the frequency and duration of toxic episodes in the North Bay.
- Expand the spatial extent of urban stormwater runoff monitoring in the Bay system.

In order to address the first objective, water sampling at Mallard Island was modified and increased to collection of three samples per week for a continuous four-month period covering winter and spring (February through May), with each sample being tested for toxicity on an individual basis. Using this approach, the frequency of short-term toxic events could be determined; equally as important, the observation of toxicity in consecutive samples could be used to infer that the ambient waters in the North Bay were continuously toxic over this same time period. Prior to this continuous sampling, Mallard Island water samples were collected only following storm events in October though December, followed by biweekly sampling in January.

In order to address the second objective, urban creek stormwater runoff sampling and testing was expanded to include the mouth of Pacheco Slough which drains the Concord-Pleasant Hill-Walnut Creek area. Unlike other major urban creek drainages (e.g., Alameda Creek, Guadalupe Slough, etc.), the Pacheco Slough drainage has not yet been subjected to stormwater runoff toxicity characterization, particularly downstream in the mixing zone with Bay water. Water samples were collected here, as well as in Guadalupe Slough, immediately following storm events.

Episodic Toxicity During the Winter-Spring of 1997–1998

The results of the toxicity testing performed during the winter and spring of 1997–1998 are summarized in Table 3.2.

A total of fourteen storm events were sampled at Guadalupe Slough, two of which resulted in significant mysid mortality (50% or greater). Of the fourteen water samples collected, eight had elevated concentrations of diazinon and/or chlorpyrifos (as measured by ELISA analysis). In one of the toxic Guadalupe Slough water samples, the measured chlorpyrifos concentration exceeded the reported acute LC_{50} for *Mysidopsis bahia*.

Table 3.2. Summary of RMP episodic toxicity testing, 1997–1998.

	Guadalupe Slough	Pacheco Slough	Mallard Island
Number of Tests	14	13	70
Tests with Significant Toxicity to Mysid Shrimp	2	5	10

However, in the other toxic sample, the measured concentrations of diazinon and chlorpyrifos were below toxic levels, suggesting that other contaminants were responsible for the observed toxicity.

Pacheco Slough

A total of thirteen storm events were sampled at Pacheco Slough, five of which resulted in statistically significant mortality, although only one toxic sample exhibited greater than 50% mortality. Of the thirteen water samples collected, ten had measurable concentrations of diazinon and/or chlorpyrifos. In one of the toxic Pacheco Slough water samples, the measured chlorpyrifos concentration exceeded the reported acute LC_{50} for *Mysidopsis bahia*. However, in the other four toxic samples, the measured concentrations of diazinon and chlorpyrifos were below toxic levels, again suggesting that other contaminants were responsible for some of the observed toxicity.

Mallard Island

Ambient water samples were collected at Mallard Island and tested from October 9, 1997 through May 30, 1998 (the results of these tests are summarized in Figure 3.45). Of the seventy water samples collected, ten resulted in significant mysid mortality (eight of which exhibited > 50% mortality). More importantly, there were two time periods, February 12–17 and May 5–9, during which three consecutive water samples were toxic, suggesting that the ambient waters in North Bay were similarly toxic for at least two extended time periods during this monitoring effort.

In order to save costs, ELISA analysis was not performed routinely on the water samples collected from Mallard Island. We believe that the greatest likelihood of elevated pesticide concentrations in these ambient waters will be during stormwater runoff events; therefore, diazinon and chlorpyrifos were measured in the Mallard Island water samples only following significant rainstorms and at the same time that Guadalupe and Pacheco Slough water samples were being analyzed. Only two of the toxic water samples from Mallard Island had diazinon or chlorpyrifos concentrations that exceeded the reported LC_{50}. In six of the toxic water samples, including two of the three consecutively toxic samples in February, both diazinon and chlorpyrifos were below the ELISA detection limit (well below the LC_{50}s), indicating that other contaminants were responsible for the observed toxicity.

Summary and Conclusions

The Regional Monitoring Program has been assessing aquatic toxicity of ambient waters in the San Francisco Bay system two or three times annually since 1993. It is now known that variations in contaminant concentrations occur on smaller time scales due to events, such as urban runoff following rainstorms or from similar surface runoff following application of pesticides in agricultural areas, and our monitoring has revealed significant toxicity coincident to such events. Moreover, this year's monitoring has indicated that the North Bay waters may be toxic for extended periods of time, perhaps as long as a week, following such events. This observation is even more problematic given that at least one important resident invertebrate, the crustacean *Palaemon macrodactylus*, is reported to be even more sensitive to these pesticides than *Mysidopsis*. While there is a growing body of information (including these RMP studies) that suggest that pesticides in surface water runoff may cause toxicity to invertebrates in waters within the Sacramento-San Joaquin River basins and the San Francisco Estuary, no link has yet been conclusively established. Long-term studies of zooplankton distribution and abundance in the Sacramento-San Joaquin Delta have reported significant declines in zooplankton, with recent zooplankton densities being one to two orders of magnitude lower than in the early 1970s. Use of pesticides such as diazinon and chlorpyrifos has increased substantially since their introduction in the 1950s and 1960s, suggesting a possible link between pesticide toxicity and zooplankton declines.

Maintaining healthy, viable invertebrate communities in the San Francisco Estuary is and should be an objective in and of itself. However, it can be argued that an even more important role for these invertebrate resources is as food for key fish populations. Numerous studies have documented that virtually all of the important fish populations in the San Francisco Estuary rely upon these invertebrates, particularly during their vulnerable early life stages. If pulses of toxicity through this ecosystem diminish the available invertebrate resources at critical periods, such as when larval fish are using the invertebrates for food, then adverse effects on fish populations can be expected. This potential problem is of paramount importance as the period of high pesticide concentrations in these waters (January–June) coincides with the presence of early life stages of most of the fish populations currently in decline.

While pesticides, particularly diazinon and chlorpyrifos, are most commonly linked with ambient water toxicity in the Estuary, it must be pointed out that several of the water samples which were toxic in our study had diazinon and chlorpyrifos concentrations well below levels reported to be toxic. This indicates that other contaminants are also contributing to the observed toxicity problems. A future objective of studies investigating the ambient water toxicity in this Estuary should be the characterization and identi-

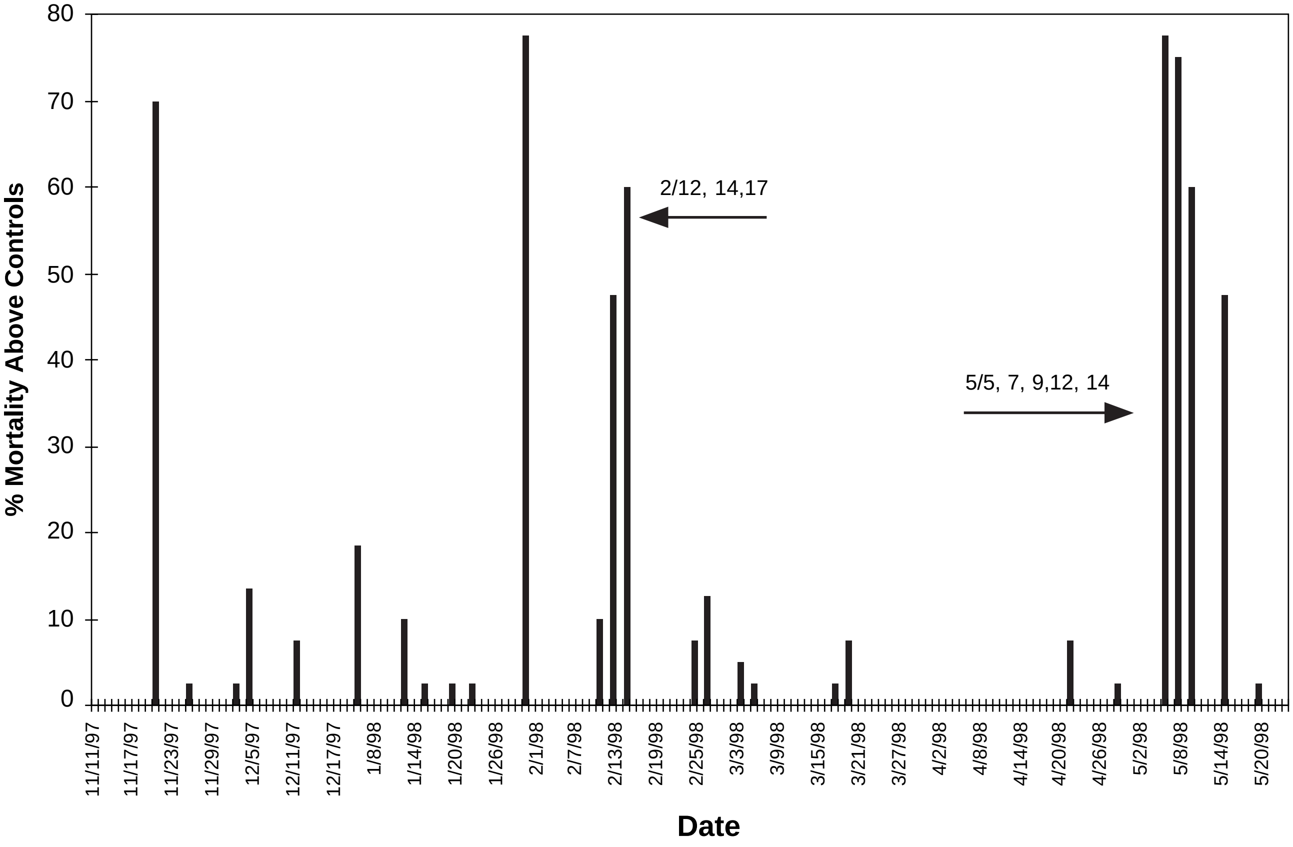

Figure 3.45. Mysid mortality at Mallard Island, 1997–1998.

fication of these other toxicants using the toxicity identification and evaluation (TIE) process.

Finally, while many of the urban creek watersheds have been studied, and while our own monitoring is beginning to provide a clearer picture of ambient water toxicity apparently resulting from Sacramento-San Joaquin River (and possible 'within Delta' sources) surface water runoff into northern San Francisco Bay, other significant inputs into the Bay, such as the Napa River or Petaluma River, have yet to be as well studied. Therefore, an additional objective of future studies should be the characterization of possible ambient water toxicity resulting from contaminant input from these other watersheds that include both urban and agricultural land uses.

Water-Quality Variability in San Francisco Bay: General Patterns of Change During 1997

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Introduction

One goal of the Regional Monitoring Program (RMP) is to determine seasonal and annual trends of variability in the chemical and biological water quality of the San Francisco Estuary. The United States Geological Survey (USGS) maintains a program of monthly water-quality measurements to supplement RMP monitoring done three times each year. This element of the RMP is designed to describe the changing spatial patterns of water-quality variability from the lower Sacramento River to the southern limit of the South Bay. Five water-quality parameters are measured as descriptors of the chemical-biological status of the Estuary, and as indicators of the key processes that control the concentration, chemical form, or biological availability of toxic contaminants.

A second objective of the RMP is to determine long-term trends in the concentrations of trace elements and organic contaminants in the San Francisco Estuary. This objective poses a difficult challenge because estuaries have large natural variability that acts as noise around any signals of water quality improvement or degradation over time. Progress toward this second objective will require innovative approaches for characterizing the natural variability of biological and chemical conditions in the Estuary, and then separating these natural fluctuations from any trends of change. In this chapter we summarize results of the USGS measurement program for 1997, and use these results to illustrate the general patterns of water-quality change caused by natural processes of variability in the San Francisco Bay-Delta ecosystem. Identification of these patterns, and their underlying mechanisms, is an important step in the determination of trends of change in trace contaminants.

The Measurement Program Design

This element of the RMP characterizes water quality in the deep channel of the Bay-Delta system. It includes measurements at a series of fixed stations spaced every 3–6 km, from Rio Vista (lower Sacramento River, Figure 3.46), through Suisun Bay, Carquinez Strait, San Pablo Bay, the Central Bay, and the South Bay to the mouth of Coyote Creek. Vertical profiles are taken at each station, so this measurement program provides two-dimensional (longitudinal-vertical) descriptions of spatial structure. Sampling along the 145 km transect requires 12–15 hours, so measurements are taken at varying phases of the semidiurnal tide cycle. Although it is logistically difficult to synchronize sampling to a constant tidal phase, we minimized the effects of intratidal variability by sampling near the periods of monthly minimum tidal energy when possible. Therefore, this sampling program is biased toward neap tide conditions, and it is confounded by intratidal variability during the course of sampling. Sampling is confined to the central channel, so it does not measure directly the transverse component of water-quality variability across the broad shoals. However, sampling along the axial transect does describe variability along the estuarine salinity gradient, and it provides an integrative picture of all the processes occurring upstream, in adjacent marshes and lateral shoals, due to point source discharges, and within the local water column (Jassby *et al.*, 1997). Sampling

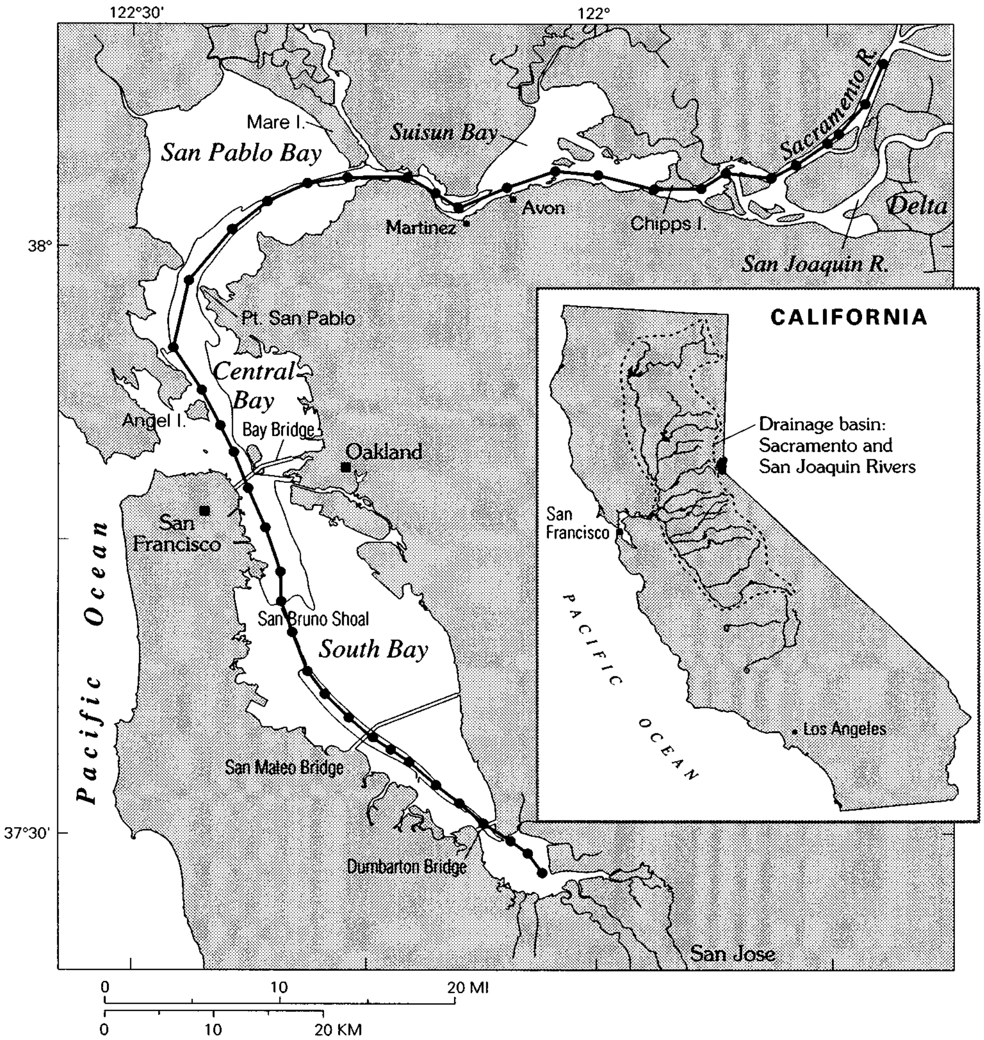

Figure 3.46. Map showing locations of USGS sampling stations along the axial transect of the San Francisco Bay-Delta, from the lower Sacramento River to the southern South Bay. Distances along the transect are referenced as positive values for the North Bay and negative values for the South Bay (see Figures 3.47–3.51), starting at station 18, south of Angel Island.

Table 3.3. Dates of USGS water-quality sampling in the San Francisco Bay-Delta in 1997. Listed for each date are the range of station numbers, and a description of the spatial sampling: SB = South Bay only, NBSB = North Bay and South Bay.

Date, 1997	Station Range	Coverage
13 January	36–9	NBSB
28 January	36–657	NBSB
14 February	36–21	SB
19 February	36–21	SB
26 February	36–657	NBSB
6 March	36–21	SB
11 March	36–21	SB
17 March	36–21	SB
25 March	36–21	SB
1 April	36–21	SB
10 April	36–21	SB
22 April	36–657	NBSB
30 April	36–21	SB
14 May	36–657	NBSB
10 June	36–657	NBSB
15 July	36–657	NBSB
5 August	36–657	NBSB
9 September	34–657	NBSB
7 October	36–657	NBSB
6 November	33–657	NBSB

was done once each month along the entire North Bay-South Bay transect. More frequent sampling was done in the South Bay to follow the dynamic water-quality changes caused by the spring phytoplankton bloom (Cloern, 1996), such as depletion of dissolved metals (Luoma *et al*., 1998). Sampling dates for 1997 are listed in Table 3.3.

Water Quality Parameters

This element of the RMP measures five water-quality parameters, each reflecting a different set of processes that cause estuarine variability. Salinity measures the relative proportion of freshwater and seawater, and the salinity distribution reflects the changing importance of river flow as a source of dissolved materials carried into the Bay-Delta from the Estuary's watersheds. Water temperature is an independent indicator of mixing, and an important control on biological transformations of reactive trace substances. The concentration of suspended particles (as total suspended solids, TSS) changes in response to the alternating tidal cycles of sediment deposition and resuspension, episodic wind-driven resuspension, and riverine inputs of new sediments during periods of high flow. These processes are relevant to the RMP because many trace substances are reactive with particle surfaces, so the pathways of transport, retention, and incorporation of these contaminants into the food web are influenced by the transport of sediments. For example, RMP data show strong correlations between suspended solids concentration and the concentration of total mercury in San Francisco Bay waters (Schoellhamer, 1997). This USGS measurement program provides information about the large-scale changes in the spatial distribution of TSS associated with river inputs. Variability at shorter time scales is characterized by the continuous measurements of TSS by moored instruments at fixed locations (Schoellhamer, 1996).

The phytoplankton community represents the single largest component of living biomass in San Francisco Bay, and we measure the distribution of chlorophyll *a* as an index of this biomass. Unlike salinity and TSS, chlorophyll *a* is a nonconservative quantity that changes in response to processes of production and consumption, as well as inputs and transports. The production of phytoplankton biomass involves the uptake of inorganic forms of elements (including carbon, nitrogen, phosphorus, and some trace metals) dissolved in the water, and then transformation of these inorganic raw materials into new organic matter packaged as algal cells. The partitioning of reactive elements between dissolved and particulate forms can be highly influenced by the phytoplankton community in San Francisco Bay (Cloern, 1996; Luoma *et al*., 1998), and chlorophyll *a* concentration is a simple indicator of the potential for these biotransformations.

We measure dissolved oxygen (DO) concentration as an indicator of the net trophic status of the Estuary. If the oxygen content of water is undersaturated (less than that at equilibrium with atmospheric oxygen), then oxygen is being consumed by the biota faster than it is produced by photosynthesis (community respiration exceeds primary production). Supersaturation of oxygen occurs when the photosynthetic production of oxygen within the Estuary is faster than all the processes of consumption. Therefore, DO concentration is an index of the balance between production and oxygen consumption, a key descriptor of the status of the ecosystem. Episodes of DO supersaturation occur during periods of rapid phytoplankton primary production when the inorganic forms of elements (carbon, nitrogen, phosphorus, silicon, cadmium, etc.) are rapidly removed from solution and converted into particulate form. Therefore, DO provides a useful indicator of the rate of phytoplankton-mediated transformations of reactive elements and compounds in the water column. Whereas chlorophyll *a* measures the abundance (or biomass) of the phytoplankton, DO measures the activity level of the phytoplankton community.

Methods

Data for this RMP element were collected with an instrument package that includes sensors for measuring: sampling depth, conductivity, temperature, salinity (calculated from conductivity and temperature), TSS (optical backscatter sensor), chlorophyll *a* (fluorometer), and DO (oxygen electrode). The instrument package is lowered through the water column, taking measurements about every 4 cm. Here, we report only the measurements made in the upper meter of the water column, calculated as the mean of all measurements made between 0.5 m and 1.5 m. The complete data set, including measurements made at all depths, is available as a data report (Baylosis *et al.*, 1998) or over the Internet at the USGS website that archives and displays results of the water-quality program at http://sfbay.wr.usgs.gov/access/wqdata/.

The conductivity and temperature sensors were calibrated by Sea-Bird Electronics prior to the first sampling in January 1997. The optical backscatter sensor, fluorometer, and oxygen electrodes were calibrated each sampling date with analyses of water samples. Surface samples were collected by pump, and bottom samples were collected with a Niskin bottle. Aliquots were analyzed for: TSS (gravimetric method of Hager, 1993); chlorophyll *a* (spectrophotometric method of Lorenzen, 1967, using the equations of Riemann, 1978); and dissolved oxygen (automated Winkler titration, following Granéli and Granéli, 1991). Values reported here are calculated quantities based on daily calibrations of the optical backscatter, fluorescence, and oxygen sensors from linear regressions of measured concentrations versus voltage output of each instrument.

1997 Results

The Year of the Big Storm

Residents of northern California will remember 1997 as the year of the Big Storm, a three-day period of record precipitation and river flow centered on New Year's Day. The New Year's storm was preceded by high precipitation in December 1996, when runoff was about three times the December mean. Roos (1997) describes the event:

> Record streamflow, especially the 3-day flood volumes, were produced in many of the major rivers. The sheer volume of runoff exceeded the flood control capacity of Don Pedro and Millerton reservoirs in the central Sierra foothills, sending large amounts of excess water down the Tuolumne and San Joaquin rivers. Most other foothill reservoirs made releases that brought rivers downstream up to maximum flood design capacity. Major flooding occurred along the uncontrolled Cosumnes River southeast of Sacramento, on the Tuolumne River near Modesto, and the San Joaquin River near Fresno.

Roos estimates that runoff during January 1997 was about 390 percent of the average, and probably a record for the month. He ends his description:

> The New Year's Day storm is one for the record books. December 1996 and January 1997 are the two wettest consecutive months on record for the northern Sierra 8-station average, with a combined total of 47.6 inches of precipitation.

January 1997 was followed by very dry periods in February and March, so the 1997 record of Delta outflow into the San Francisco Estuary was characterized by exceptional outflows in January, receding outflows in February and March, and then persistently low outflows the remainder of the year (Figure 3.47). This simple, high-amplitude fluctuation in Delta outflow provides an excellent example for illustrating the principle that the water quality and biological communities of estuaries respond quickly and strongly to changes in river flow. Some of these changes have direct relevance to the RMP and its objectives of determining trends of change.

Effects of the Big Storm on Water Quality of the Estuary

Water quality of San Francisco Bay, like all urbanized estuaries, is influenced by a combination of both natural forces and human activities. Estuaries are ecosystems where freshwater and seawater mix, and the proportions of fresh and seawater change in response to fluctuations in river flow. The freshwater-seawater mix within the Estuary is measured as the salinity distribution, and the changing salinity distribution reflects large changes in water quality and biological communities caused by change in the relative proportions of fresh and seawater. The New Year's Flood of 1997 provides a large natural experiment to show how water quality and biological communities and processes of the San Francisco Estuary change in response to an extreme event of high river flow.

Results from the USGS salinity measurements are depicted in Figure 3.47, which shows the changing spatial patterns of salinity as grayscale shadings. The upper panel shows the daily record of the Delta Outflow Index (DOI). The bottom panel shows the patterns of salinity variability as shaded contour images, where shading intensity is proportional to salt content of the surface waters. The vertical axis represents the longitudinal transect from the lower Sacramento River (top of image, at kilometer 92), to the Central Bay at Angel Island (kilometer 0), and then to the lower South Bay at the mouth of Coyote Creek (kilometer -52.7). The horizontal axis represents monthly variability during 1997. This, and following images, are based on interpolations of the 533 surface measurements made during the twenty USGS sampling cruises in 1997. Here, dark shading indicates high salinity and light shading indicates low salinity. The thick solid line shows the changing position of the surface salinity of 2 psu—an index of the location of the interface between freshwater and brackish water in the Estuary. This image shows the strong response of the salinity distribution to the New Year's Flood. The first USGS sampling was done on January 13, and sampling was stopped in Carquinez Strait because flows were so great that the research ship could not progress further upstream against the strong currents. The next sampling on January 28 was completed up to Rio Vista, and it showed a remarkable salinity distribution with freshwater in the surface layer as far downstream as San Pablo Bay. A nearly-fresh (salinity of 1 psu) surface layer was found in the Central Bay near Angel Island on January 28.

The solid diamonds on Figure 3.47 show the times and locations of USGS measurements during the three periods of RMP water sampling. The first RMP sampling of 1997 occurred at the time of the most extreme change in the salinity distribution, about three weeks after the January 5 peak in Delta outflow. The mean DOI during the first RMP water sampling was 6,420 m^3/s, nearly double the previous high DOI during an RMP sampling (Table 3.4). The mean surface salinity along the entire USGS sampling transect was only 3.4 psu on January 28; during this period, the surface waters of the Estuary were, on average, about 90% freshwater. This period when the freshwater fraction in the Estuary was very high should be reflected in the distributions of trace contaminants measured by other RMP elements. For example, the pattern in Figure 3.47 suggests that contaminants with local sources were flushed from the Estuary during this period of unusually high river flow and low salinity.

The patterns in Figure 3.47 show only the results of the surface measurements, and these do not reflect the salinity of deep waters in the Estuary. Freshwater has lower density than

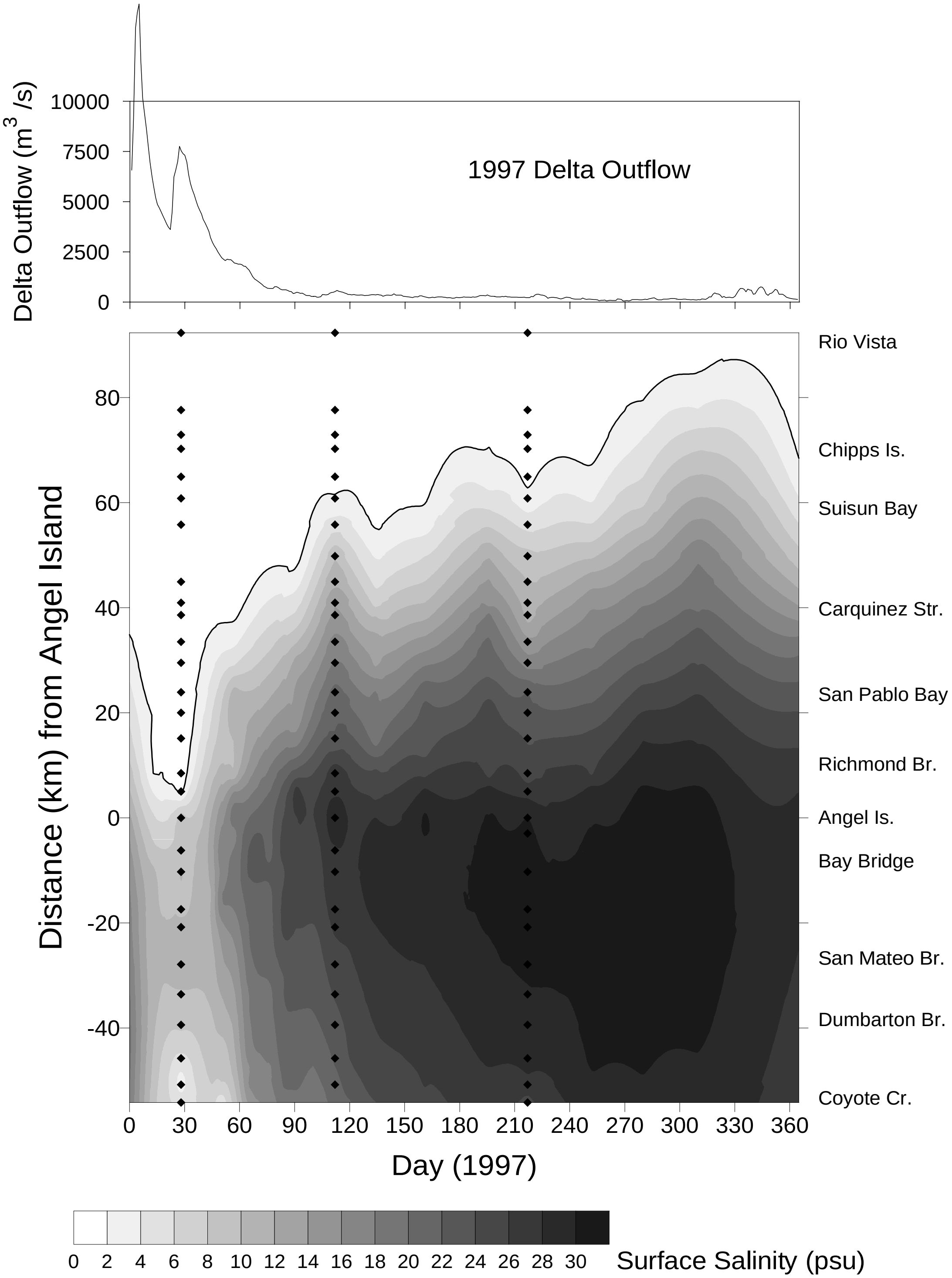

Figure 3.47. Daily Delta Outflow Index (from California Department of Water Resources) for 1997 (upper panel) and the changing distribution of surface salinity along the USGS transect (lower panel). Intensity of shading is proportional to salinity, with darker shadings indicating higher salinities. The vertical axis represents variability in space, from the lower Sacramento River (top of figure) to Central Bay (at kilometer 0) and then to the lower South Bay (bottom of vertical axis). The horizontal axis represents variability in time, matched to the flow-variability above. The thick solid line shows the changing position of the location where surface salinity was 2 psu. Small diamonds show the locations of USGS measurements that coincided with the three RMP samplings of 1997 (see Table 3.4).

Table 3.4. Summary of hydrographic/water quality conditions in the San Francisco Estuary around the periods of RMP water sampling, 1993–1997. Columns 2 and 3 show dates of RMP sampling and the corresponding dates of USGS sampling. Delta outflow is the mean Delta Outflow Index (from California Department of Water Resources) for the period of RMP sampling. Values for salinity, temperature, concentration of total suspended solids (TSS), chlorophyll *a*, and dissolved oxygen are mean values of near-surface (1 m) measurements at all USGS stations along the transect from Rio Vista to Coyote Creek (see Figure 3.46). Values in parentheses show the range of measurements along the transect. "." indicates no data.

RMP Sample Number	RMP Sample Dates	USGS Sample Date	Mean Delta Outflow Index (m^3/s)	Salinity (psu)	Temperature (°C)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)	Dissolved Oxygen (% saturation)
1	2–12 March 1993	24 Feb. 1993	995	10.8 (0.07–22.4)	10.9 (9.3–11.9)	67 (11–170)	1.8 (1.3–3.0)	93 (79–96)
2	24–27 May 1993	12 May 1993	762	12.9 (0.06–25.8)	17.0 (13.8–18.1)	25 (1–103)	2.2 (1.5–4.9)	89 (83–94)
3	13–16 Sept. 1993	8 Sept. 1993	123	22.2 (0.09–29.7)	20.9 (18.1–22.8)	9 (5–27)	2.9 (0.7–11.8)	94 (71–110)
4	31 Jan. – 9 Feb. 1994	16–17 Feb. 1994	402	16.8 (0.1–28.1)	11.1 (9.8–11.8)	19 (7–36)	2.0 (1.1–4.1)	98 (92–104)
5	19–27 April 1994	19 April 1994	273	18.0 (0.1–28.6)	17.2 (14.9–18.6)	25 (5–76)	3.7 (1.6–9.1)	96 (82–102)
6	15–23 Aug. 1994	30–31 Aug. 1994	110	23.2 (0.09–32.2)	20.4 (16.5–21.7)	10 (5–24)	3.1 (1.7–6.2)	95 (85–102)
7	6–15 Feb. 1995	7 Feb. 1995	2,490	6.5 (0.07–16.3)	12.2 (10.9–13.6)	49 (6–100)	1.3 (0.7–2.5)	88 (82–93)
8	18–27 Apr. 1995	18–19 Apr. 1995	2,276	8.3 (0.07–17.4)	13.6 (12.4–14.3)	49 (10–239)	8.2 (3.0–18.0)	.
9	16–23 Aug. 1995	16 Aug. 1995	314	15.5 (0.25–27.6)	21.2 (18.5–23.0)	19 (8–48)	3.7 (1.2–6.5)	91 (79–102)
10	5–14 Feb. 1996	6 Feb. 1996	3,490	8.5 (0.07–22.4)	11.8 (10.6–14.0)	41 (11–89)	1.2 (0.3–2.5)	85 (80–100)
11	22–29 Apr. 1996	1 May 1996	1,060	14.8 (0.08–29.8)	17.5 (12.4–21.8)	19 (4–77)	5.9 (3.0–21.5)	95 (68–117)
12	22–30 July 1996	17 July 1996	231	16.9 (0.06–29.2)	20.0 (16.9–21.6)	44 (9–122)	1.9 (0.6–5.7)	94 (76–100)
13	21–29 Jan. 1997	28 Jan. 1997	6,420	3.4 (0.05–11.7)	11.1 (10.4–12.5)	91 (2–227)	6.5 (1.7–11.2)	90 (82–103)
14	14–23 Apr. 1997	22 Apr. 1997	450	16.7 (0.1–30.3)	16.8 (13.1–19.2)	38 (4–159)	11.1 (2.5–34.9)	104 (90–133)
15	28 July–6 Aug. 1997	5 Aug. 1997	233	18.2 (0.07–30.6)	21.2 (18.3–22.8)	.	2.6 (1.3–9.7)	94 (71–99)

seawater, so it has a tendency to float on top of seawater unless turbulent mixing from wind and tides is strong enough to vertically mix the surface freshwater and deep seawater. During periods of high river flow, such as January and February 1997, the water in the Estuary channels becomes layered, or stratified, with low-salinity water carried seaward on top of high-salinity deep water. For example, on January 28 when the surface salinity at Angel Island (USGS station 17) was only 2 psu (nearly freshwater), the bottom waters at that location had salinity of 21.1 psu (mostly seawater). Therefore, events of high river flow change both the horizontal and the vertical distributions of salinity and other water-quality constituents.

The exceptional peak of freshwater inflow in early January (DOI = 14,840 m^3/s) was followed by a second peak (DOI =7,514 m^3/s) in late January, and then a spring of receding inflow and a summer/autumn of persistent low inflow. The gray-scale shadings of Figure 3.47 show how the surface salinity of the Estuary responded to the periods of receding river flow, with the entire Estuary becoming progressively saltier after the January storms ended. This progressive increase in the seawater fraction was reflected in the changing position of the line where surface salinity = 2 psu (Figure 3.47). By the time of the second RMP water sampling in April 1997, this position was displaced about 75 km upstream and positioned in Suisun Bay. Between the RMP first and second samplings, the mean surface salinity of the Estuary increased from 3.4 to 16.7 psu (Table 3.4), and we expect large changes in the concentrations of some trace substances between these two sampling periods. The third RMP water sampling, in late July/early August, occurred after three months of sustained low flow, when the mean surface salinity along the USGS transect was 18.2 psu (Table 3.4).

The salinity distribution of Figure 3.47 shows how dissolved components of water quality can change in response to seasonal fluctuations in river flow. Other aspects of water quality change with river flow, including the distribution and concentration of suspended matter. In Figure 3.48 we show the changing patterns of total suspended solids (TSS) concentration as a measure of the abundance of particles suspended in surface waters of the Estuary. Most suspended particles in the San Francisco Estuary are mineral (clay) particles, and the gray-scale shadings in Figure 3.48 show the large pulse input of suspended sediments to the northern Estuary following the 1997 New Year's Flood. The highest TSS concentration measured in surface waters by the USGS monitoring was 227 mg/L. During the first RMP water sampling, TSS concentrations were uniformly high in the northern Estuary, and a plume of low salinity-high turbidity water was observed into the Central Bay. The mean TSS concentration in surface waters along the USGS transect was 91 mg/L, the highest mean concentration in the five years of RMP sampling (Table 3.4).

As the river flow receded in spring, the riverine sources of sediments to the Estuary were reduced, and the mean TSS concentration fell to 38 mg/L (Table 3.4). Since many trace contaminants are reactive with particle surfaces, we expect large changes in the concentrations and distributions of the particle-reactive substances between the first and second RMP samplings of 1997. We also expect that these seasonal trends continued into the time of the July/August sampling when TSS concentrations were low throughout the Estuary (Figure 3.48). This image also shows localized regions of high TSS concentration in the lower South Bay, especially below the Dumbarton Bridge, reflecting inputs of sediments from the urban watershed of the South Bay during the January storms.

The Spring Phytoplankton Bloom

As the RMP evolves and matures, we continue to learn new lessons about the key processes which control the transport, biogeochemical cycling, and ecosystem effects of trace contaminants in the San Francisco Estuary. In recent years we have learned that phytoplankton uptake and assimilation of trace metals (such as cadmium, nickel, zinc, and selenium) is a key biological process which transforms these elements from dissolved to particulate phases (Luoma *et al.*, 1998). These biological transformations are a key step in the

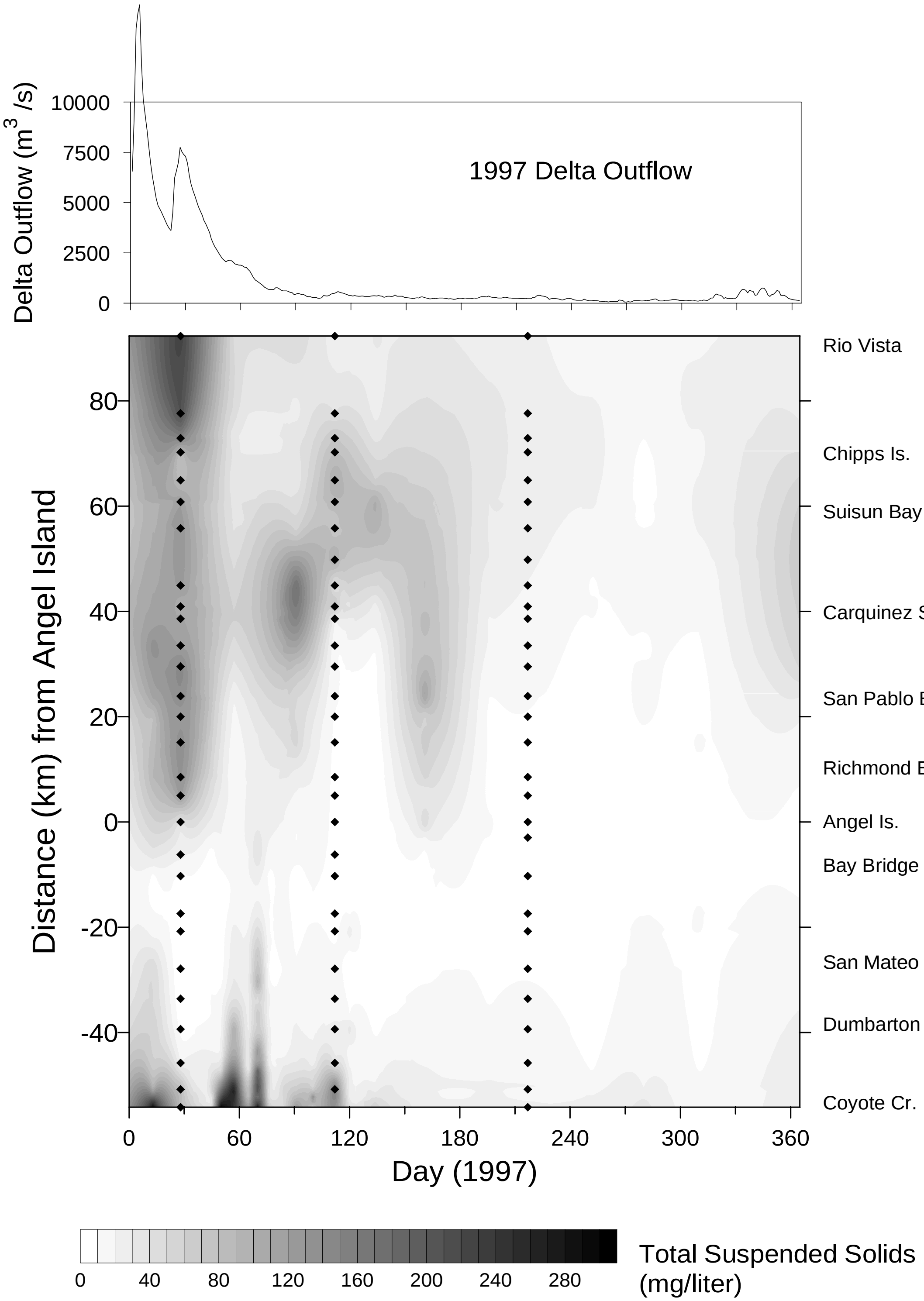

Figure 3.48. Delta Outflow Index (top panel) and concentrations of total suspended solids (lower panel) along the USGS transect for 1997. Intensity of shading is proportional to TSS, with darker shadings indicating higher concentrations of total suspended solids. Small diamonds show the locations of USGS measurements that coincided with the three RMP samplings of 1997.

trophic transfer of trace contaminants leading to bioaccumulation within the tissues of upper-trophic-level consumer animals. Phytoplankton, as the dominant primary producers in the Estuary, probably also play a key role in the uptake and metabolism of some trace organic contaminants, such as PCBs. The USGS water-quality element of RMP follows phytoplankton dynamics in San Francisco Bay by measuring chlorophyll concentration (an index of the biomass, or abundance, of the phytoplankton community) and dissolved oxygen concentration (as an index of the rate of photosynthesis, or productivity, of the phytoplankton community).

Chlorophyll distributions show that phytoplankton abundance in the San Francisco Estuary is usually low, except for periods of very high biomass (algal blooms) which can develop in the South Bay during the months February through April (Cloern, 1996). During 1997, the South Bay spring bloom was characterized by four distinct episodes of enhanced chlorophyll biomass, beginning with a small event north of the San Mateo Bridge in late January (Figure 3.49). This was followed by three larger events of rapid chlorophyll increase, and then decline, in late February, late March, and late April (at the time of the second RMP water sampling). These events of enhanced phytoplankton biomass were reflected in the dissolved oxygen (DO) content of surface waters, and we observed simultaneous events of oxygen supersaturation during the March and April algal bloom events (Figure 3.49). The patterns of DO variability (Figure 3.50) suggest that phytoplankton primary productivity was very high in the South Bay during late March and late April, so we expect large changes in the form or concentrations of reactive trace substances between the RMP water samplings in January (low phytoplankton activity) and April (high phytoplankton activity). The third RMP water sampling occurred in July/August, after three months of persistent low phytoplankton biomass and productivity, suggesting that the biological effect of phytoplankton on trace substances was small then.

Results of USGS sampling suggest that the RMP sampling in April 1997 should provide an excellent opportunity to measure the effects of phytoplankton uptake/metabolism on trace contaminants, because this sampling was done during the period of highest chlorophyll concentration (maximum 34.9 mg/m^3) and DO concentration (maximum 133% saturation) among all the RMP water samplings done since 1993 (Table 3.4).

The 1997 El Niño Event

One of the strongest El Niño events of the past century developed in 1997, when temperatures in the eastern Pacific Ocean warmed to over five degrees Celsius (°C) above normal. This global-scale climatological phenomenon propagated along the west coast of South and North America, and its effects remind us that the San Francisco Estuary is connected to, and influenced by, changes in the adjacent coastal ocean. The surface water temperatures of the southern and northern regions of the Estuary (Figure 3.51) were not unusual in 1997, but the water temperatures in the Central Bay (closest to the Pacific Ocean) were the highest recorded since the RMP sampling began. Effects of oceanic warming, which reflect large-scale changes in coastal oceanic circulation, were most pronounced during the RMP water sampling of July/August (Figure 3.51). For example, bottom temperature at USGS station 18 in Central Bay was 17.67 °C on August 5, compared to bottom temperature of only 15.44 °C in August 1996. This temperature anomaly suggests that the character of the Central Bay region, including its water quality and biological communities, could have been affected by coastal changes influenced by the 1997 El Niño event.

Although we are far from a complete understanding of how coastal oceanographic processes influence water quality in the San Francisco Estuary, RMP results from recent years show that water quality does change in response to coastal upwelling (Cloern *et al.*, 1997) and El Niño warming. These coastal forcings probably induce a cascade of chemical and biological changes within the Estuary, through linkages which are not yet fully understood. Observations during the 1997 El Niño suggest one mechanism through which the coastal ocean might influence estuarine water quality and toxicity. The USGS and SFEI con-

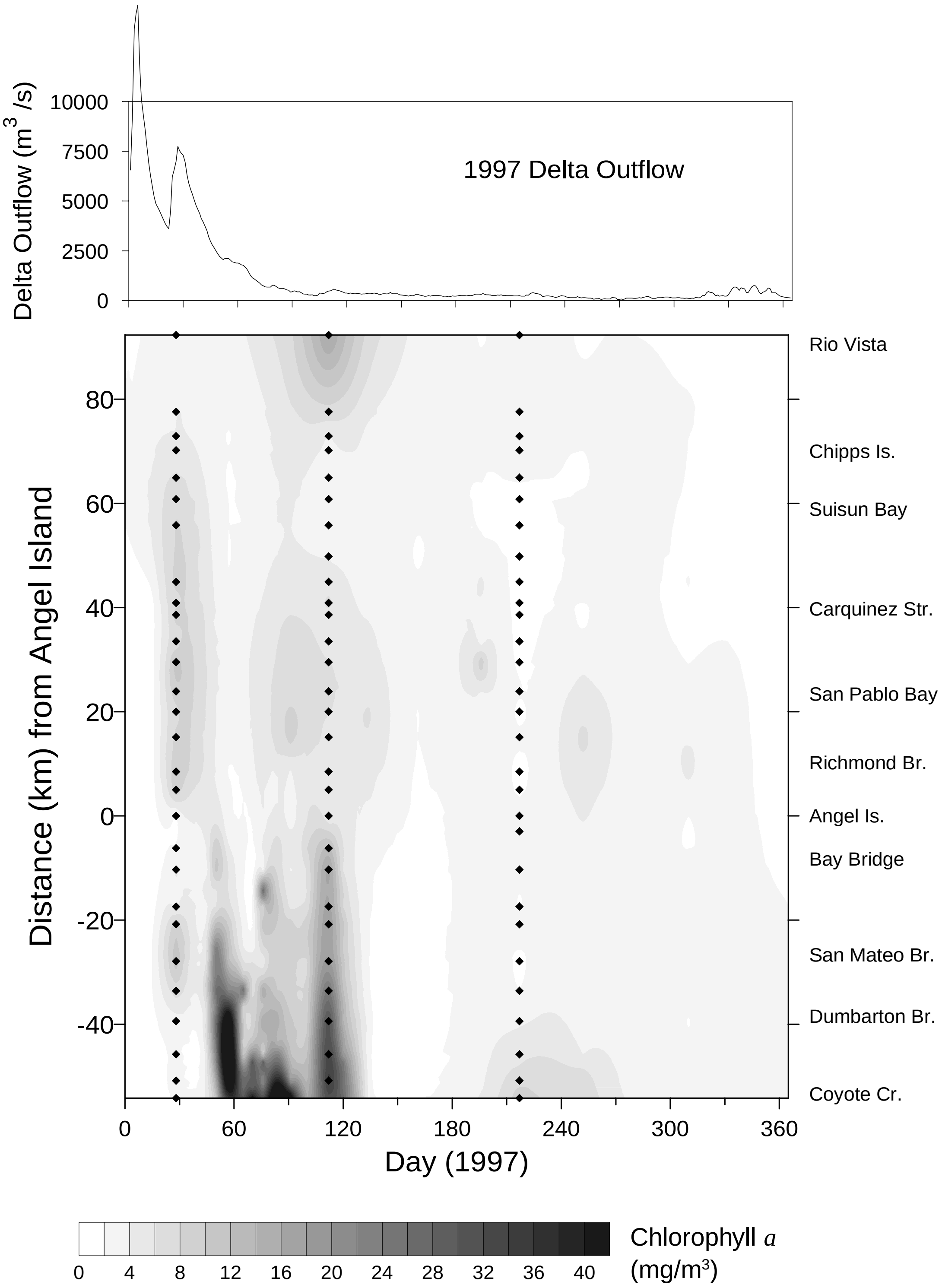

Figure 3.49. Delta Outflow Index (top panel) and concentrations of chlorophyll *a* (lower panel) along the USGS transect for 1997. Intensity of shading is proportional to chlorophyll *a*, with darker shadings indicating higher concentrations. Small diamonds show the locations of USGS measurements that coincided with the three RMP samplings of 1997.

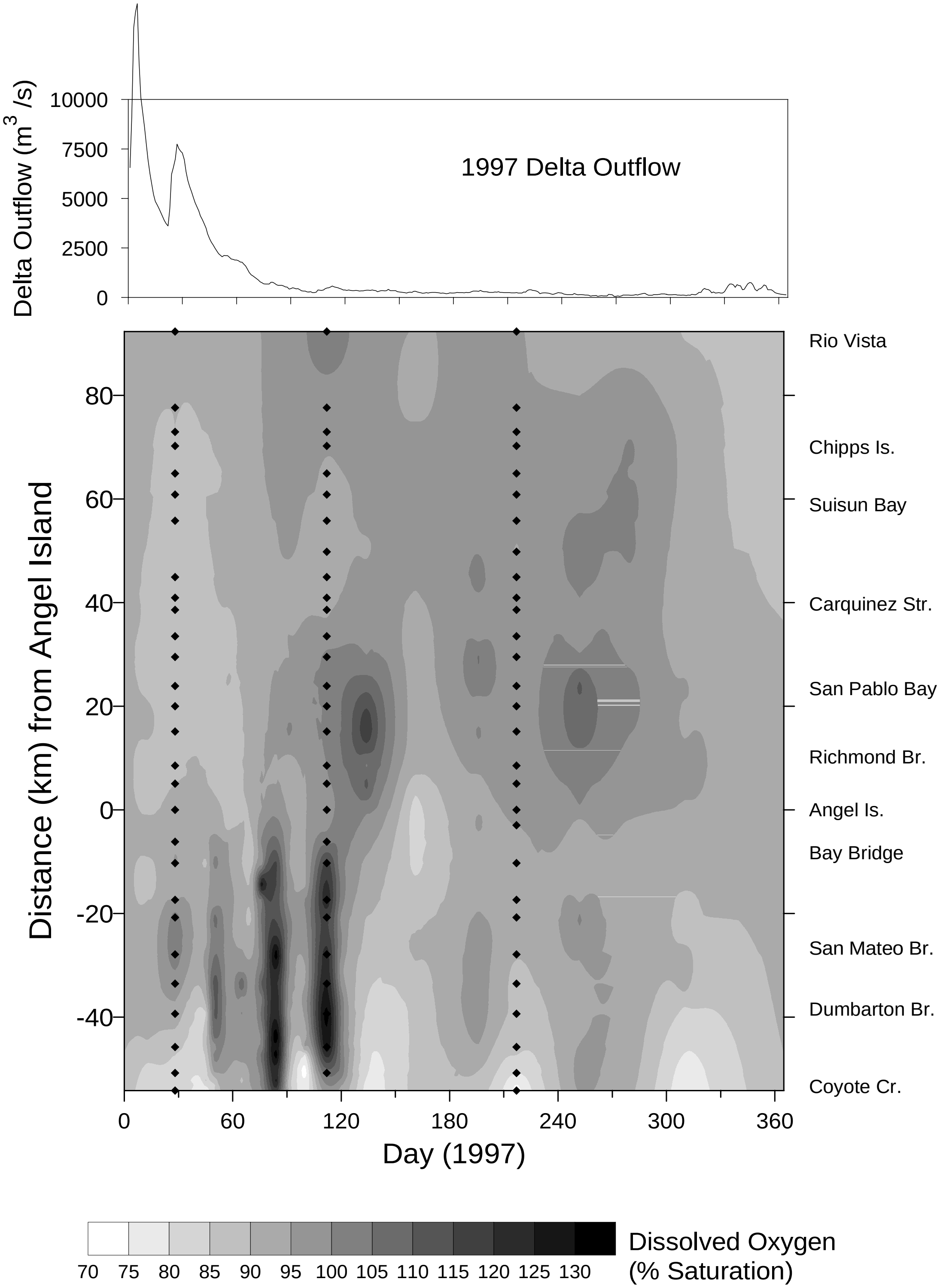

Figure 3.50. Delta Outflow Index (top panel) and concentrations of dissolved oxygen (lower panel) along the USGS transect for 1997. Intensity of shading is proportional to DO in the surface waters, with darker shadings indicating higher concentrations. Small diamonds show the locations of USGS measurements that coincided with the three RMP samplings of 1997.

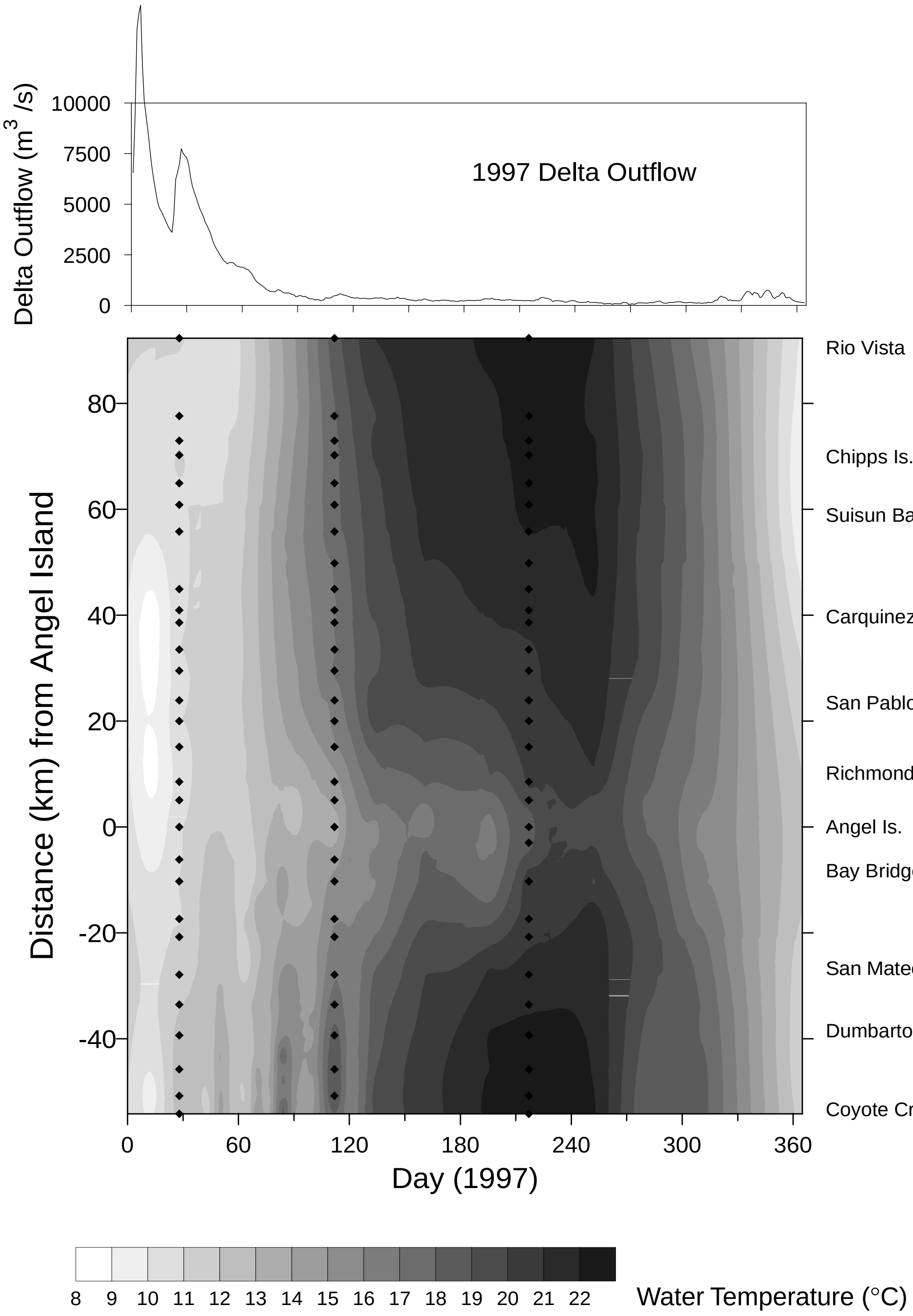

Figure 3.51. Delta Outflow Index (top panel) and surface water temperatures (lower panel) along the USGS transect for 1997. Intensity of shading is proportional to temperature, with darker shadings indicating higher temperatures. Small diamonds show the locations of USGS measurements that coincided with the three RMP samplings of 1997.

ducted a special study during August 1997 in response to reports of animal mortalities and visible red tides in regions of the Central Bay (Cole and Cohen, 1998). This study showed high abundances of the dinoflagellate *Gymnodinium sanguineum*, a toxin-producing species of phytoplankton usually found in tropical or subtropical waters. During this red tide episode Cole and Cohen (1998) observed mortalities and poor condition of attached invertebrate animals, such as mussels and tunicates, in marinas around Central Bay. Numerous dead fish (including adult striped bass and halibut) were observed in Aquatic Park lagoon.

The simultaneous occurrence of temperature anomalies (warm water) and toxic red tides in Central Bay shows how events of change in the coastal ocean can propagate into the San Francisco Estuary and cause changes in water quality and biological communities. The unusual events of summer 1997 remind us that reports of fish and shellfish mortality are increasing in response to nutrient enrichment and stimulation of harmful algal blooms in estuaries around the world. They also remind us that San Francisco Bay harbors at least twenty known species of toxin-producing phytoplankton (Rodgers *et al*., 1996). Therefore, sources of toxicity can be produced biologically within the Estuary, so the RMP goals of determining trends of water-quality change should include consideration of the potential impact of toxic blooms and the prospect that events of algal-derived toxicity could become more frequent in San Francisco Bay, as they have in other nutrient-rich coastal ecosystems.

Summary

In this chapter, we use results from twenty USGS sampling cruises to describe some key features of water-quality variability in San Francisco Bay during 1997. The patterns of variability are displayed as shaded images showing the annual cycle and the spatial gradients of water quality, from the Sacramento River to the southern South Bay. The five water-quality parameters described here were chosen as indicators of different processes of estuarine variability, so results from this program element can be used as a starting place for interpreting the more complex patterns of variability in trace contaminants and their effects. We use results from 1997 to illustrate some general lessons of estuarine variability that are clearly evident in the easily-measured quantities: salinity, temperature, TSS, chlorophyll, and DO. These same lessons apply to trace substances, and we hope these lessons will be useful guides for identifying the patterns and causes of variability in trace substances, which are also influenced by the large events of 1997: the New Year's Flood of 1997; sustained periods of high phytoplankton production in the South Bay during spring; and the changes induced by the 1997 El Niño event.

Acknowledgments

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Time Series of Suspended-Solids Concentration in Honker Bay During Water Year 1997

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Suspended-solids concentration (SSC) responds differently to seasonal variations, such as Delta outflow and wind in shallow water areas than in deep-water channels. Although San Francisco Bay includes extensive areas of shallow water, with about one-half of the surface area of the Bay being less than 2 meters deep (Conomos and Peterson, 1977), deep-water channels along the spine of San Francisco Bay, not shallow waters, are generally sampled by the Regional Monitoring Program (RMP; SFEI, 1997) and the U.S. Geological Survey (USGS; Buchanan and Schoellhamer, 1996; Edmunds *et al*., 1997; Freeman *et al*., 1997).

The purpose of this article is to provide an example of how SSC varies in shallow water. Time series of SSC were measured at several sites in Honker Bay. Measurements were made from December 1996 to March 1997 to observe the first wintertime freshwater flood pulse pushing salinity out of Honker Bay and delivering the first flush of sediment from the Central Valley watershed to the Bay. Instruments also were deployed from April to August 1997 to measure the return of salinity to Honker Bay as freshwater flow diminished, and to measure resuspension of sediment by wind-waves. Honker Bay was chosen because of its ecological significance to many estuarine plants and animals that depend on shallow waters for shelter and nourishment (Atwater *et al*., 1979; Cloern *et al*., 1983).

Total concentrations of seven trace elements measured by the RMP are well correlated with SSC (Schoellhamer, 1997a, 1997b). Thus, the spatial and temporal variability of some trace elements of concern to the RMP is analogous to the SSC variability discussed in this article.

Time-Series Data

The USGS collected time-series data of water velocity, water depth, wind-waves, salinity, temperature, and SSC at six sites in Honker Bay, a shallow subembayment at the landward end of Suisun Bay (Figure 3.52). The four shallow water sites were designated *cmid*, *barse*, *cse*, and *back*. The two deep-water sites were designated *hs2* near the boundary between Suisun Bay and Honker Bay, and *hdol* near the southeast end of the Suisun Cutoff channel. A continuous SSC monitoring station has been operated by the USGS near Honker Bay at Mallard Island in the deep (13.5 meter) channel at the landward boundary of Suisun Bay (Figure 3.52) since February 1994.

SSC was determined at 10-minute intervals with optical backscatterance (OBS) sensors that measure the amount of suspended material in the water, the output of which was converted to SSC using calibration curves developed from the analysis of water samples. Sensors at each of the sampling locations were serviced every three to five weeks to retrieve data, to collect water samples for sensor calibration, and to clean the sensors, which are susceptible to biological fouling.

Spatial Variability

During the winter deployment, all of the sampling locations showed similar temporal SSC trends (Figure 3.53). During the spring deployment, which is more indicative of typical flow and wind conditions, Honker Bay was not a homogeneous environment. For example, data collected at sites *cmid* and *barse* show large SSC spikes that persisted for several weeks in late April and early

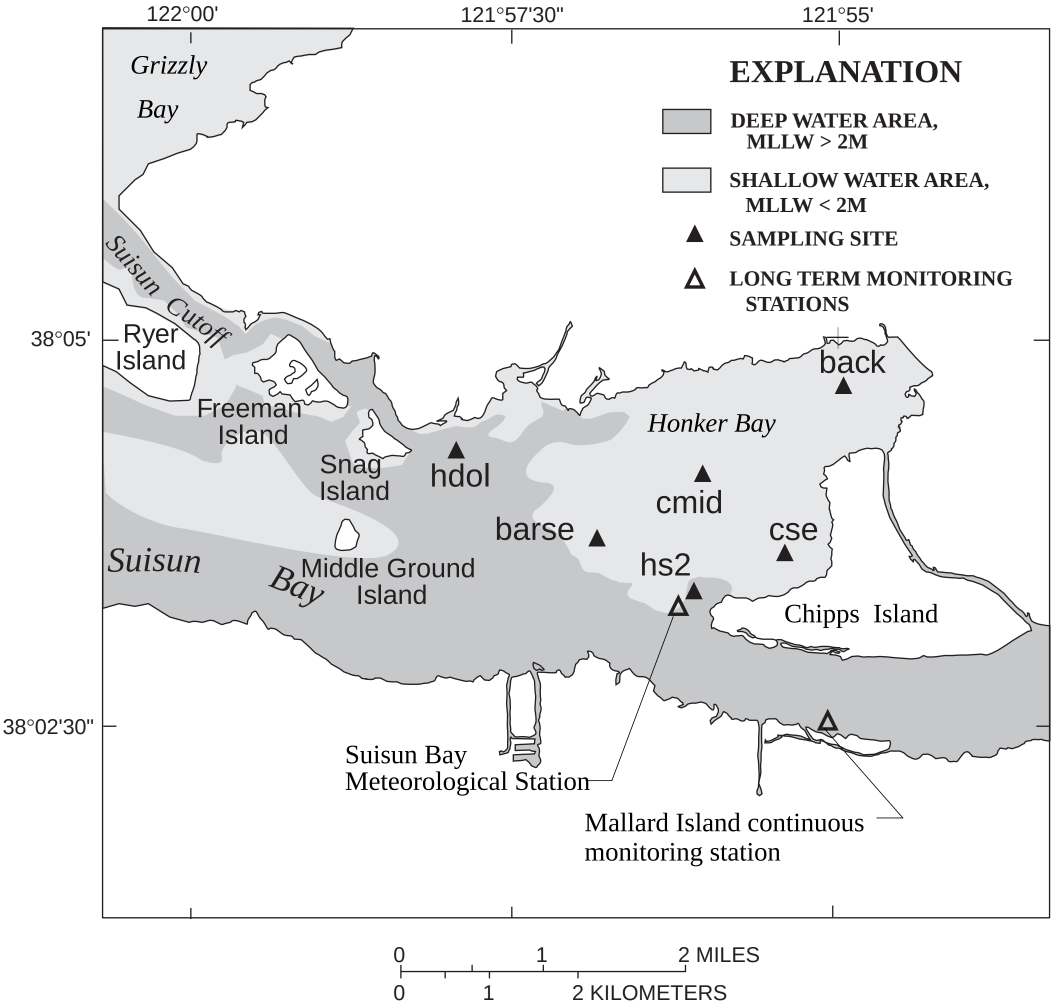

Figure 3.52. Location of study area and sampling sites.

May, probably due to wind-wave resuspension of sediment at low tide from a bar at the mouth of Honker Bay. In contrast, SSC at site *back* began to increase in July, which may be because of sediment moving from the bar northeastward towards the head of the Bay. No wind-wave signal is present at site *cse* because it is more protected from wind so there is less wind shear to resuspend bottom sediments. Tidally induced variations in SSC, seen as a thicker black band along the baseline of the SSC data, tend to be more dominant at the sites located near the mouth of Honker Bay—*hdol*, *cmid*, *barse*, and *hs2* (Figure 3.53). These tidally induced variations in SSC are most dramatic at site *hdol*, which is heavily influenced by tidal action in the Suisun Cutoff channel. In contrast, the SSC time-series at sites *cse* and *back*, which are further from the mouth of Honker Bay, exhibit less influence from tidal variations.

A statistical analysis of the SSC data collected during each deployment is presented in Tables 3.5 and 3.6. The winter deployment had less spatial variability between the sites and less sediment in suspension. The site at *cse* was not in operation during the first deployment.

The mean SSC at each shallow water site during the spring deployment fell between 110

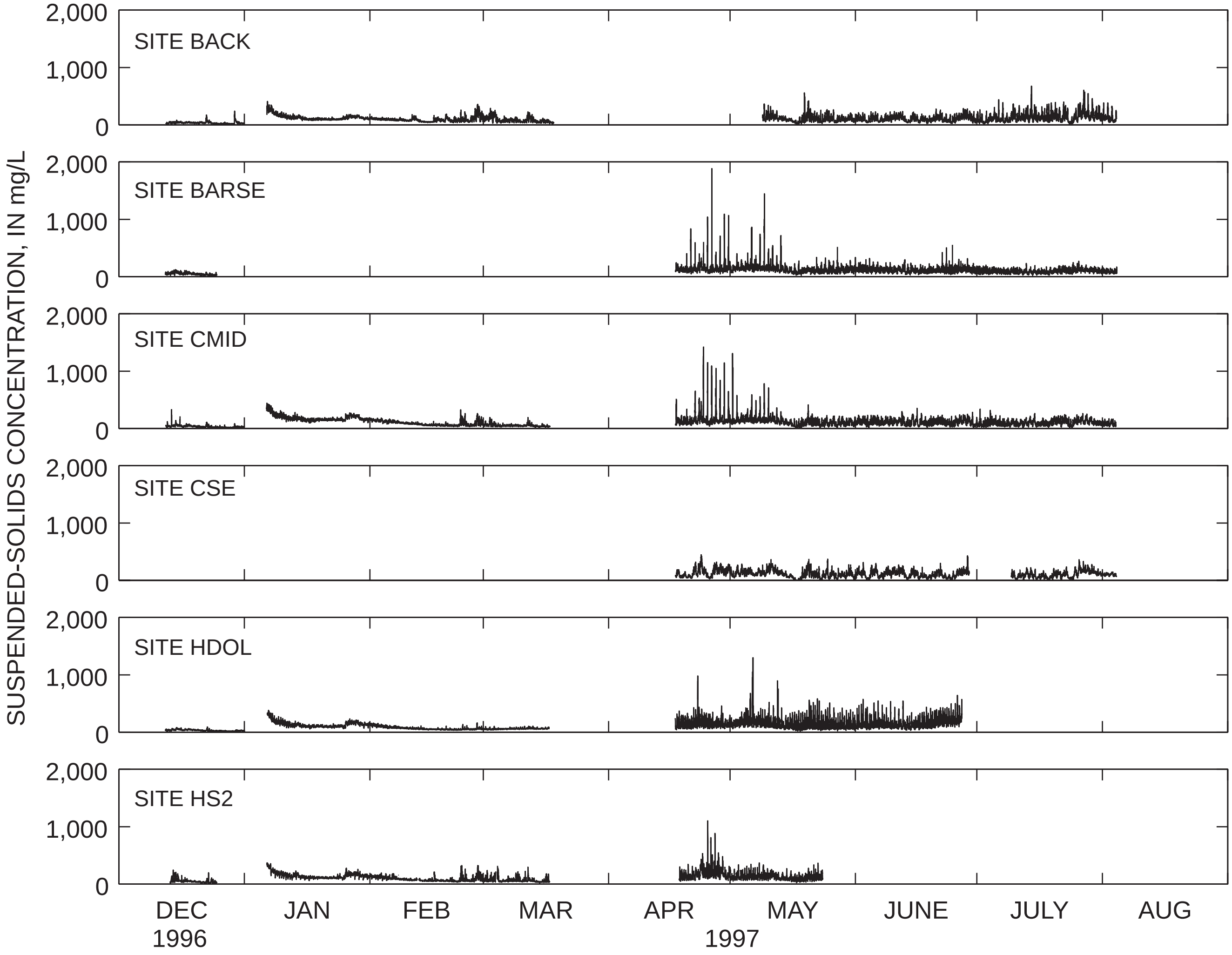

Figure 3.53. Suspended-solids concentration time series at Honker Bay sampling sites: *back, barse, cmid, cse, hdol,* and *hs2*. Due to instrument fouling or failure, not all of the sites have data sets covering the entire deployment period. There is a month break from mid-March to mid-April between the two deployments. mg/L = milligrams per liter.

Table 3.5. Statistical analysis of suspended-solids concentration data, December 1996–March 1997. [m = meter; mg/L = milligrams per liter]

Site	Mean lower low water (m)	Sensor height from bottom (m)	Valid data (percent)	Mean (mg/L)	Median (mg/L)	Lower quartile (mg/L)	Upper quartile (mg/L)
back	1.9	0.5	94	88	85	47	110
barse	1.9	0.5	13	50	46	30	63
cmid	1.9	0.5	94	100	85	44	150
hdol	5.5	2.5	94	76	60	44	99
hs2	8.5	0.5	80	94	82	52	120
Mallard Island	7.6	6.7	97	45	34	29	45

Table 3.6. Statistical analysis of suspended-solids concentration data, April–August 1997. [m = meter; mg/L = milligrams per liter; > = actual value is greater than value shown]

Site	Mean lower low water (m)	Sensor height from bottom (m)	Valid data (percent)	Mean (mg/L)	Median (mg/L)	Lower quartile (mg/L)	Upper quartile (mg/L)
back	1.9	0.5	>99	110	100	68	150
barse	1.9	0.5	>99	120	110	85	150
cmid	1.9	0.5	>99	110	110	71	140
cse	1.9	0.5	90	110	99	61	140
hdol	5.5	0.6	64	150	130	91	190
hs2	8.5	0.5	33	130	120	89	160
Mallard Island	7.6	6.7	81	65	61	51	74

milligrams per liter (mg/L) at site *cse* to 120 mg/L at site *barse* (Table 3.6).

Although the mean SSC throughout Honker Bay is similar at each of the sites, there can be considerable differences among the sites at any given time. The standard deviation of the SSC values at sites *cmid*, *cse*, and *barse* for each OBS meter reading during the spring deployment shows that the spatial variability of the SSC data among the sites is also highly variable in time (Figure 3.54). Sites *barse, cse*, and *cmid* were used in this analysis because they had the most complete data sets and included data for late April and early May. The standard deviation is greatest in early spring, peaking at 900 mg/L, which corresponds to Krone's (1979) observation that unconsolidated bottom sediments are easily resuspended due to increased wind-wave action in early spring. Spatial variability is attributable to nonhomogeneous bathymetry, currents, and wind shear in Honker Bay.

For the purpose of this article, site *cmid* was selected to be a representative site in Honker Bay because it is located in the center of the shallow water study area and displays similar behavior to site *barse*. The impacts of spatial variability in shallow water on sampling programs are discussed in greater detail in the following sections of this article.

Flood Pulses

The immediate effect of flood pulses is an abrupt increase in SSC in the deep channel and shallow

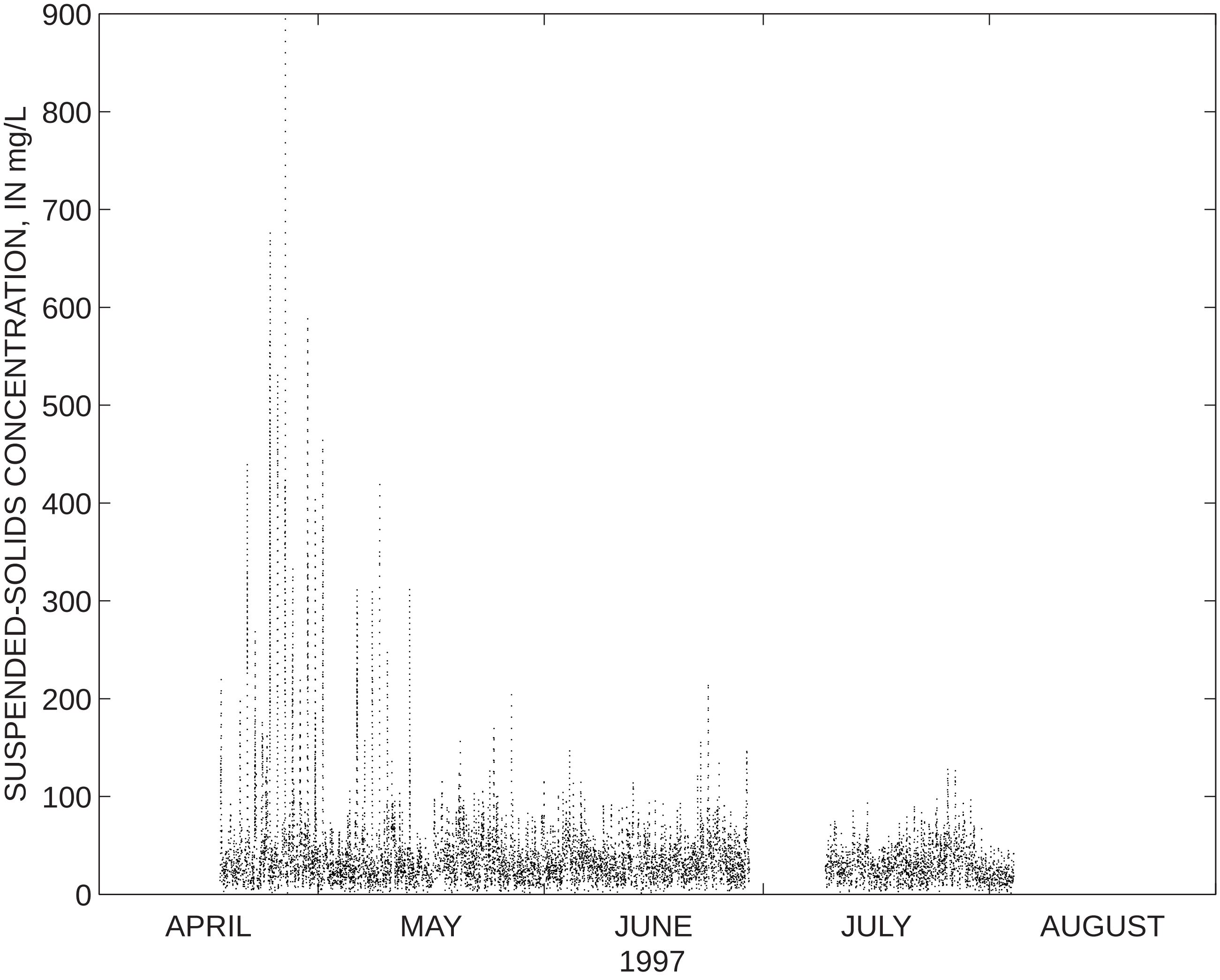

Figure 3.54. Standard deviation in suspended-solids concentrations (SSC) among sites *barse, cmid,* and *cse.* mg/L = milligrams per liter.

water areas as sediment from the Central Valley watershed is flushed into San Francisco Bay. Estimates of discharge from the Sacramento-San Joaquin River Delta were obtained from the California Department of Water Resources (1986). The first flood pulse of water year 1997 occurred on January 4, 1997 peaking at approximately 524,000 cubic feet per second (ft^3/s), and a second flood occurred several weeks later on January 27, 1997 peaking at approximately 274,000 ft^3/s (California Department of Water Resources, 1986). Six days of data (January 1–6) were lost at all of the shallow water sites in Honker Bay due to equipment malfunction; however, the Mallard Island SSC monitoring site was operational during this period (Figure 3.52). Increases in the baseline Mallard Island SSC time-series data generally correlate to increases in Delta outflow (Figure 3.55). However, during the second flood pulse, the SSC values were approximately 25 percent of those during the first flood peak even though the magnitude of the second flood peak was more than 50 percent of the first. The diminished SSC response to the second flood pulse is likely due to a lack of available sediment because the first flush reduces the sediment supply by transporting large quantities of the readily erodible material into the Bay (Goodwin and

Denton, 1991). Note that the relationship between Delta outflow and SSC is not linear.

In comparing Mallard Island data to site *cmid* data, there is a marked difference between these two sites after the influx of sediment from the two 1997 flood pulses (Figure 3.55). Both sites have a baseline SSC of 25–50 mg/L before the first flood pulse. Mallard Island approaches baseline concentrations 1–2 weeks after each flood pulse, whereas site *cmid* reaches higher concentrations than Mallard Island and does not approach baseline concentrations until nearly one month after the second flood pulse.

SSC was greater in Honker Bay than at Mallard Island during January and February because of differences in suspended sediment supply. The dominant suspended sediment source at Mallard Island is flood-derived sediment that is transported past the site and into the Bay. The suspended sediment source at site *cmid*, however, is a combination of the initial pulse of sediment arriving with the flood waters and sediment resuspension due to tidal currents. The smaller tidal currents in Honker Bay allow sediment deposition on the Bay floor, which are then susceptible to repeated episodes of resuspension and deposition due to tidal currents in January and February. Later in the year, as sediment consolidation progresses, tidal currents alone are not sufficient to resuspend bottom sediments. This recycling of flood-derived sediment accounts for greater SSC in Honker Bay than at Mallard

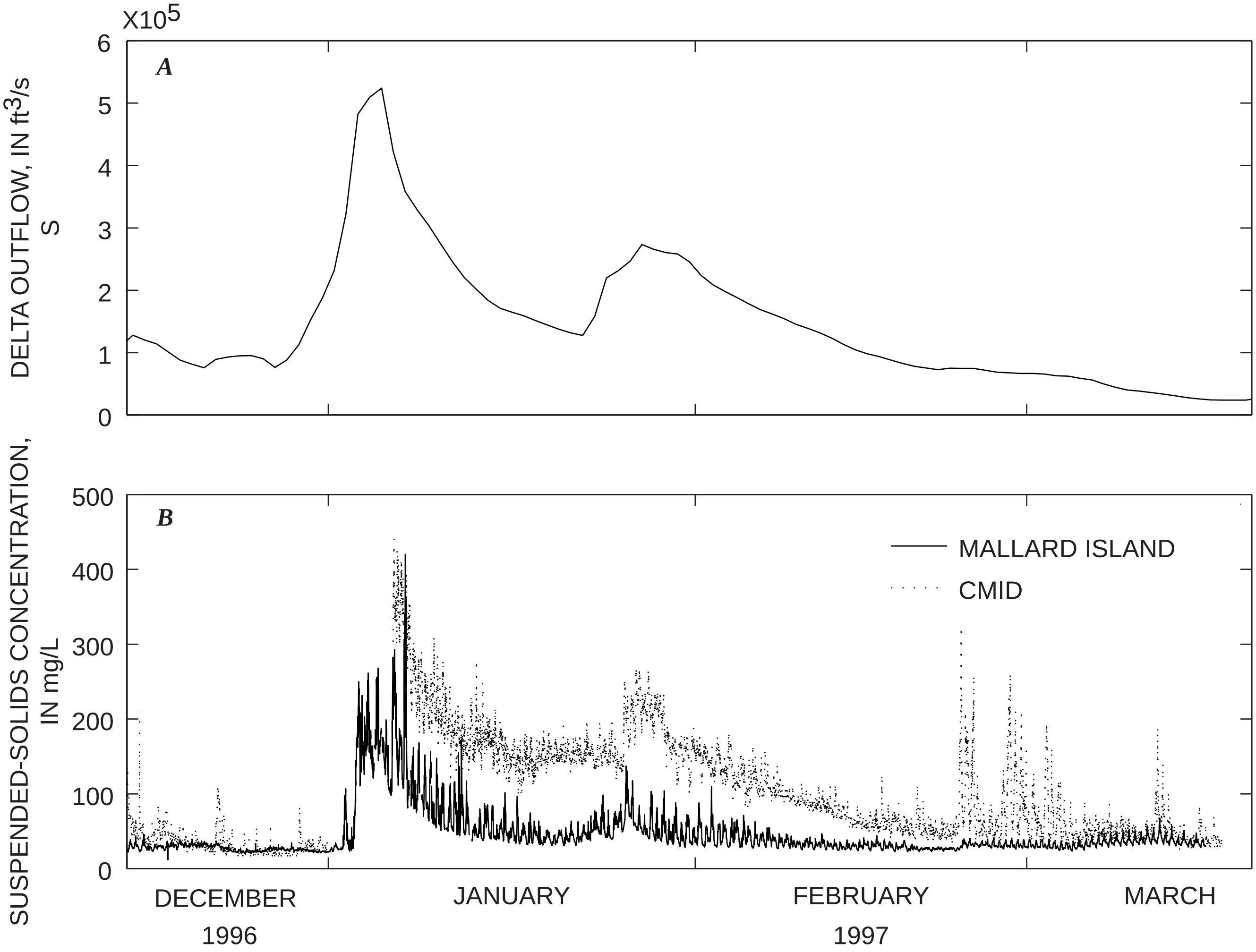

Figure 3.55. Delta outflow *A*, suspended-solids concentrations at Mallard Island and site *cmid* during the winter deployment *B*. ft^3/s = cubic feet per second; mg/L = milligrams per liter.

Island in January and February. Reservoir releases of water with relatively low SSC after storms also may contribute to the lower SSC at Mallard Island, compared to that at site *cmid*. In addition, increasing winds at the end of February caused sediment resuspension significantly greater than that produced by tidal currents alone (Figure 3.55).

SSC time-series data in Honker Bay have broadened peaks and lag behind SSC time-series data at the Mallard Island channel site after each flood pulse, indicating that the residence time of flood-derived sediment in Honker Bay is longer than in the neighboring channel. Shallow water provides temporary off-channel storage for sediment on the Bay floor, which is slowly depleted through repeated tidally-driven cycles of resuspension, transport, and deposition. Note that baseline concentrations are reached at site *cmid* about 4 weeks after the second flood pulse (Figure 3.55), whereas seasonal wind-driven resuspension generally affects San Francisco Bay for several months (Schoellhamer, 1996, 1997b). Because SSC is well correlated with several trace elements (Schoellhamer, 1997a, 1997b), the trace elements associated with flood-related sediment will also tend to have longer residence times in shallow water than in the channel.

Wind-Waves

Sediment resuspension by wind-waves in shallow water is an important factor controlling SSC during the spring when the wind velocity increases (Krone, 1979; Schoellhamer, 1996, 1997b). Wind blowing over shallow water generates waves that create a shear stress on the Bay floor.

Wind data were measured by the USGS at a continuously operated meteorological station near Honker Bay (Figure 3.52). During the study, the highest SSC values occurred in late April and early May 1997, which corresponds to a period of strong winds, averaging approximately 7.4 meters per second (m/s), and high associated bottom shear stress. Bed shear stress is approximately proportional to the square of the bottom orbital velocity and increases as the water depth decreases (Dean and Dalrymple, 1984). Linear wave theory and spectral analysis of wave data were used to calculate bottom orbital velocity (Schoellhamer, 1995). Even though the relatively large wind and bed shear stresses continued until the end of the study period, spikes in the SSC data cease in May 1997 (Figure 3.56). An explanation for the observed pattern is that, early in the spring, unconsolidated fine sediments can easily be resuspended, however, as the fine sediments are winnowed from the bed, the remaining sediments become progressively less erodible (Krone, 1979; Nichols and Thompson, 1985).

A brief windy period at the end of February 1997 illustrates the effects of wind-waves on SSC (Figure 3.57). When the bed shear stress increases, spikes in the SSC at site *cmid* appear during low tides, and when bed shear dissipates, the SSC spikes decrease. Note that SSC peaks tend to continue even after the wind shear has dissipated, indicating that sediment will tend to remain in suspension for some time after the wind ceases and will be transported past the sample site during one to three tidal cycles before settling on the Bay floor.

Thus, the timing of sample collection for trace elements associated with SSC is important, particularly if only sparse data can be collected. In Honker Bay, the greatest temporal and spatial SSC variability occurs on windy days at low tide in early spring (Figure 3.54 and 3.57). If only a few samples that are representative of spatial and temporal trends can be collected from shallow areas, sampling at low tide on windy days should be avoided, particularly in the early spring. However, if maximum concentrations of trace elements associated with SSC are sought, trace element concentration peaks will most likely occur on windy days at low tide in early spring.

Conclusions

Suspended-solids concentrations respond differently in shallow water areas than in deeper channels to seasonal forces, such as Delta outflow and wind. During flood pulses, particularly during the first flood pulse of the season, SSC increases in both shallow water areas and deep channels. Shallow bays provide temporary off-channel

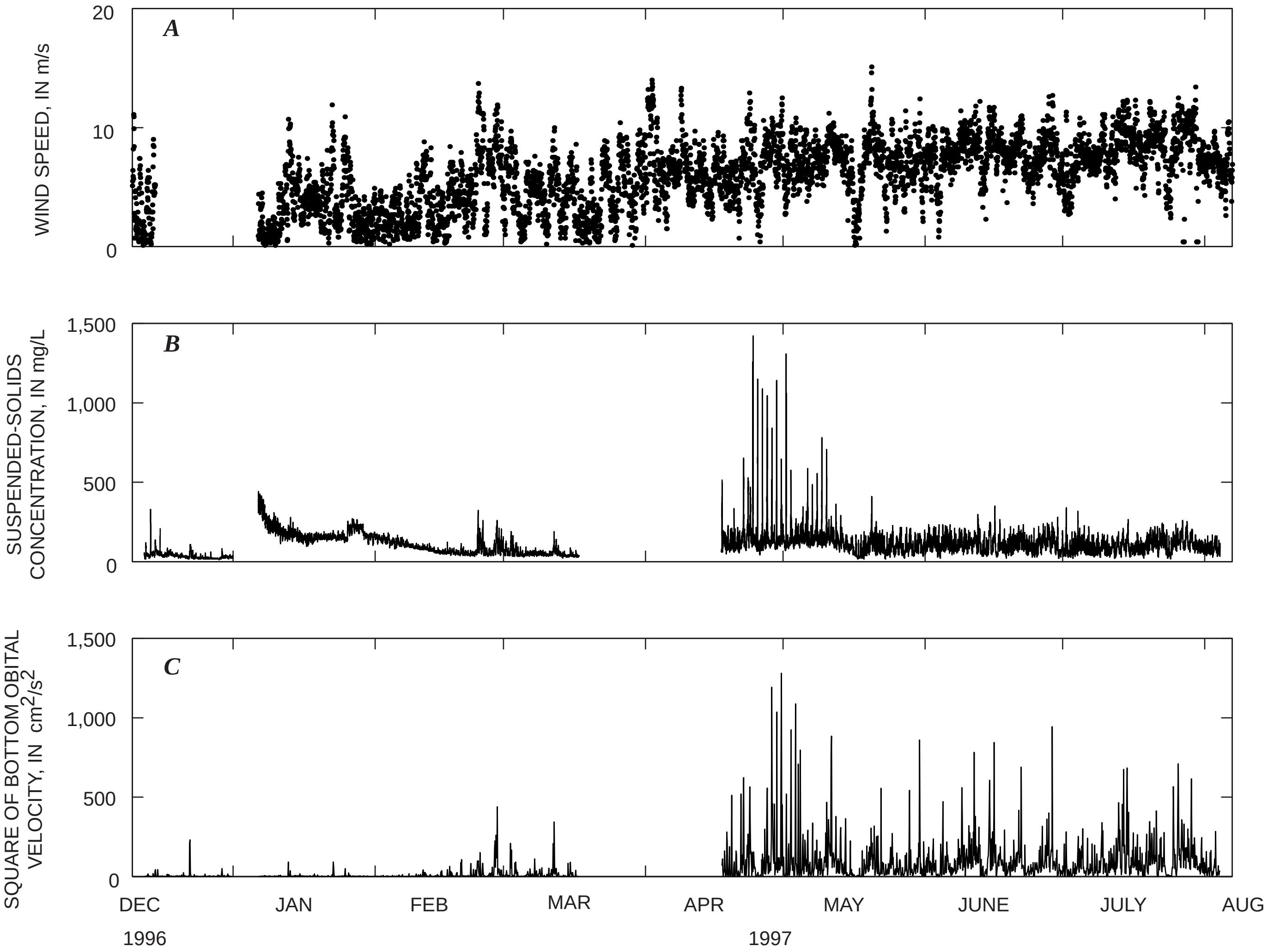

Figure 3.56. Wind speed A, suspended-solids concentration B, and square of bottom orbital velocity C at site *cmid*. m/s = meters per second; mg/L = milligrams per liter; cm^2/s^2 = centimeters squared per second squared.

storage for suspended-solids and their associated trace elements, and therefore have higher concentrations than neighboring channels following flood pulses. Subsequent resuspension of unconsolidated bed sediment in shallow water by tidal currents cause SSC in shallow water to take longer to return to baseline concentrations than in the deeper channel water. In early spring, wind-waves resuspend fine bed sediments causing the greatest spatial variability of SSC in shallow water. Later in the summer, after fine sediments have been winnowed from the Bay floor, less erodible sediments are left behind and SSC decreases, even though wind-generated bed shear stress remains high. Therefore, spatial and temporal variations in SSC should be considered when developing sampling programs for trace elements associated with suspended sediment.

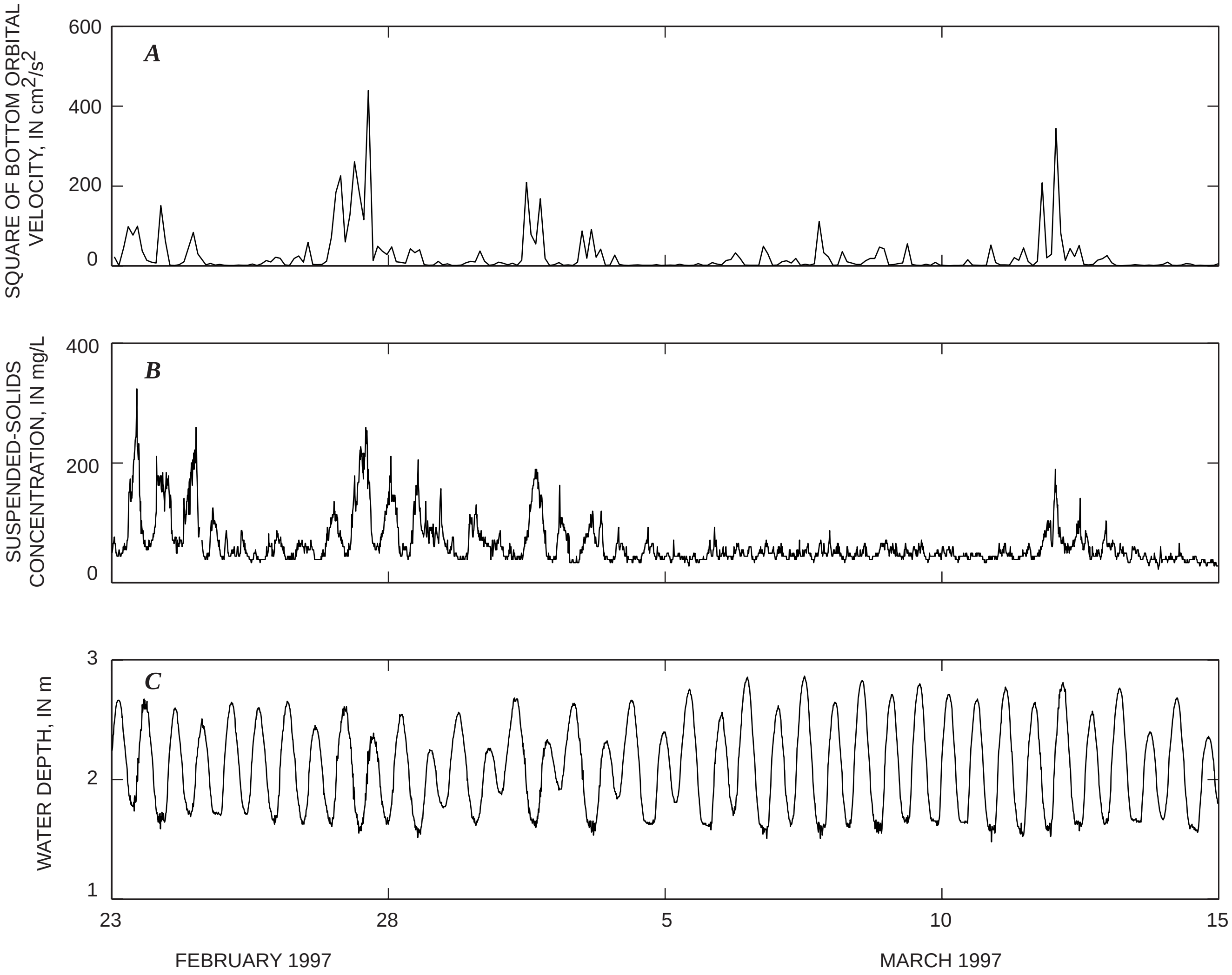

Figure 3.57. Square of bottom orbital velocity A, suspended-solids concentration B, and water depth C, at site *cmid* February 23–March 15, 1997. cm^2/s^2 = centimeters squared per second squared; mg/L = milligrams per liter; m = meters.

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Water Monitoring Discussion

The Big Storm

In the *1996 Annual Report*, the water monitoring discussion focused on seasonal and spatial patterns that emerged over the first four years of the RMP. While these general patterns largely persisted in 1997, the extremely unusual hydrology of early 1997 did have a conspicuous impact on the concentrations of some contaminants. As described by Cloern *et al.* (see *Water-Quality Variability in San Francisco Bay: General Patterns of Change During 1997*, this Chapter), 1997 was the year of the Big Storm, with record-setting precipitation in the watershed in December and January (Hunrichs *et al.*, 1998). Heavy rainfall and record streamflow in January was then followed by unusually dry weather in February and March and low freshwater inflow for the rest of the year. This discussion will focus on ways in which the 1997 results were unusual in comparison to the persistent general patterns observed in RMP water monitoring from 1993 to 1996.

The extreme hydrological variation in early 1997 created a sharp contrast in conventional water quality parameters between the first two sampling cruises of the year. During the January sampling, the surface waters of the Bay were approximately 90% freshwater, with low salinity waters pushing well into Central Bay. By the April cruise the surface waters of the Bay were down to about 50% freshwater. The January sampling therefore characterized a very different water mass than the April sampling, with the January sampling overwhelmingly influenced by the high flows from the Sacramento and San Joaquin rivers and the April sampling more equally influenced by the Rivers and saline waters within the Bay. The January flows also carried a relatively large load of suspended solids, producing the highest baywide mean concentration of total suspended solids (TSS) observed in the five years of the RMP. The mean TSS in April was less than half of the January mean.

The Effect of the Big Storm on Contaminant Concentrations

Dissolved concentrations of several trace elements, including chromium, lead, mercury, nickel, and zinc, were relatively high in January. Dissolved concentrations of chromium, mercury, and lead were especially high, leading to the highest baywide average concentrations (including all stations shown in figures 3.4–3.23) of these elements for any cruise since the beginning of the RMP.

The average concentration of dissolved mercury in January (0.0045 µg/L) was four times higher than the average concentrations in April and August (0.0011 and 0.0010 µg/L, respectively). The January average was heavily influenced by an extremely high value (the second highest observed in the RMP) at the Petaluma River (BD15). Dissolved mercury was also elevated in January at the other Northern Estuary and Rivers stations. The average concentration of dissolved chromium in January (1.86 µg/L) was even more sharply elevated over the April average (0.24 µg/L), an eight fold difference. Concentrations were uniformly elevated at the Northern Estuary and Rivers stations. Ten of the eleven highest chromium concentrations recorded in the RMP were measured in the northern reach. The highest chromium concentration (8.79 µg/L) was measured at the Petaluma River station (BD15). The average dissolved lead concentration in January (0.17 µg/L) was three times higher than the April average (0.05 µg/L). In the South Bay, concentrations of dissolved mercury, chromium, and lead were not strongly affected by the Big Storm. The high dissolved concentrations observed during high flow conditions in the watershed suggest mobilization and transport of large masses of more bioavailable forms of these elements during this period.

Total (dissolved + particulate) concentrations of some trace elements that are transported primarily in the particulate phase were also sharply elevated in January. The highest baywide average total concentrations of chromium, copper, mercury, nickel, lead, and zinc since the beginning of the RMP were measured in January. Baywide average TSS concentrations fell from 91 mg/L in January to 38 mg/L in April, and baywide average concentrations of these elements showed similar declines, generally dropping to about 50% of the January concentrations. Total mercury, for example, fell from a baywide average of 0.036 µg/L in January to 0.014 µg/L in April. The largest drop was observed for chromium, from 17.7 µg/L in January to 5.3 µg/L in April, a 3.3-fold difference. As for the dissolved concentrations, the high baywide averages in January were principally due to high concentrations in the northern reach, and the South Bay was relatively unaffected by the Big Storm. The dissolved and particulate forms of trace elements mobilized during the Big Storm were likely derived from both natural and anthropogenic sources.

High concentrations of some organics were also observed in January. Dissolved chlordanes and DDTs were highest in January at all Northern Estuary stations, although the magnitude of this seasonal difference was not as great as for dissolved mercury, chromium, and lead. The Petaluma River (BD15) and Napa River (BD50) stations in January had the highest concentrations of dissolved DDTs and chlordanes observed in the northern reach. Dissolved chlordanes and DDTs did not exhibit clear seasonal variation in the southern reach.

Diazinon is found almost entirely in the dissolved phase in RMP samples. Unlike chlordanes and DDTs, diazinon concentrations showed seasonal variability in both the northern and southern portions of the Bay. The highest concentrations for the year were observed at the Northern Estuary and Rivers stations in January, ranging between approximately 10 and 40 ng/L. These concentrations were high relative to RMP data from other years, but not the highest.

Total (dissolved + particulate) chlordanes and DDTs were also elevated in the January sampling. Total DDT concentrations at the Rivers were the highest yet observed for these stations in the RMP. Total DDT concentrations were also elevated in January at the Northern Estuary stations. Total concentrations of dieldrin and chlordanes at the Northern Estuary stations were the highest yet observed for these stations in the RMP. The high dissolved + particulate concentrations of DDTs, chlordanes, and dieldrin in the Northern Estuary suggest transport of contaminated sediment particles from the Central Valley during the high flows in January.

In contrast to the organochlorine pesticides, dissolved + particulate PCB concentrations at the Rivers and Northern Estuary stations were not elevated during the Big Storm. This suggests that the sediment particles washing into the Estuary from the Central Valley were relatively uncontaminated with respect to PCBs. This observation is consistent with previous observations of relatively low TSS-normalized concentrations of PCBs at the Northern Estuary and Rivers stations (Jarman and Davis in the *1995 Annual Report*).

Overall, due to a combination of high flows and elevated concentrations, the mass loading of many contaminants to the Bay was greatly increased during the Big Storm of 1997.

Comparison to Water Quality Guidelines

This section provides a brief overview of how 1997 data compare to relevant water quality guidelines (Table 3.7). Of the ten trace elements measured, concentrations of chromium, copper, mercury, nickel, and zinc were higher than guidelines on one or more occasions (Table 3.8). Nickel, mercury, and chromium concentrations were most frequently above guidelines. Several trace organics also had concentrations above guidelines, including PCBs, DDTs, chlordanes, dieldrin, and PAHs (Table 3.9). Congener-based ∑PCBs were well above the congener-based 170 pg/L guideline in most of the samples.

Table 3.7. Water quality guidelines (WQG) used for evaluation of 1997 RMP results. Dissolved trace element water quality criteria are from the Proposed California Toxics Rule (U.S. EPA, 1997). Total trace element water quality criteria are from the Basin Plan (SFBRWQCB, 1995). Organic compounds are listed on a total (dissolved + particulate) basis. Units are in µg/L. Bold and italicized values are hardness dependent criteria and were calculated using a hardness value of 100 mg/L.

	Aquatic Life				**Human Health (10^{-6} risk for carcinogens)**	
Parameter	**Freshwater**		**Saltwater**		**Freshwater**	**Salt- & Freshwater**
	1-hour	**4-day**	**1-hour**	**4-day**	**Water & Organisms**	**Organisms only**
Dissolved trace metals						
Ag	***3.4***	.	1.9	.	.	.
As	340	150	69	36	.	.
Cd	***4.3***	***2.2***	42	9.3	.	.
Cr VI	16	11	1100	50	.	.
Cu	***13***	***9***	5	3.1	1300	.
Ni	***468***	***52***	74	8.2	610	4600
Pb	***65***	***2.5***	210	8.1	.	.
Zn	***117***	***118***	90	81	.	.
Total trace metals						
Ag [A]	***4.1***		***2.3***		.	.
As	360	190	69.0	36.0	.	.
Cd	***3.9***	***1.1***	***43.0***	***9.3***	.	.
Cr VI	16	11	1100.0	50.0	.	.
Hg	2.4	0.025	2.1	0.025	.	.
Ni [B]	***1419***	***158***	.	7.1	.	.
Pb	***81.0***	***3.2***	***140.0***	***5.6***	.	.
Se [C]	5	.	.	.	.	.
Zn [D]	***21***	***23***	58.0	.	.	.
Trace organics						
alpha-HCH	.	.	.	.	0.0039	0.013
Acenaphthene	.	.	.	.	1200	2700
Anthracene	.	.	.	.	9600	110000
Benz(a)anthracene	.	.	.	.	0.0044	0.049
Benzo(a)pyrene	.	.	.	.	0.0044	0.049
Benzo(b)fluoranthene	.	.	.	.	0.0044	0.049
Benzo(k)fluoranthene	.	.	.	.	0.0044	0.049
beta-HCH	.	.	.	.	0.014	0.046
Chlordane	2.4	0.0043	0.09	0.004	0.00057	0.00059
Chlorpyrifos [E]	0.083	0.041	0.011	0.0056	.	.
Chrysene	.	.	.	.	0.0044	0.049
Dibenz(a,h)anthracene	.	.	.	.	0.0044	0.049
Dieldrin	0.24	0.056	0.71	0.0019	0.00014	0.00014
Endosulfan I	0.22	0.056	0.034	0.0087	110	240
Endosulfan II	0.22	0.056	0.034	0.0087	110	240
Endosulfan Sulfate	.	.	.	.	110	240
Endrin	0.086	0.036	0.037	0.0023	0.76	0.81
Fluoranthene	.	.	.	.	300	370
Fluorene	.	.	.	.	1300	14000
gamma-HCH	0.095	0.08	0.16	.	0.019	0.063
Heptachlor	0.52	0.0038	0.053	0.0036	0.00021	0.00021
Heptachlor Epoxide	0.52	0.0038	0.053	0.0036	0.0001	0.00011
Hexachlorobenzene	.	.	.	.	0.00075	0.00077
Indeno(1,2,3-cd)pyrene	.	.	.	.	0.0044	0.049
p,p'-DDD	.	.	.	.	0.00083	0.00084
p,p'-DDE	.	.	.	.	0.00059	0.00059
p,p'-DDT	1.1	0.001	0.13	0.001	0.00059	0.00059
Pyrene	.	.	.	.	960	11000
Mirex [E]	.	0.001	.	0.001	.	.
Total PCBs	.	0.014	.	0.03	0.00017	0.00017
Total PAHs [F]	.	.	.	.	0.031	0.031

[A] Silver value is the instantaneous maximum

[B] Nickel saltwater value is 24-hour average

[C] Selenium values are region-specific criteria as outlined in the National Toxics Rule — 1992: values are for total recoverable selenium results and freshwater criteria apply to the whole Estuary.

[D] Zinc saltwater value is 24-hour average

[E] Chlorpyrifos and mirex are not listed in the proposed CTR but EPA criteria do exist for them.

[F] Total PAHs is not listed in the proposed CTR but an EPA criterion does exist for it.

Table 3.8. Summary of trace elements that were above water quality guidelines (WQGs) for 1997 RMP water samples. Dissolved WQGs used in this comparison are from the proposed EPA—California Toxics Rule (1997) 304(a) Criteria. Total WQGs used are from the San Francisco Basin Plan (1995). Of the ten RMP trace element compounds that have WQGs, only compounds that were above guidelines are listed. • = above guideline, - = data not available.

			Dissolved						Total																				
				Cu			Ni			Cr			Hg			Ni			Pb			Se			Zn	
	Code	**Station**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**
Southern Sloughs	C-1-3	Sunnyvale							•	•		•	•		•	•	•	•	-	-				•		
	C-3-0	San Jose		•					•		•	•		•	•	•	•		-	-					•	•
South Bay	BA10	Coyote Creek		•	•							•	•		•	•			-	-						
	BA20	South Bay		•	•				•			•			•	•	•		-	-						
	BA30	Dumbarton Bridge		•								•			•				-	-						
	BA40	Redwood Creek										•							-	-						
	BB15	San Bruno Shoal																	-	-						
	BB30	Oyster Point																	-	-						
	BB70	Alameda																	-	-						
Central Bay	BC10	Yerba Buena Island																	-	-						
	BC20	Golden Gate																	-	-						
	BC30	Richardson Bay																	-	-						
	BC41	Point Isabel																	-	-						
	BC60	Red Rock																	-	-						
Northern Estuary	BD15	Petaluma River	•		•	•			•		•	•		•	•		•	•	-	-				•		•
	BD20	San Pablo Bay							•			•		•	•		•		-	-						
	BD30	Pinole Point							•			•			•			•	-	-				•		
	BD40	Davis Point							•		•	•			•		•	•	-	-				•		
	BD50	Napa River							•		•	•			•		•	•	-	-				•		
	BF10	Pacheco Creek							•	•	•	•			•	•		•	-	-				•		
	BF20	Grizzly Bay							•			•		•	•	•		•	-	-				•		-
	BF40	Honker Bay							•	•		•	•		•	•		•	-	-				•		
Rivers	BG20	Sacramento River							•			•			•			•	-	-				•		
	BG30	San Joaquin River																•	-	-						
Estuary Interface	BW10	Standish Dam							-	•	•		•						-	-		•	•			
	BW15	Guadalupe River							-	•		•	•	•					-	-					•	

Table 3.9. Summary of trace organic contaminants that were above water quality guidelines (WQGs) for 1997 RMP water samples. WQGs used in this comparison are from the proposed EPA—California Toxics Rule (1997) 304(a) Criteria. Of the 28 RMP organic compounds that have WQCs, only those listed had concentrations that were above guidelines. • = above guideline, - = data not available.

			Benz(a)anthracene			Benzo(k)fluoranthene			Dieldrin			Heptachlor Epoxide			p,p'-DDD			p,p'-DDE			p,p'-DDT			Total Chlordanes			Total PCBs			Total PAHs		
		WQG (ppb):	**0.049**			**0.049**			**0.00014**			**0.00011**			**0.00084**			**0.00059**			**0.00059**			**0.00059**			**0.00017**			**0.00077**		
	Code	**Station**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**	**Jan**	**Apr**	**Aug**
Southern Sloughs	C-3-0	San Jose								•	•		-	-	•			•		-			-	•		•	•	•	•	•	•	•
South Bay	BA10	Coyote Creek			-			-			-																•	•	•	•	•	-
	BA30	Dumbarton Bridge			-			-	•		-			-									-				•	•	•	•	•	
	BA40	Redwood Creek							•																		•	•	•	•	•	
	BB70	Alameda							•																		•	•	•			
Central Bay	BC10	Yerba Buena Island							•																		•	•	•			
	BC20	Golden Gate																														
	BC60	Red Rock							•																			•	•			
Northern Estuary	BD15	Petaluma River							•			•								•							•	•	•	•	•	•
	BD20	San Pablo Bay							•																			•	•			•
	BD30	Pinole Point							•									•			•						•	•	•			
	BD40	Davis Point							•									•			•							•	•			•
	BD50	Napa River							•									•			•						•	•	•	•		•
	BF20	Grizzly Bay																•			•							•	•			
Rivers	BG20	Sacramento River							•	•	•							•			•							•	•			
	BG30	San Joaquin River							•		•																		•			
Estuary Interface	BW10	Standish Dam							•	•	•			-	•			•	•	•	•			•	•		•	•	•	•	•	
	BW15	Guadalupe River		•			•		•	•	•		•		•			•	-	-	•	•		•	•		•	-	•	•	•	•

Effects of Water Contamination

Clear statistically and biologically significant toxicity was observed in the *Mysidopsis* test in January 1997 at Sacramento River (BG20) and San Joaquin River (BG30). Statistically significant toxicity with higher percent survival was also observed at Grizzly Bay (BF20) and Napa River (BD50). In August 1997 clear toxicity was also observed in the *Mysidopsis* test at four South Bay stations: Redwood Creek (BA40), Coyote Creek (BA10), Sunnyvale (C-1-3), and San Jose (C-3-0). Percent survival was 33% at Redwood Creek (BA40), and 0% at the other three stations.

Toxicity tests using *Mytilus* larvae indicated statistically significant toxicity in January at Grizzly Bay (BF20), Pinole Point (BD30), Redwood Creek (BA40), and Sunnyvale (C-1-3), but percent normal development in these samples was relatively high. The statistical significance of these results is due to the low variability in the control treatments and does not indicate toxicity in the samples.

In 1996 a special study was initiated to investigate episodic toxicity following storm events, as described in detail in Ogle and Gunther (this Chapter). In the winter of 1996–1997, ambient toxicity monitoring was conducted at the mouths of Guadalupe Slough and Alviso Slough in the South Bay and in Napa River and at Mallard Island in the North Bay. In the winter of 1997–1998, more temporally-intensive sampling was performed at Mallard Island, sampling continued at Guadalupe Slough, and sampling at Pacheco Slough was added. Toxicity has been detected consistently in this special study. In some instances, ELISA analysis of diazinon and chlorpyrifos in the samples has yielded results consistent with these organophosphates being the possible cause of toxicity. In most samples, however, diazinon and chlorpyrifos concentrations were below toxic levels, suggesting that other contaminants were responsible for the observed toxicity.

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CHAPTER 4

Sediment Monitoring

Sediment Introduction

Background

Sediments are monitored because they are an important component of the Bay and Estuary ecosystem and information about sediments addresses aspects of all RMP Objectives (RMP Objectives are listed in *Chapter 1: Introduction*). In this Chapter, patterns and trends in sediment contamination are described (Objective 1) and compared to several sets of sediment quality guidelines (Objective 4). The results are used to make some inferences about the sources and loadings of sediment-associated contaminants (Objective 2). Sediment bioassays and the Benthic Pilot Study address contaminant effects (Objective 3). Several RMP Pilot and Special Studies and summaries of Regional Board studies on sediments are included, addressing Objective 5.

Information about sediment contamination is used in making decisions related to many important management issues: the identification of sediment "toxic hot spots" is currently a priority for the State and Regional Boards, the clean-up of numerous military bases in the region requires information about background contaminant levels, and the continuous dredging of the Estuary requires testing and comparisons to some reference, or background concentrations. The RMP provides information that may be used by others to assess the condition of Estuary sediments.

Most contaminants accumulate in sediments to concentrations that are orders of magnitude above those in water. The geochemistry of sediments is complex, and in order to interpret contaminant concentrations measured in sediments, it is necessary to understand how hydrology (flows) and other non-contaminant sediment properties may affect contaminant concentrations. An overview of Estuary hydrology and water quality was presented in *Chapter 1: Introduction*. CTD (conductivity, temperature, depth) profiles of the water column were collected at all RMP sediment stations. Those data are not presented in this report, but are available from SFEI upon request. Several sediment quality parameters that may affect sediment contaminant concentrations (grain-size, organic carbon, ammonia, and sulfides) are also monitored, and are listed in *Appendix C: Data Tables*.

Sediment contaminant monitoring includes trace elements and trace organic contaminants at 22 RMP Base Program stations. Sediments were also monitored at two stations at the southern end of the Estuary in cooperation with the Regional Board and the cities of San Jose (station C-3-0) and Sunnyvale (station C-1-3). In addition, sediments were monitored at two stations in the southern end of the Estuary, Standish Dam on Coyote Creek (station BW10), and Alviso Slough on the Guadalupe River (station BW15), as part of the Estuary Interface Pilot Study (see *Chapter 6: Pilot and Special Studies*).

Station locations are shown on the inside of the front cover. Sediment samples were collected during the wet season (January–February) and dry season (August). Sampling dates are shown on Table 1.2 in *Chapter 1: Introduction*. *Appendix A* contains detailed methods of collection and analysis. Table 1.1 in *Chapter 1: Introduction* lists parameters measured in sediment. Sediment quality parameters including station depths, and all contaminant concentrations are tabulated in *Appendix C*.

In order to compare sediment monitoring results among the major sub-regions of the Estuary, the RMP stations are separated into six groups of stations in five Estuary reaches based subjectively on geography, similarities in sediment types, and patterns of trace contaminant concentrations. The Estuary reaches are: the Southern Sloughs (C-1-3 and C-3-0), South Bay (seven stations, BA10 through BB70), Central Bay (five stations, BC11 through BC60), Northern Estuary (eight stations, BD15 through BF40), and Rivers (BG20 and BG30). Stations with coarse sediments (>60% sand: six stations in the wet season and five in the dry season) generally have considerably lower contaminant concentrations and are identified on Figures 4.1–4.15.

Concentrations of copper and silver are not reported for some sites because the method blanks were contaminated to a degree above acceptable levels. Those samples are identified on Figures 4.4 and 4.9.

Sediment Quality Guidelines

There are currently no Basin Plan objectives or other regulatory criteria for sediment contaminant concentrations in the Estuary. However, there are several sets of sediment quality guidelines (Table 4.8) that may be used as informal screening tools for sediment contaminant concentrations, but hold no regulatory status.

The U.S. EPA has produced draft criteria for five trace contaminants: three PAHs—acenapthene, fluoranthene, and phenanthrene—and two pesticides—dieldrin and endrin (U.S. EPA, 1991). Those draft criteria have recently been redesignated as "guidelines".

Sediment quality guidelines developed by Long *et al.* (1995) are based on data compiled from numerous studies in the United States that included sediment contaminant and biological effects information. The guidelines were developed to identify concentrations of contaminants that were associated with biological effects in laboratory, field, or modeling studies. The Effects Range-Low (ERL) value is the concentration equivalent to the lower 10th percentile of the compiled study data, and the Effects Range-Median (ERM) is the concentration equivalent to the 50th percentile of the compiled study data. Sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects. Concentrations between the ERL and ERM are "occasionally" associated with adverse effects, and concentrations above the ERM are "frequently" associated with adverse effects. Effects-range values for mercury, nickel, total PCBs, and total DDTs have low levels of confidence associated with them. The Effects-Range values used for chlordanes and dieldrin are from Long and Morgan (1990). There are no Effects-Range guidelines for selenium, but the Regional Board has suggested guidelines of 1.4 ppm (Wolfenden and Carlin, 1992), and 1.5 ppm (Taylor *et al.*, 1992).

A new set of sediment quality guidelines developed by the Regional Board is introduced in this report. Ambient Sediment Concentration (ASC) values are based on ambient or "background" concentrations (see article by Gandesbery *et al.* in this Chapter).

Sediment Bioassays

Sediment bioassays are conducted to determine the potential for biological effects from exposure to sediment contamination. Two sediment bioassays were conducted at 14 of the RMP stations (Figure 4.16) in January–February and again in August of 1997. Sampling dates are listed in Table 1.2 of *Chapter 1: Introduction*. Amphipods (*Eohaustorius estuarius*) were exposed to whole sediment for ten days with percent survival as the endpoint. Larval mussels (*Mytilus* sp.) were exposed to sediment elutriates (water-soluble fraction) for 48 hours with percent normal development as the endpoint. The control sediment used in the *Eohaustorius* test was "home" sediment from Yaquina Bay, Oregon where the amphipods were collected. The control used for the *Mytilus* (mussel) test was clean seawater from Granite Canyon, California. *Appendix A* contains detailed methods of collection and testing and *Appendix B* contains quality assurance information. There were no significant quality assurance exceptions in the 1997 sediment bioassays.

When a sample is found to be toxic, it is interpreted as an indication of the potential for biological effects. However, since sediments are mixtures of numerous contaminants, it is difficult to determine which contaminant(s) may have caused any toxicity observed (see *Sediment Discussion Monitoring*).

A sample was considered toxic if:

1. there was a significant difference between the laboratory control and test replicates using a t-test, and
2. the difference between the mean endpoint value in the control and the mean endpoint value in the test sample was greater than the 90th percentile minimum significant difference (MSD).

The MSD is a statistic that indicates the difference between the two means that will be considered statistically significant given the observed level of between-replicate variation and the alpha level chosen for the comparison. The 90th percentile MSD value is the difference that 90% of the t-tests will be able to detect as statistically significant. Use of the 90th percentile MSD is similar to establishing statistical power at a level of 0.90, and is a way to insure that statistical significance is determined based on large differences between means, rather than small variation among replicates. MSDs were established by analysis of numerous bioassay results for San Francisco Bay (Anderson and Hunt, unpubl.; Hunt *et al*. 1996). Based on those analyses, the 90th percentile MSD for *Eohaustorius* was 18.8% and for the bivalve larvae test 21%. For the 1997 sediment bioassays, an amphipod bioassay was toxic if it had below 79.2% survival in February or 80.2% survival in August. A larval bivalve bioassay was toxic it if had below 73% or 69% normal development in January–February or August, respectively.

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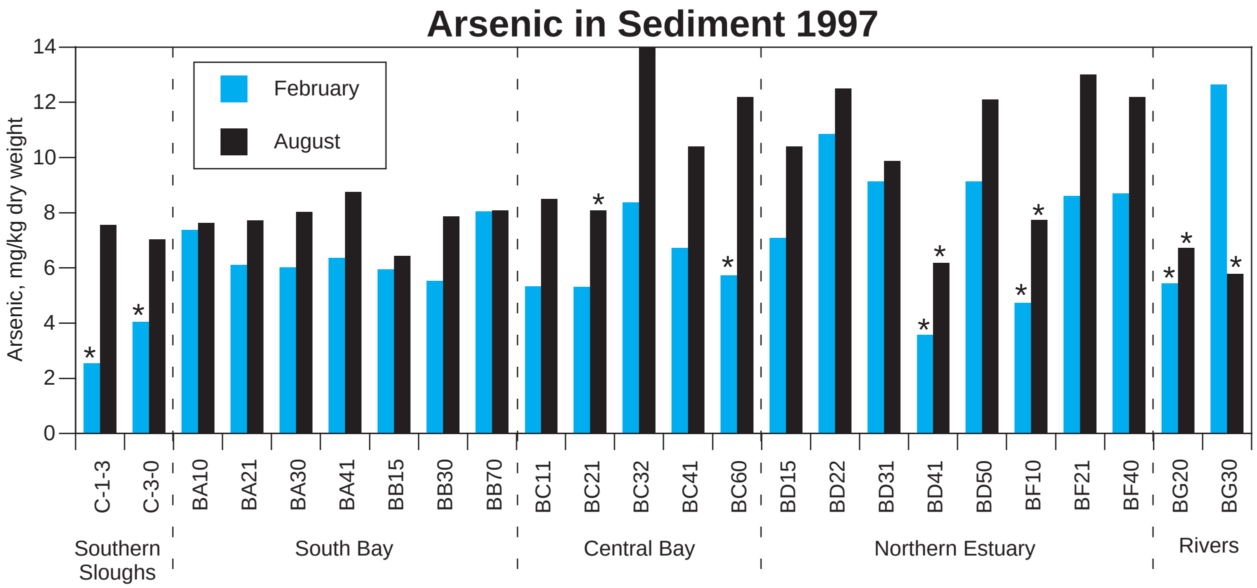


Figure 4.1. Arsenic (As) concentrations in sediment in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Arsenic concentrations ranged from 2.5 to 14 ppm. The highest concentration was sampled at Richardson Bay (BC32) in August and the lowest at Sunnyvale (C-1-3) in February. Average concentrations were highest (10.6 ppm) in the Central Bay in August and lowest (3.3 ppm) in the Southern Sloughs in February. All stations had concentrations below the ERM value of 70 ppm. However, seven stations in February and eleven stations in August had concentrations above the ERL value of 8.2 ppm.

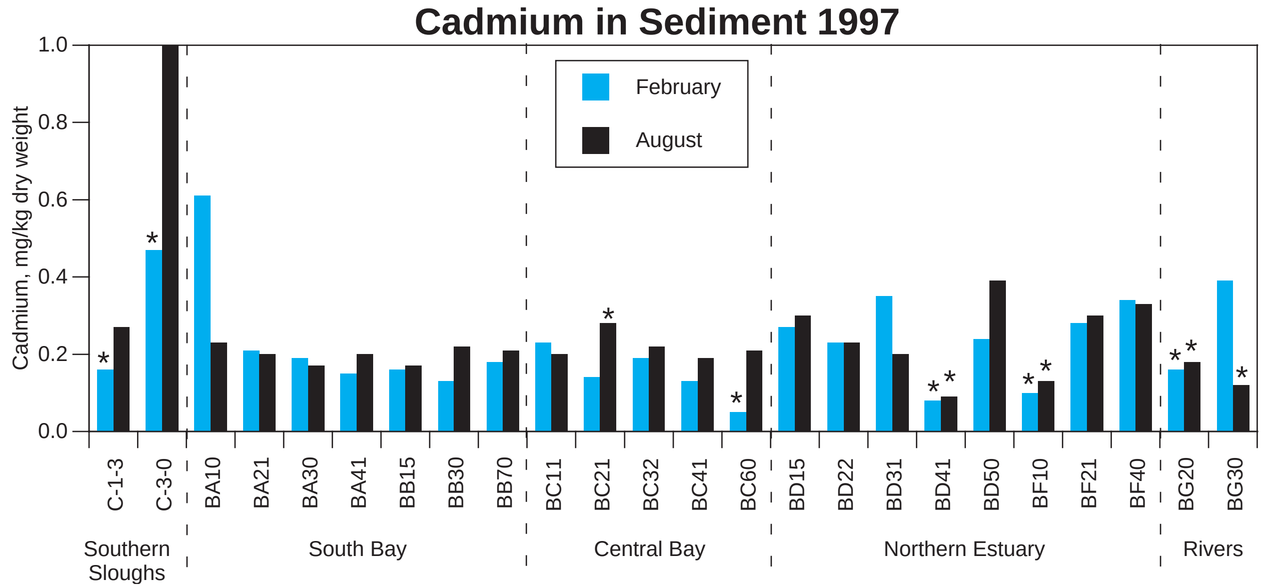


Figure 4.2. Cadmium (Cd) concentrations in sediment in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Cadmium concentrations ranged from 0.05 to 1 ppm. The highest concentration was sampled at San Jose (C-3-0) in August and the lowest at Red Rock (BC60) in February. Average concentrations were highest (0.64 ppm) in the Southern Sloughs in August and lowest (0.15 ppm) in the Central Bay in February. All stations had concentrations below the ERM value of 9.6 ppm and the ERL value of 1.2 ppm.

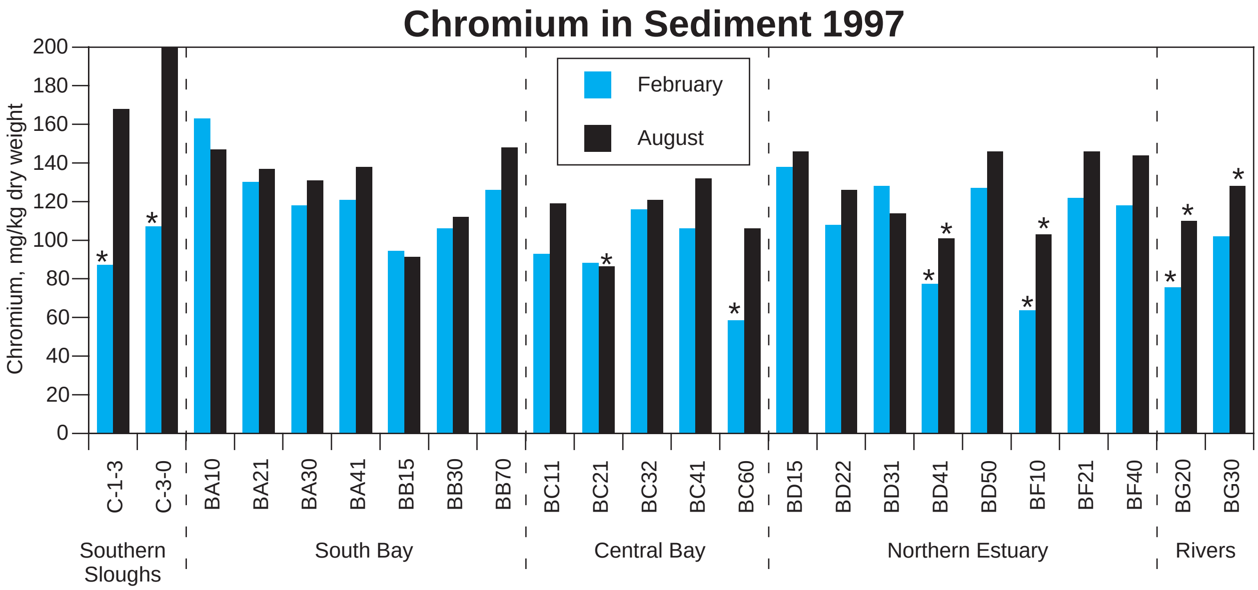


Figure 4.3. Chromium (Cr) concentrations in sediment in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Chromium concentrations ranged from 58.5 to 200 ppm. The highest concentration was sampled at San Jose (C-3-0) in August and the lowest at Red Rock (BC60) in February. Average concentrations were highest (184 ppm) in the Southern Sloughs in August and lowest (88.8 ppm) in the Rivers in February. All stations had concentrations below the ERM value of 370 ppm. However, twenty stations in February and all stations in August had concentrations above the ERL value of 81 ppm.

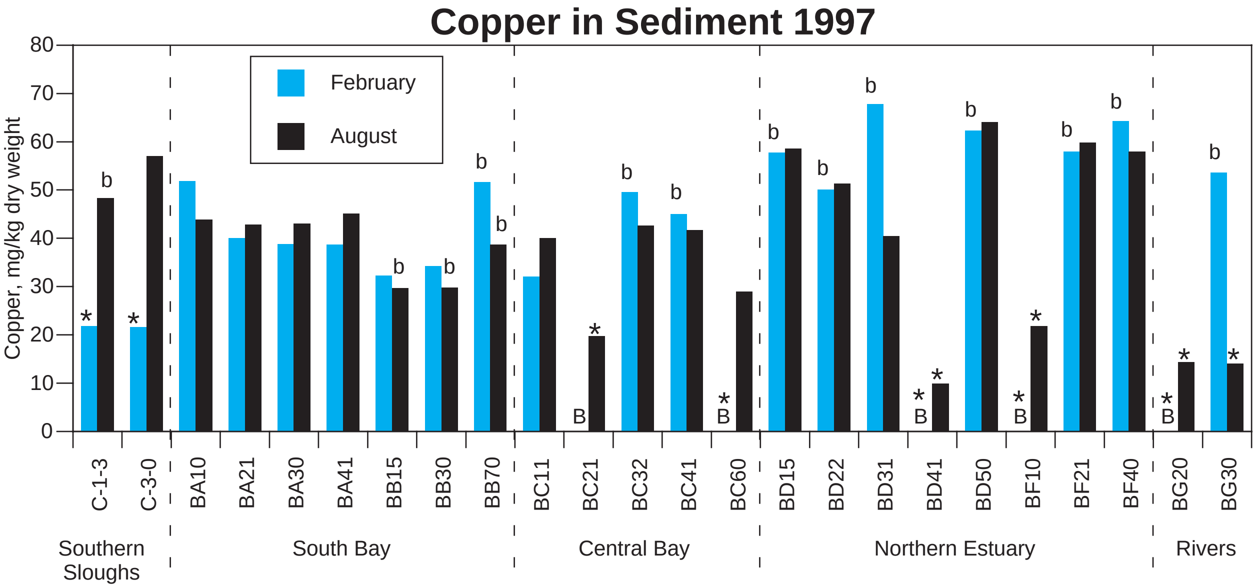


Figure 4.4. Copper (Cu) concentrations in sediment in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Data is not shown for a number of sites because the blanks were contaminated (as indicated by B). b = blank contamination <10% of measured concentration. Copper concentrations ranged from 9.9 to 67.7 ppm. The highest concentration was sampled at Pinole Point (BD31) in February and the lowest at Davis Point (BD41) in August. Average concentrations were highest (60.0 ppm) in the Northern Estuary in February and lowest (14.2 ppm) in the Rivers in August. All stations had concentrations below the ERM value of 270 ppm. However, fifteen stations in February and sixteen stations in August had concentrations above the ERL value of 34 ppm.

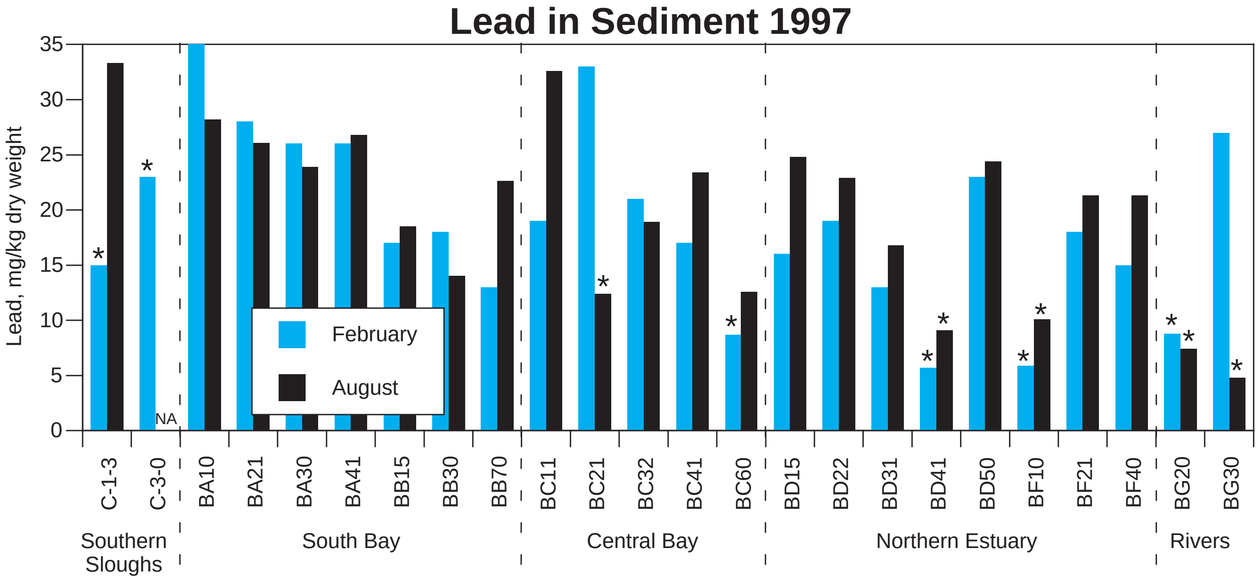


Figure 4.5. Lead (Pb) concentrations in sediment in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. NA indicates data not available. Lead concentrations ranged from 4.8 to 35 ppm. The highest concentration was sampled at Coyote Creek (BA10) in February and the lowest at San Joaquin River (BG30) in August. Average concentrations were highest (33.3 ppm) in the Southern Sloughs and lowest (6.1 ppm) in the Rivers, both in August. All stations had concentrations below the ERM value of 218 ppm and the ERL value of 46.7 ppm.

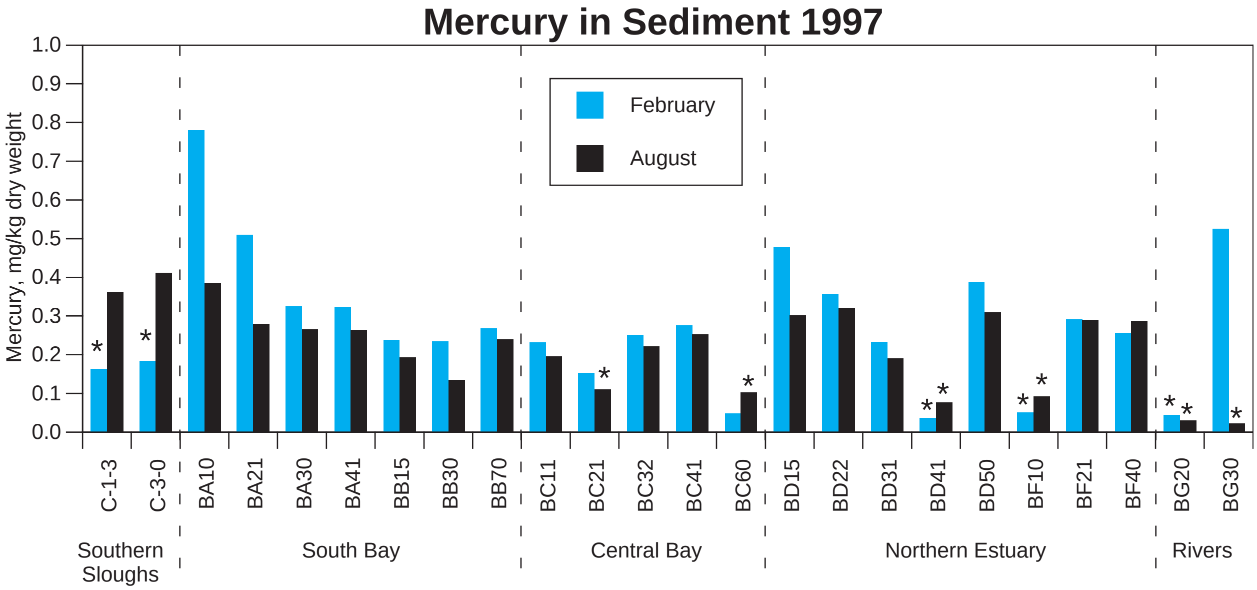


Figure 4.6. Mercury (Hg) concentrations in sediments in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Mercury concentrations ranged from 0.023 to 0.78 ppm. The highest concentration was sampled at Coyote Creek (BA10) in February and the lowest at San Joaquin River (BG30) in August. Average concentrations were highest (0.39 ppm) in the Southern Sloughs and lowest (0.03 ppm) in the Rivers, both in August. One station in February had concentrations above the ERM value of 0.71 ppm. Twenty stations in February and seventeen stations in August had concentrations above the ERL value of 0.15 ppm.

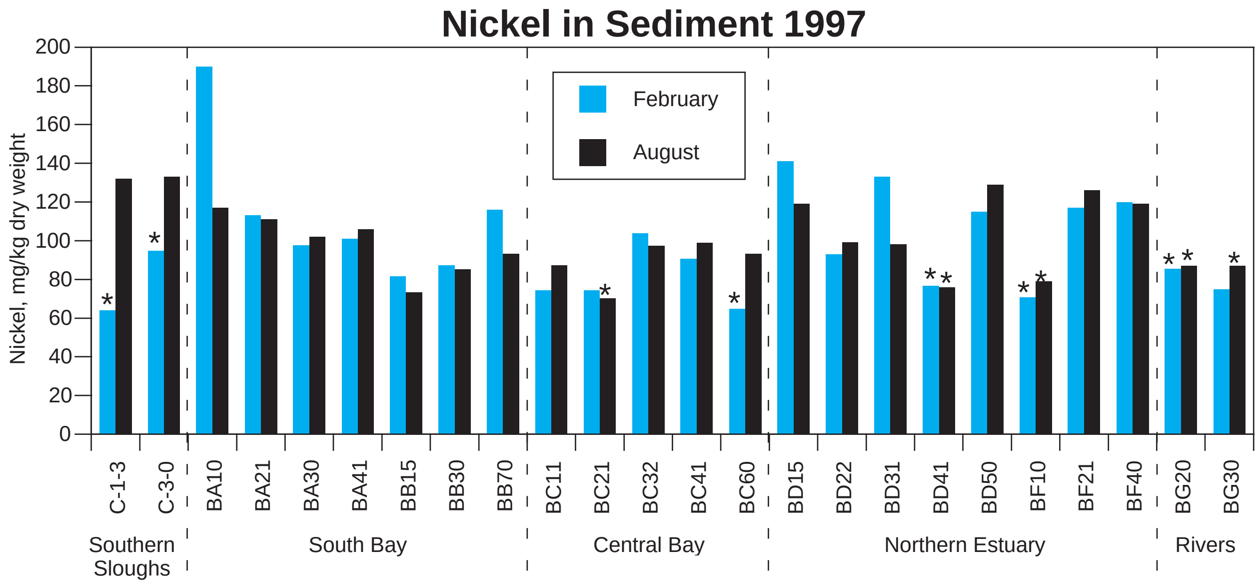


Figure 4.7. Nickel (Ni) concentrations in sediments in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Nickel concentrations ranged from 64 to 190 ppm. The highest concentration was sampled at Coyote Creek (BA10) and the lowest at Sunnyvale (C-1-3), both in February. Average concentrations were highest (132.5 ppm) in the Southern Sloughs in August and lowest (79.5 ppm) in the Southern Sloughs in February. All stations had concentrations above the ERM value of 51.6 ppm and the ERL value of 20.9 ppm.

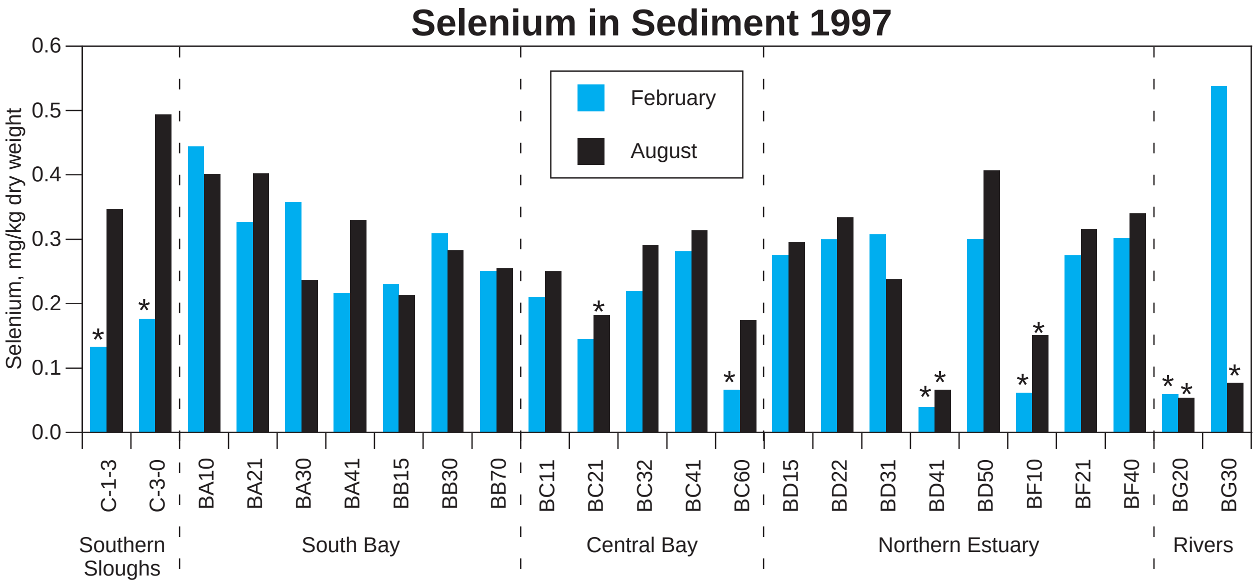


Figure 4.8. Selenium (Se) concentrations in sediments in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Selenium concentrations ranged from 0.04 to 0.54 ppm. The highest concentration was sampled at San Joaquin River (BG30) in February and the lowest at Davis Point (BD41) in February. Average concentrations were highest (0.42 ppm) in the Southern Sloughs in August and lowest (0.07 ppm) in the Rivers in August. There are no ERM and ERL values for selenium.

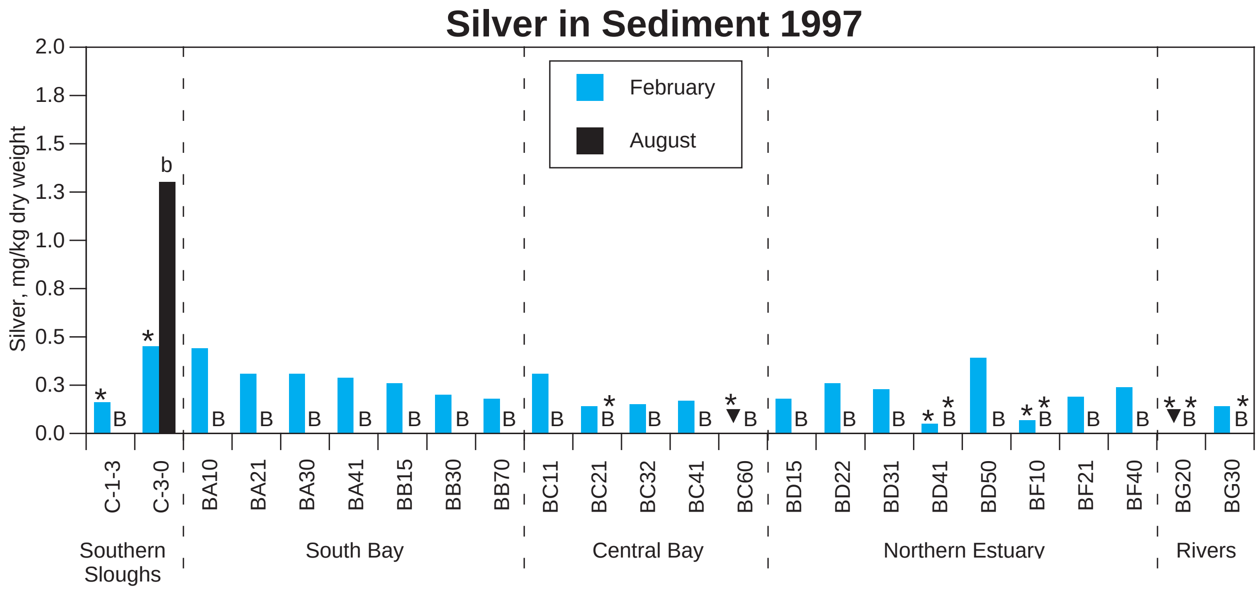


Figure 4.9. Silver (Ag) concentrations in sediments in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. ▼ = not detected, b = blank contamination <10% of measured concentration, B = blank contamination >10% of measured concentration. Silver concentrations ranged from 0.05 to 1.3 ppm. The highest concentration was sampled at San Jose (C-3-0) in August. Average concentrations were highest (1.3 ppm) in the Southern Sloughs in February. All stations had concentrations below the ERM value of 410 ppm. However, one station in February and two stations in August had concentrations above the ERL value of 150 ppm.

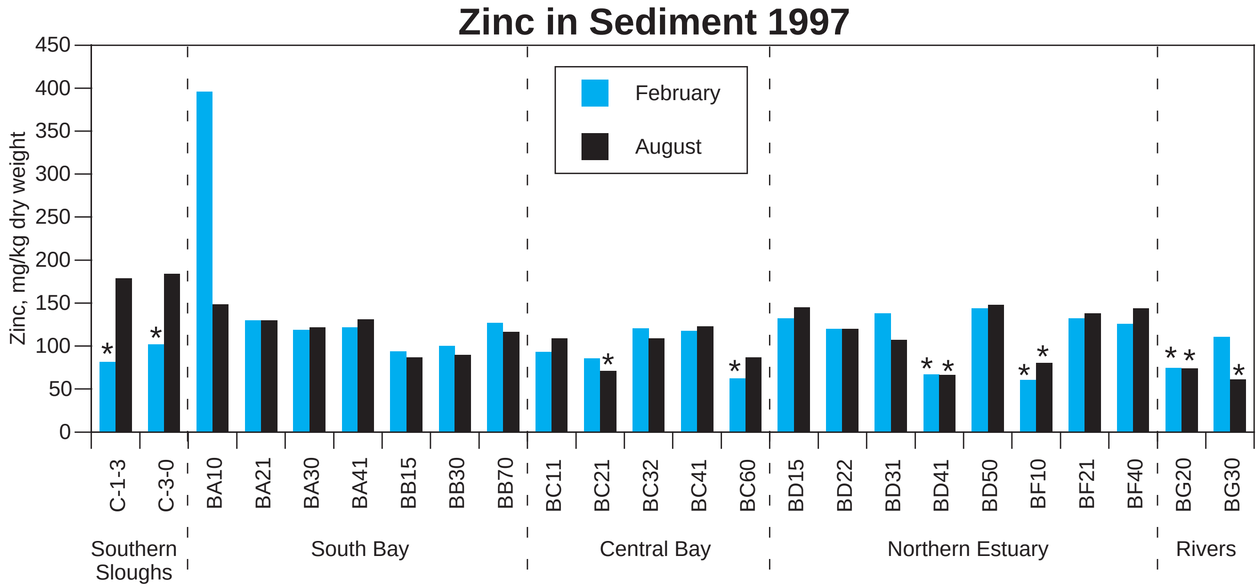


Figure 4.10. Zinc (Zn) concentrations in sediments in parts per million, dry weight (ppm) at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. Zinc concentrations ranged from 60.5 to 396 ppm. The highest concentration was sampled at Coyote Creek (BA10) in February and the lowest at Pacheco Creek (BF10) in February. Average concentrations were highest (181.5 ppm) in the South Sloughs and lowest (67.8 ppm) in the Rivers, both in August. All stations had concentrations below the ERM value of 3.7 ppm. However, one station in August had a concentration above the ERL value of 1 ppm.

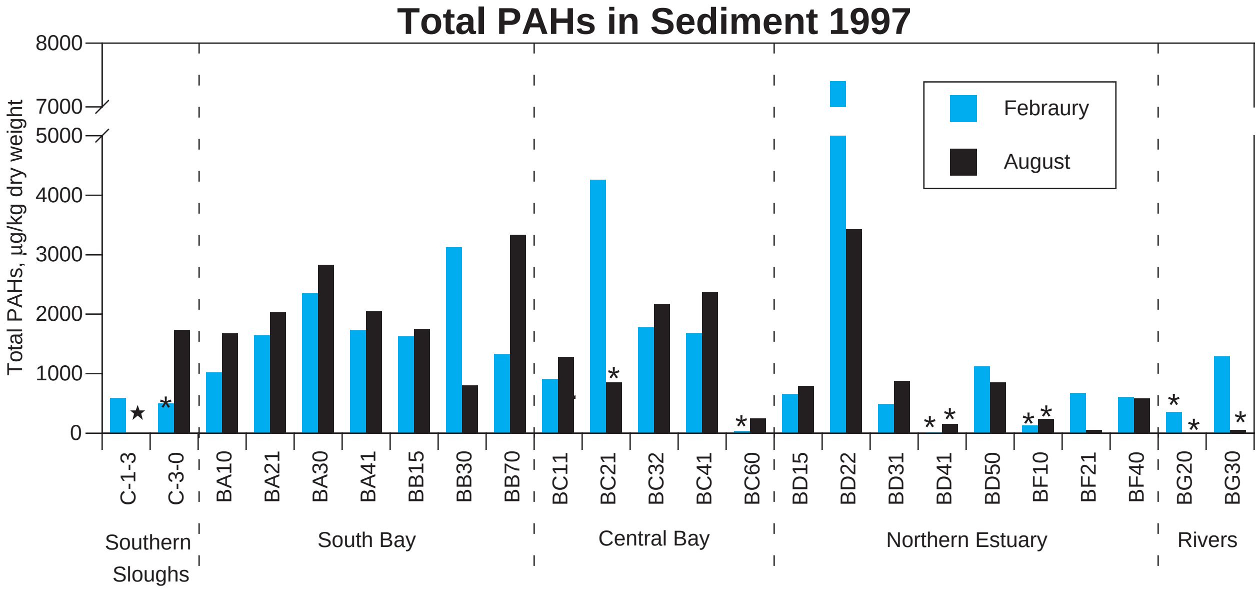


Figure 4.11. Total PAH concentrations in sediment in parts per billion (ppb), dry weight at 24 stations sampled in February and August of 1997. * indicates coarse sediment stations. ★ = not analyzed. Total PAH concentrations ranged between 2.3 and 7,406 ppb. The highest concentration was sampled at San Pablo Bay (BD22) in February and the lowest at Sacramento River (BG20) in August. Average concentrations were highest (2,070 ppb) in the South Bay and lowest (26.9 ppb) in the Rivers, both in August. Concentrations were below the ERM of 44,792 ppb at all stations, however, two stations in February were above the ERL of 4,022 ppb.

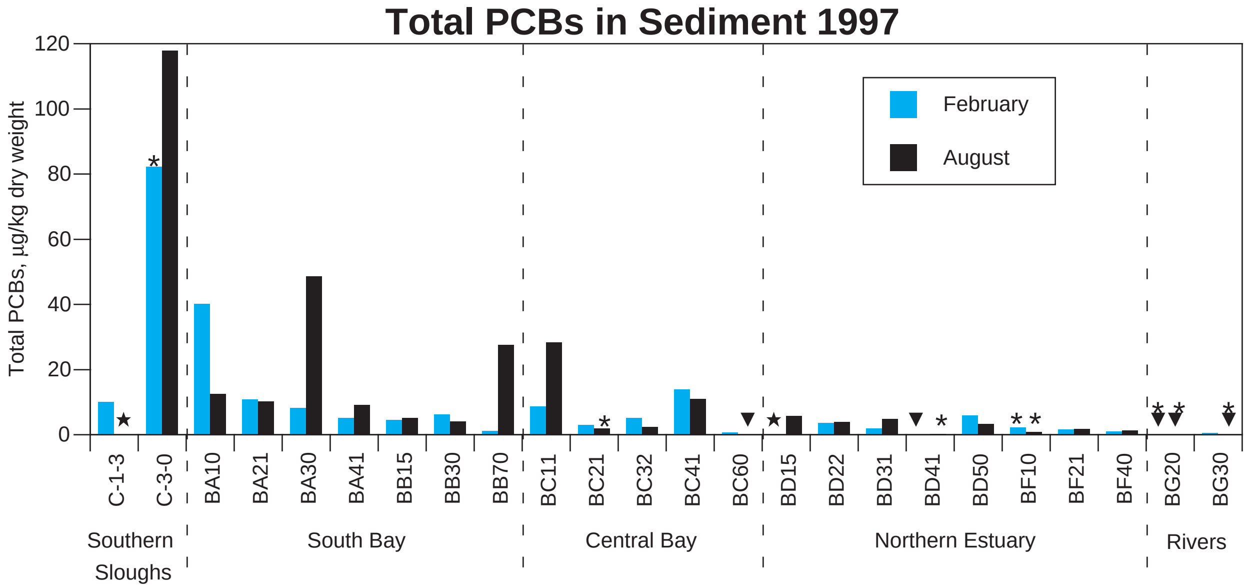


Figure 4.12. Total PCB concentrations in sediment in parts per billion (ppb), dry weight at 24 stations sampled in February and August 1997. * indicates coarse sediment stations. ★ = not analyzed. ▼ = below detection limit. Total PCB concentrations ranged between not detected (▼) and 119 ppb (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in August. Average concentrations were highest (119 ppb) in the Southern Sloughs in August. Concentrations were below the ERM of 180 ppb at all stations, however, two stations in February and four stations in August were below the ERL of 23 ppb.

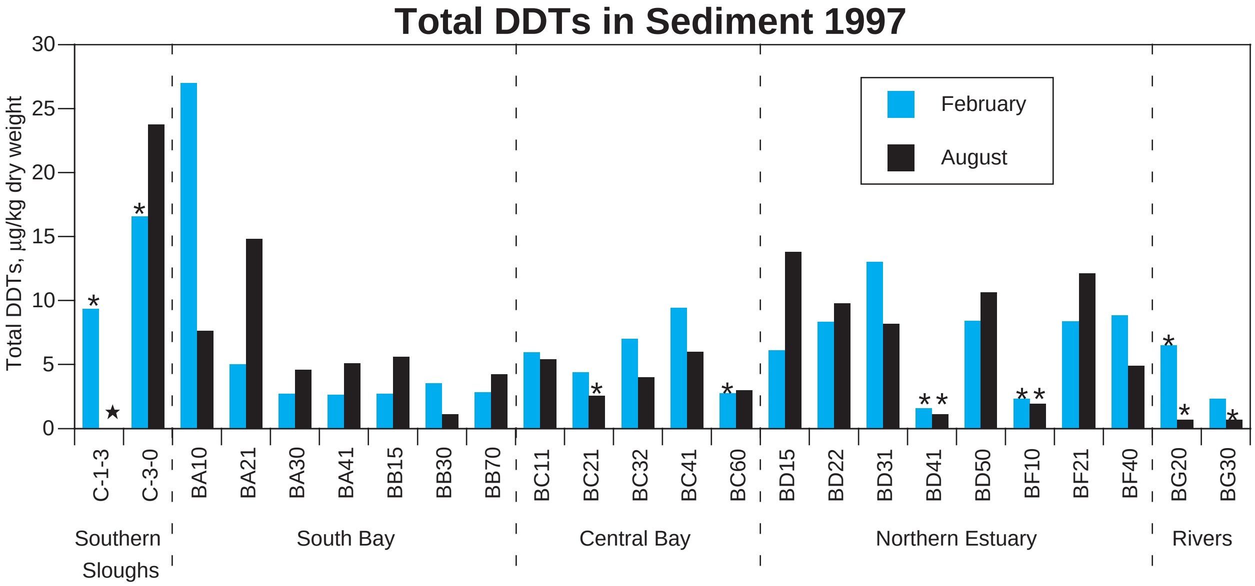


Figure 4.13. Total DDT concentrations in sediment in parts per billion (ppb), dry weight at 24 stations sampled in February and August 1997. * indicates coarse sediment stations. ★ = not analyzed. DDT concentrations ranged between 0.7 and 27.0 ppb (see *Appendix B* for MDLs). The highest concentration was sampled at Coyote Creek (BA10) in February. Average concentrations were highest (23.7 ppb) in the Southern Sloughs and lowest (0.7 ppb) in the Rivers, both in August. Concentrations were below the ERM of 46 ppb at all stations, however, concentrations were above the ERL of 1.58 ppb at 23 stations in February and 19 stations in August.

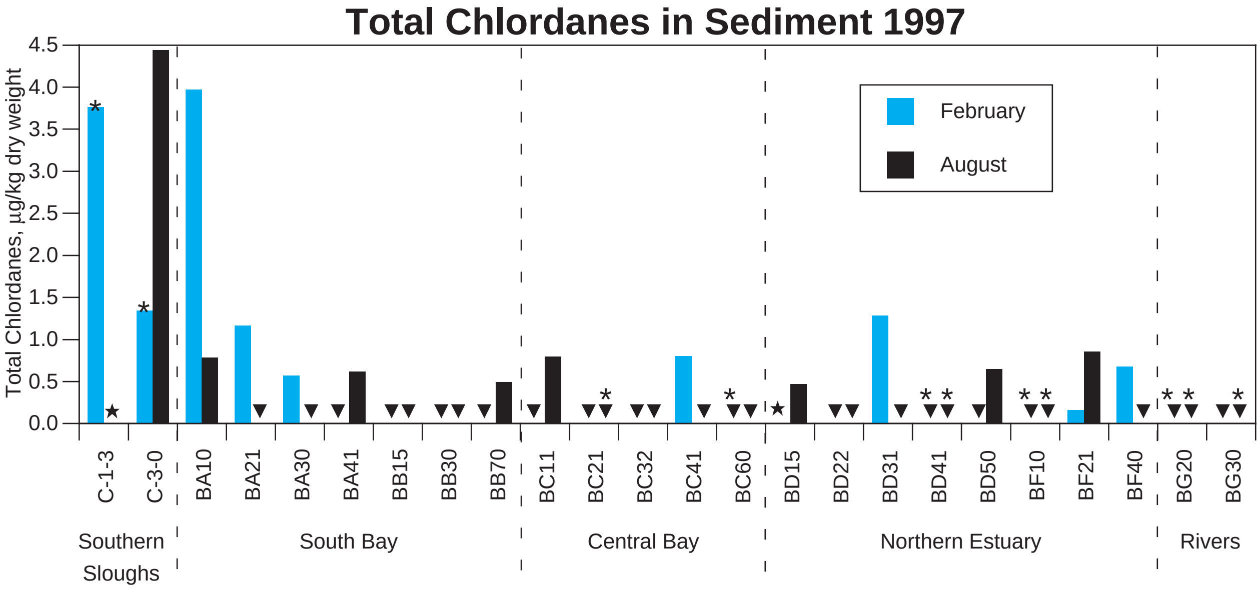


Figure 4.14. Total chlordane concentrations in sediment in parts per billion (ppb), dry weight at 24 stations sampled in February and August 1997. * indicates coarse sediment stations. ★ = not analyzed. ▼ = below detection limit. Chlordane concentrations ranged between not detected (▼) and 4.4 ppb (see *Appendix B* for MDLs). The highest concentration was sampled at San Jose (C-3-0) in February. Average concentrations were highest (4.4 ppb) in the Southern Sloughs in August. Concentrations were below the ERM of 6 ppb at all stations. Concentrations were above the ERL of 0.5 ppb at 8 stations in February and 6 stations in August.

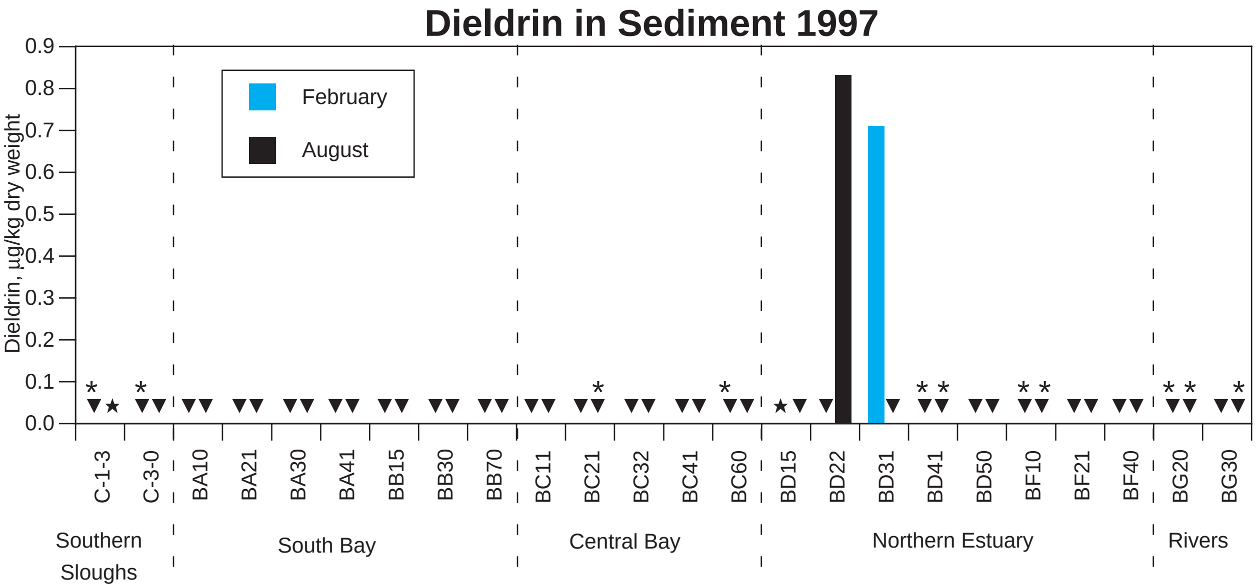


Figure 4.15. Dieldrin concentrations in sediment in parts per billion (ppb), dry weight at 24 stations sampled in February and August 1997. * indicates coarse sediment stations. ★ = not analyzed. ▼ = below detection limit. Dieldrin concentrations ranged between not detected (▼) and 0.8 ppb (see *Appendix B* for MDLs). The highest concentration was sampled at San Pablo Bay (BD22) in August. Averages were not calculated because concentrations were below the detection limit from all but two samples. Concentrations were below the ERM of 8 ppb in all stations, however, concentrations were above the ERL of 0.02 ppb at both stations where dieldrin was detected.

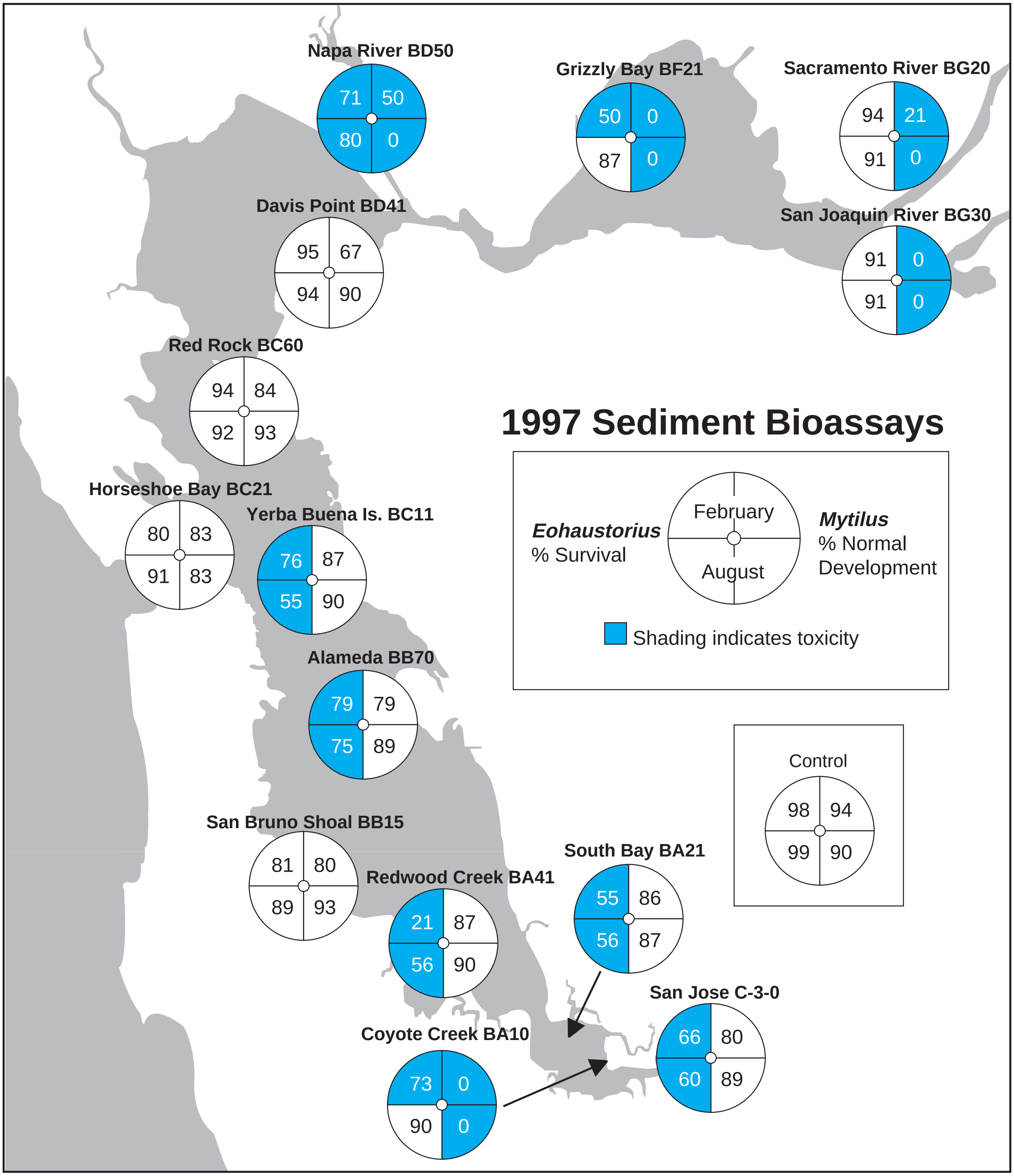


Figure 4.16. Sediment bioassay results for 1997. Sediments were not toxic (see text for definition) to either amphipods or bivalve larvae at Davis Point (BD41), Red Rock (BC60), Horseshoe Bay (BC21), and San Bruno Shoal (BB15). Amphipod toxicity was observed in both sampling periods at Napa River (BD50), Yerba Buena Island (BC11), Alameda (BB70), Redwood Creek (BA41), South Bay (BA21), and San Jose (C-3-0), and only in the wet-sampling period (February) at Grizzly Bay (BF21) and Coyote Creek (BA10). Sediments at the River stations (BG20, BG30) were not toxic to amphipods. Sediment elutriates were toxic to larval mussels during both sampling periods at Sacramento River (BG20), San Joaquin River (BG30), Grizzly Bay (BF21), Napa River (BD50), and Coyote Creek (BA10), but were not toxic to the larvae at the remaining stations. Sediment conditions that could have influenced toxicity are considered in the *Discussion*.

Sediment Trends

Sediment contaminant concentrations have been measured at most of the RMP sites since 1991. Samples were collected by the Bay Protection and Toxic Clean-up Program (BPTCP) Pilot Studies in 1991–1992 (Flegal *et al*., 1994) and by the RMP since 1993. Combining data from those two programs provides a time-series of 12 sampling periods over 7 years. Averages and ranges of concentrations for trace elements and trace organics, over time, are shown for each Estuary reach (Figures 4.17 and 4.18).

Except for the Rivers, plots for the various Estuary reaches include only muddy sediment samples (<60% sand). At the River stations, one or both stations had coarse sediments in each sampling period. A separate plot is presented showing trends for all samples with coarse (>60% sand) sediments, including the Rivers when sandy.

For the trace elements, chromium concentrations appear to have increased in most reaches (except South Bay) between 1991 and 1997, and nickel appears to have increased in the northern Estuary (Figure 4.17). Although silver in the Northern Estuary, South Bay, and Central Bay was higher in 1991 and 1992 than in subsequent years, only concentrations in the South Bay appear to have continuously decreased. There were no obvious seasonal (wet, dry) patterns in any of the trace element trends. However, the January 1997 floods noticeably changed concentrations of some trace elements measured the following month. Cadmium, mercury, nickel, and zinc were obviously elevated in some South Bay samples as evidenced by the large range bars. Conversely, arsenic appeared to decrease in the South Bay, and in the Central Bay and Northern Estuary as well. Similarly, copper and mercury were elevated in the River samples. Aside from occasional “spikes” in lead and selenium concentrations, those two elements showed no obvious trends or influence of the 1997 floods. However, both trace elements exhibited elevated concentrations at the San Joaquin River station (BG30) in February (Figures 4.5 and 4.8).

For the trace organic contaminants, total DDTs in the Northern Estuary appear to have increased since 1991, but total PCBs, total chlordanes, and dieldrin in the Rivers appear to have decreased (Figure 4.18). PCBs in the Central Bay and dieldrins in the South and Central bays have also decreased in concentration. Total PAHs at the Rivers and other reaches are often higher in concentration in the wet-sampling period than in the dry-sampling period, but there was no other obvious seasonal pattern in the trace organic contaminants. As with some of the trace elements, the 1997 flood apparently caused increases in some trace organic contaminants. The most obvious increases were in total PAHs and total DDTs at the River stations. Total chlordanes and total DDTs also increased at the South Bay sites in February, 1997.

In considering the trends in these plots, it is important to recognize that concentrations may be influenced by physical sediment factors as well as proximity to sources. In general, sediments with more silt and clay (percent fines) and higher total organic carbon (TOC) have higher concentrations than sediments with more sand and low TOC. Therefore, some of the variation represented in the plots could be attributable to spatial and temporal variations in sediment type rather than in changes in concentrations *per se*. Additionally, rigorous time-series analysis generally requires more than the 10 to 12 samples available. Further study of the relationships between concentrations and other sediment factors, and over time, are good candidates for future RMP Special Studies.

References

Flegal, A.R., R.W. Risebrough, B. Anderson, J. Hunt, S. Anderson, J. Oliver, M. Stephenson, and R. Packard. 1994. San Francisco Estuary Pilot Regional Monitoring Program: Sediment Studies. San Francisco Bay Regional Water Quality Control Board, State Water Resources Control Board.

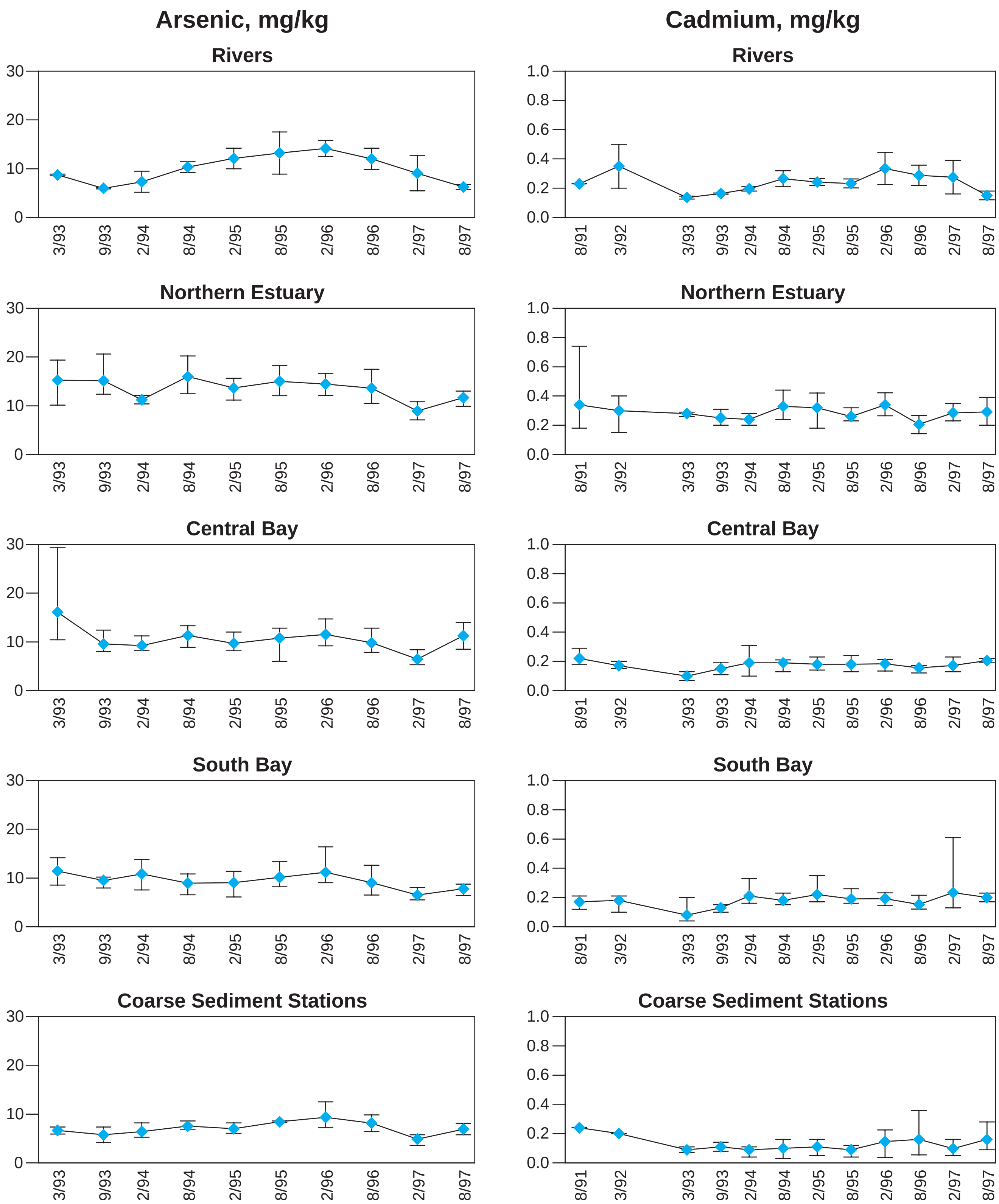

Arsenic, mg/kg
Cadmium, mg/kg
Rivers
Northern Estuary
Central Bay
South Bay
Coarse Sediment Stations

Figure 4.17. Average trace element concentrations in sediments for each Estuary reach from 1991–1997. The vertical bars represent the range of all values within a reach. The sample size varies between reach and between times. The South Bay reach does not include Southern Slough stations.

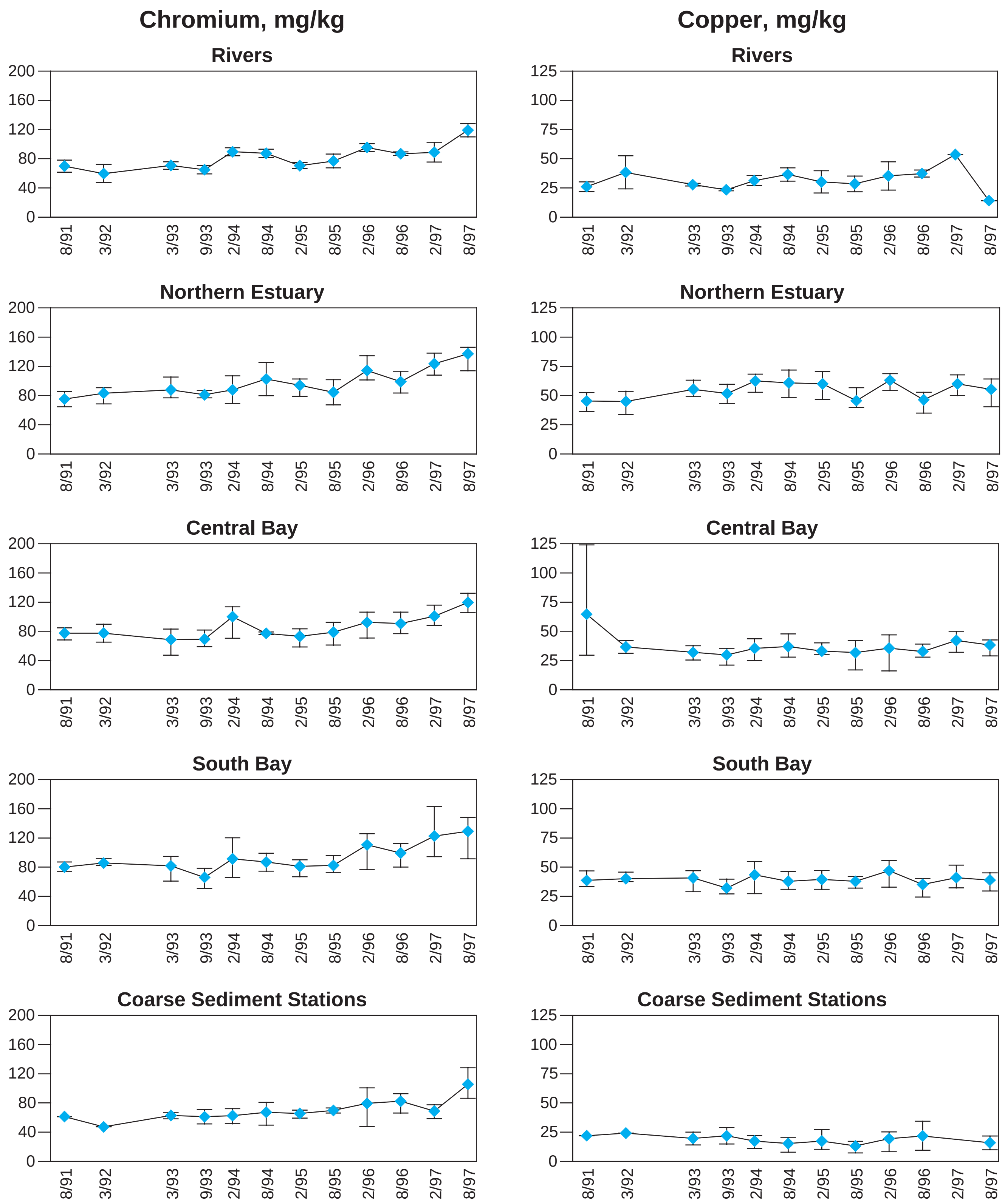


Figure 4.17 (continued). Copper data for February 1997 in the Rivers and Northern Estuary are missing because blanks were contaminated. The February 1997 Central Bay copper average consists of only one sample because blanks were contaminated. The February and August 1997 South Bay data are incomplete due to contaminated blanks. The February 1997 Coarse Sediment Station average consists of 2 samples because blanks were contaminated.

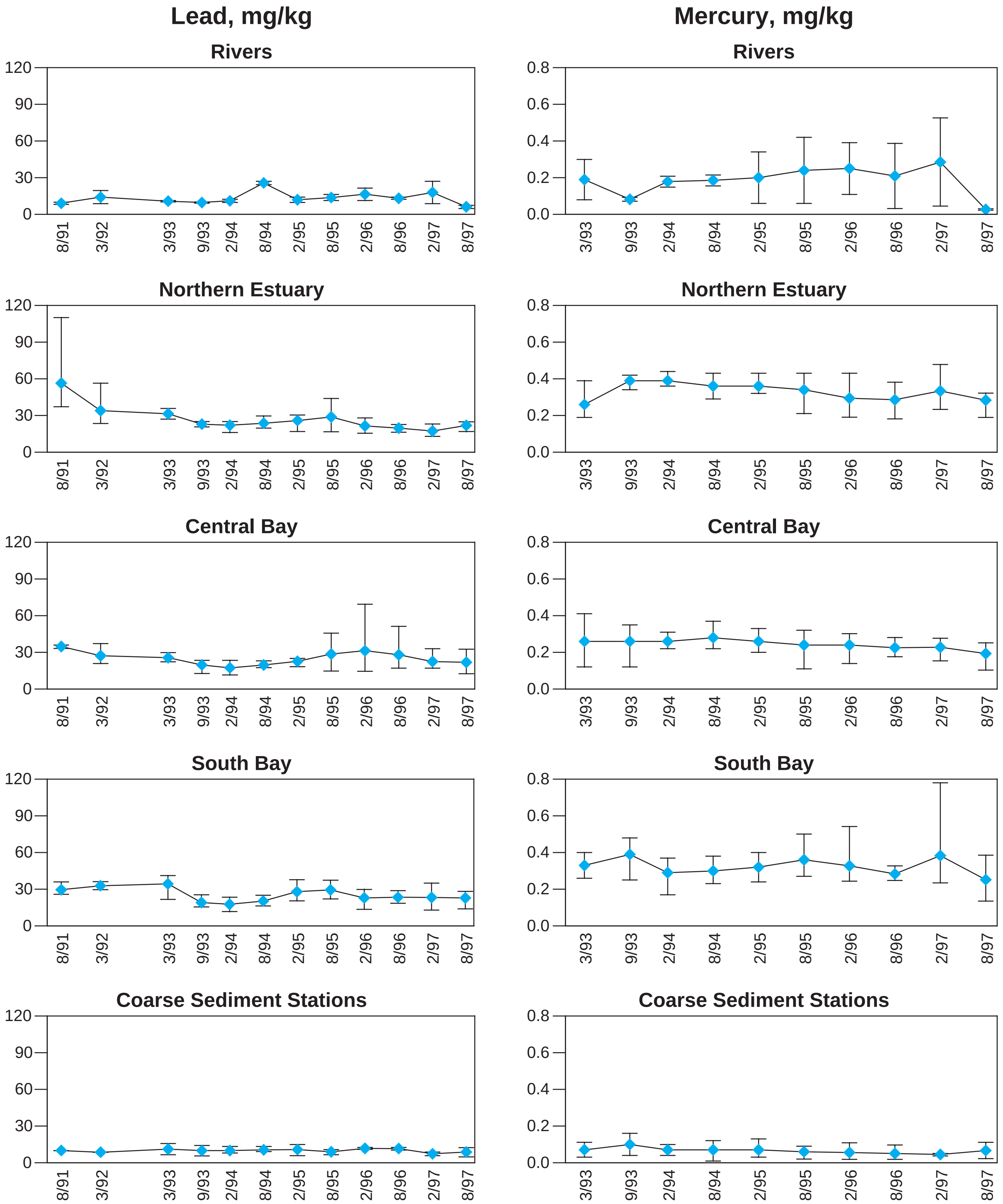
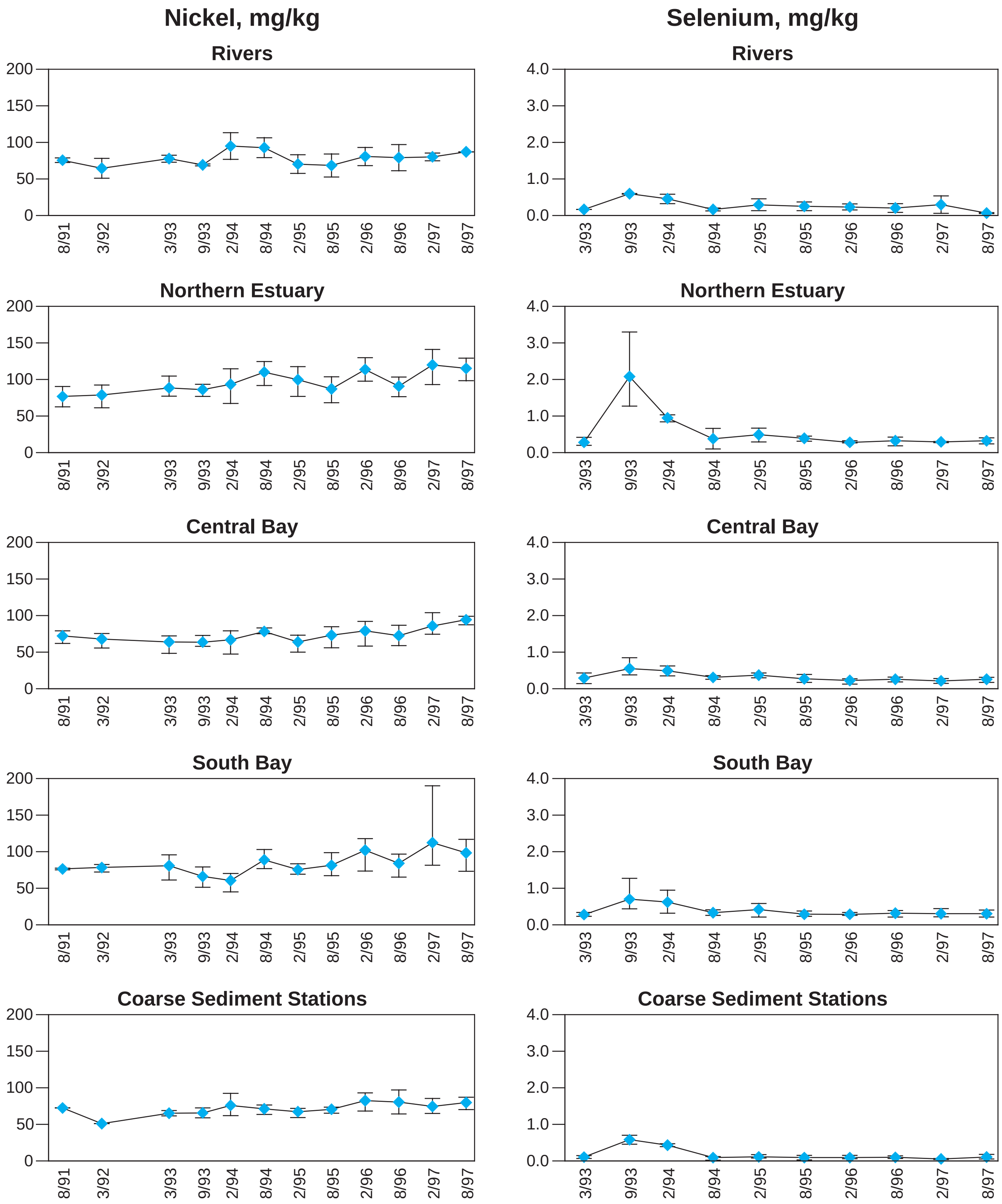


Figure 4.17 (continued).



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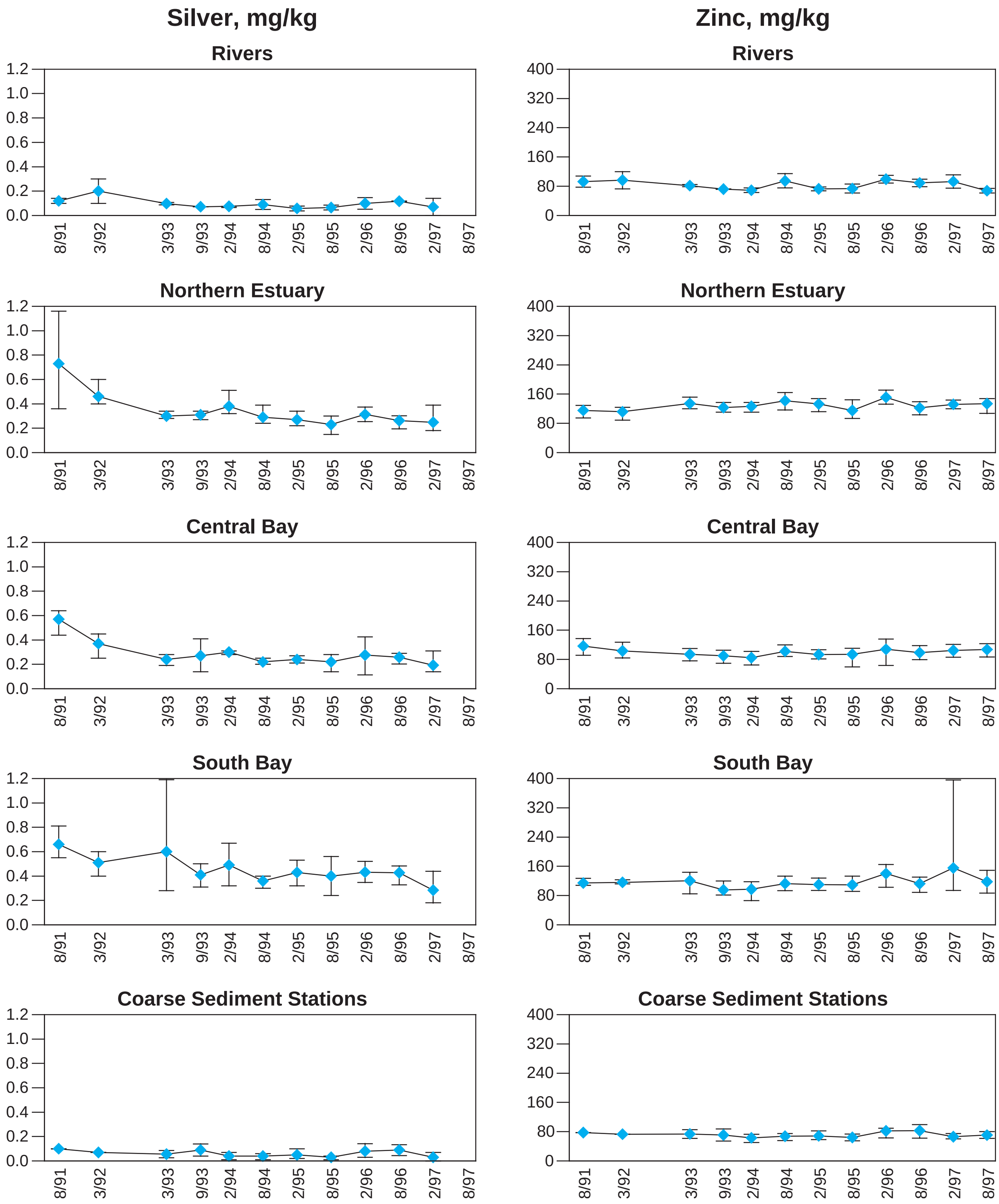
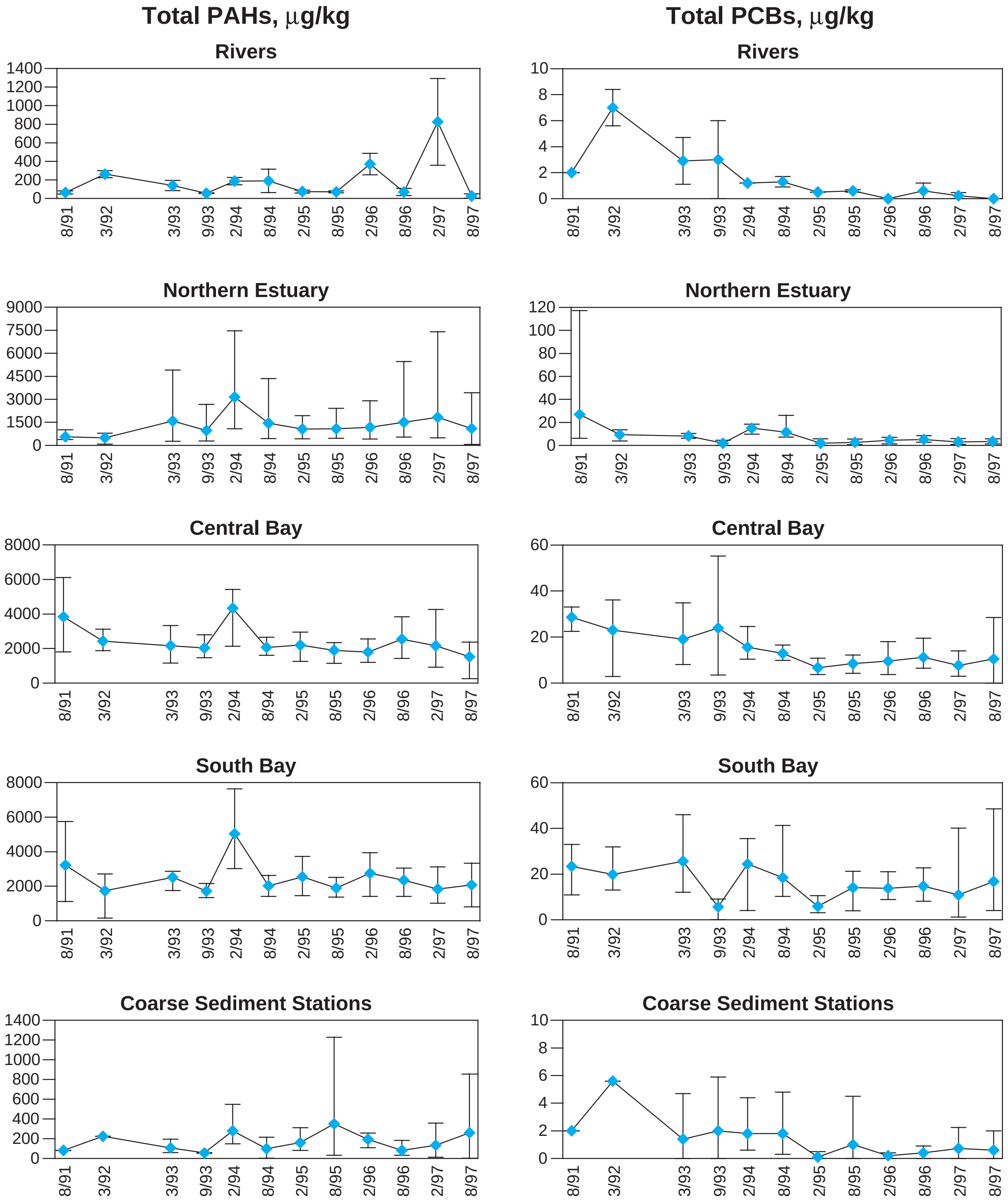


Figure 4.17 (continued). There are no data for silver in August 1997 because the blanks were contaminated.



Total PAHs, µg/kg

Total PCBs, µg/kg

Rivers

Northern Estuary

Central Bay

South Bay

Coarse Sediment Stations

Figure 4.18. Average trace organic concentrations in sediments for each Estuary reach from 1991–1997. Please note different vertical scales. The vertical bars represent the range of all values within a reach. The sample size varies between sites and between seasons. The South Bay reach does not include Southern Slough stations.

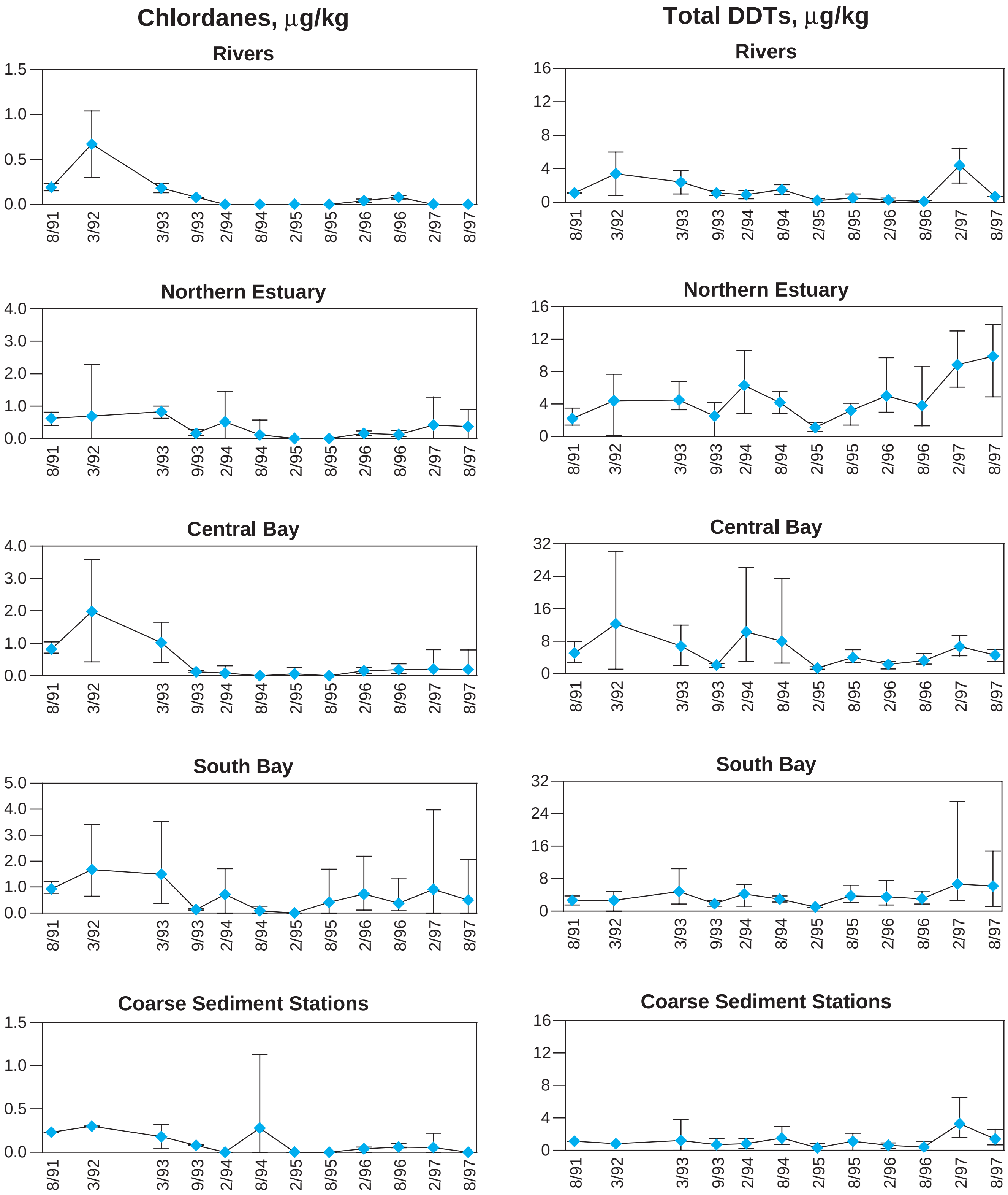
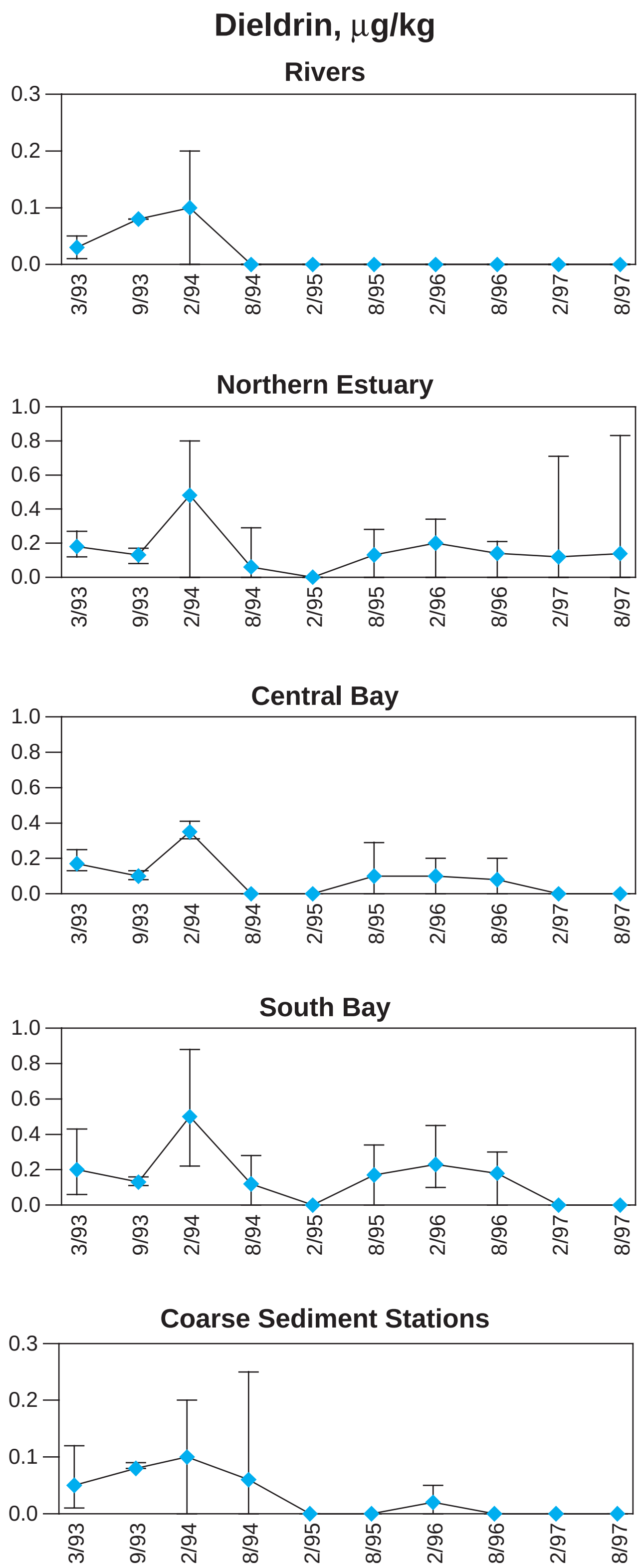


Figure 4.18 (continued). Please note different vertical scales. The vertical bars represent the range of all values within a reach.



Dieldrin, µg/kg

Rivers

Northern Estuary

Central Bay

South Bay

Coarse Sediment Stations

Figure 4.18 (continued). Please note different vertical scales. The vertical bars represent the range of all values within a reach. Dieldrin was not detected for the Rivers, Central Bay, South Bay, and Coarse Sediment Stations in February and August 1997.

Identifying Benthic Indicators for San Francisco Bay

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Introduction

Since its inception in 1994, the objective of the RMP Benthic Pilot Study has been to evaluate the use of benthic information for determining environmental conditions in the Estuary. Previous Annual Report articles have summarized the species composition and distribution of benthic assemblages and their relationship with salinity and sediment-types. They have also discussed the issue of defining ambient reference benthic conditions in the Estuary. In this article we describe the process used to identify benthic indicators which can be used to identify both impacted and ambient reference benthic assemblages (unimpacted benthic communities) in the San Francisco Estuary. We also discuss the potential and the problems of using these benthic indicators and other biological variables to evaluate test sites for contaminant effects.

Background

Biomonitoring is commonly used to assess changes in the environment. A common method of evaluation is to compare biological variables from test sites to those from reference sites. Typically, a test sample is considered to be impacted if one or more biological indicators are “significantly” different from those of the reference conditions. The key to such a strategy is the clear understanding of reference conditions.

Benthic assemblages in the San Francisco Estuary respond to many types of physical, chemical, and biological fluctuations. The Estuary experiences natural fluctuations due to variations in freshwater flows, salinity, and sedimentation, as well as historic and recurring anthropogenic influences including nutrient and organic enrichment, and contamination. It is difficult to identify a benthic response to contamination when contamination commonly covaries with many of these other environmental factors (Nichols, 1979; Peterson *et al.*, 1996; Swartz *et al.*, 1986; Spies *et al.*, 1988). Additionally, most of the benthic species that currently inhabit the Estuary are non-native species (Cohen and Carlton, 1995), therefore, large amounts of information about the changes in benthos in space and time, and the corresponding changes in environmental and contaminant factors are required to observe consistent patterns and trends (Luoma and Carter, 1991).

Identifying truly unimpacted reference locations within the Estuary is probably not possible and no other nearby estuary has characteristics similar to the San Francisco Estuary which could serve as a true “reference” location for biological comparisons. Therefore, “ambient” reference locations must be identified from the existing benthic monitoring data. An “ambient” reference benthic assemblage is defined as:

> A sample of organisms that currently inhabit the least-contaminated areas of the Estuary that includes species known (from studies elsewhere) to inhabit uncontaminated sediments, but do not include very many species known to inhabit contaminated sediments. These assemblages should exhibit natural fluctuations in species composition and abundance in response to changes in salinity and sediment-type.

Literature Review

There have been several published studies of benthic species responses to contamination in San Francisco Bay including: Filice, 1959; Nichols, 1979; Chapman *et al.*, 1987; Lee *et al.*, 1994; Hunt *et al.*, 1998. Additionally, studies of benthic responses to contamination in other locations have been used to identify the types and abundances of benthic organisms one might expect to find in unimpacted and impacted areas in the Estuary. The use of literature as an initial step avoids the common assumption that if sediments are contaminated then the benthos must be impacted. No *a priori* assumptions about sediment contamination in the Estuary are required in applying the findings from the literature.

The goal of the literature search was to create a list of benthic species (or higher taxa) that inhabit the San Francisco Estuary and have been shown to be indicators of either unimpacted or impacted conditions. The literature search included studies from around the world. We queried the University of California, Berkeley BIOSIS library database for relevant information about the 460 species identified in the 1994–1996 Benthic Pilot Studies.

Benthic impacts from contamination have typically been broadly defined to include both organic enrichment (nutrients) and contaminants which often occur together in runoff and effluent. Many articles reported organismal response to sediments containing contamination and organic enrichment, or other disturbances. Articles that reported responses exclusively to organic enrichment or other disturbances were not included. Most articles concurred in their characterization of a taxon, but a few articles were contradictory and professional judgment was used in categorizing or including the following taxa: *Corbicula fluminea*, *Corophium acherusicum*, *Euphilomedes* sp., *Mediomastus* sp., *Podarke obscura,* and *Streblospio benedicti* (see Table 4.1).

Results

Indicators of Salinity and Sediment-type

Based on Benthic Pilot Study data collected between 1994 and 1996, several benthic assemblages have been identified (Thompson *et al.*, 1997). Species composition and abundance in those assemblages generally reflect differences in salinity and sediment-types in the Estuary. The most common and abundant species in each assemblage are listed on Table 4.1. Those species may be considered to be indicators of environmental conditions from which they were collected. For example, the amphipod *Corophium spincorne* only occurs in the Fresh Brackish assemblage where salinities are below about 5 psu, in fine sediments, whereas another closely related amphipod *Corophium insidiosum* occurs only in the Central Bay assemblage, where salinities are above 30 psu, in fine sediments. Similarly, the worm *Heteropodarke* sp. was only collected at Red Rock in very sandy sediments, thus is an indicator of high salinity and sandy sediments.

Indicators of Ambient Reference and Impacted Conditions

The results of the classification and ordination analyses presented in last year's RMP Annual Report provide preliminary information about impacted and unimpacted assemblages in the Estuary. We identified a contaminated sub-assemblage of the Estuarine assemblage that had reduced numbers of species and individuals, as well as indicators of contamination (e.g., *Streblospio benedicti*). In that case, the analysis was able to distinguish a difference in species composition and abundance in the China Camp (RMP Wetlands Pilot Study) and Castro Cove (Bay Protection and Toxic Cleanup Program; BPTCP) samples from RMP samples from the adjacent Estuarine assemblage (see the *1996 RMP Annual Report* for further explanation). In the Central Bay, the two Bay Area Dischargers Associations, Local Effects Monitoring Program (BADA LEMP) sites, City and County of San Francisco (CCSF), and East Bay Municipal Utility District (EBMUD), were classified as part of the Central Bay assemblage. However, the analyses could not distinguish any difference between those samples and Central Bay samples farther from the discharge.

In both examples, no sediment contamination information was included. However, it has not been conclusively demonstrated that any of the major assemblages are more characteristic of unimpacted or impacted conditions. As shown by RMP sediment contamination monitoring, all sites

Table 4.1. The most common and abundant species in each benthic assemblage.

Fresh Brackish—muddy sediments (n = 192)
- *Manayunkia speciosa* (S*)*
- *Corophium stimpsoni* (A)
- *Corbicula fluminea* (C)
- *Limnodrilus hoffmeisteri* (T)
- *Gammarus daiberi* (A)
- *Varichaetadrilus angustipenis* (T)
- *Corophium spinicorne* (A)
- *Cyprideis* sp. A (Cy)
- *Aulodrilus limnobius* (T)
- *Dorylaimus* sp. A (D)

Fresh Brackish—sandy sediments (n = 19)
- *Corbicula fluminea* (C)
- *Paratendipes* sp. A (Ch)
- *Gammarus daiberi* (A)
- *Corophium stimpsoni* (A)
- *Marenzelleria viridis* (Sp)
- *Chaetogaster limnaei* (N)
- *Varichaetadrilus angustipenis* (T)
- *Corophium spinicorne* (A)
- *Potamocorbula amurensis* (C)
- *Limnodrilus hoffmeisteri* (T)

Fresh Brackish—estuarine transition (n = 72)
- *Potamocorbula amurensis* (C)
- *Corophium alienense* (A)
- *Marenzelleria viridis* (Sp)
- *Corophium stimpsoni* (A)
- *Gammarus daiberi* (A)
- *Nippoleucon hinumensis* (Cu)
- *Tubificoides heterochaetus* (T)
- *Limnodrilus hoffmeisteri* (T)
- *Corophium heteroceratum* (A)
- *Tubificoides fraseri* (T)

Estuarine—muddy sediments (n = 68)
- *Potamocorbula amurensis* (C)
- *Ampelisca abdita* (A)
- *Nippoleucon hinumensis* (Cu)
- *Corophium heteroceratum* (A)
- *Corophium alienense* (A)
- *Grandidierella japonica* (A)
- *Balanus improvisus* (B)
- *Tubificidae* (T)
- *Neanthes succinea* (Ne)
- *Streblospio benedicti* (Sp)

Estuarine—moderately contaminated (n = 8)
- *Tubificidae* (T)
- *Nippoleucon hinumensis* (Cu)
- *Streblospio benedicti* (Sp*)*
- *Corophium* spp. (A)
- *Gemma gemma* (V)
- *Ampelisca abdita* (A)
- *Grandidierella japonica* (A)
- *Nematoda*
- *Eusarsiella zostericola* (O)
- *Pseudopolydora kempi* (Sp)

Central Bay—muddy sediments (n = 60)
- *Corophium acherusicum* (A)
- *Ampelisca abdita* (A)
- *Corophium heteroceratum* (A)
- *Euchone limnicola* (Se)
- *Corophium* spp. (A)
- *Leptochelia dubia* (Cu)
- *Corophium insidiosum* (A)
- *Photis* spp. (A)
- *Mediomastus* spp. (Ca)
- *Exogone lourei* (Sy)

Central Bay—sandy sediments (n = 6)
- *Heteropodarke heteromorpha* (H)
- *Nematoda*
- *Grandifoxus grandis* (A)
- *Hesionura coineaui difficilis* (P)
- *Glycera tenuis* (G)
- *Tellina bodegensis* (Te)
- *Tubificidae* (T)
- *Glycera americana* (G)
- *Glycera spp.* (G)
- *Mediomastus spp.* (Ca)

Phylum: Annelida; Family: Capitellidae (Ca), Glyceridae (G), Hesionidae (H), Naididae (N), Nereidae (Ne), Phyllodocidae (P), Sabellidae (S), Sebellidae (Se), Spionidae (Sp), Syllidae (Sy), Tubificidae (T)
Phylum: Arthropoda; Family: Amphipoda (A), Balanidae (B), Chironomidae (Ch), Cumacea (Cu), Cytheridae (Cy), Ostracoda (O)
Phylum: Mollusca; Family: Corbiculidae (C), Tellinidae (Te), Veneridae (V)
Phylum: Nematoda; Family: Dorylaimidae (D)

have moderate amounts of contamination (see sediment sections). The above examples demonstrate the need for unbiased assessment based on indicators alone.

The results of the literature search characterized 30% of all taxa identified in the 1994–1996 Benthic Pilot Study. These taxa are listed in Table 4.2 and comprise half of the ten most common and abundant species found in each benthic assemblage in the Estuary (Table 4.1). *Capitella "capitata"* is one of the most well known marine pollution indicators and has been found to be tolerant of a wide variety of contaminants including trace metals, hydrocarbons, and general pollution (Levin *et al*., 1996; Bridges *et al*., 1994; Plante-Cuny *et al*., 1993; Daan *et al*., 1996; Peterson *et al*., 1996; Daan *et al*., 1994; Chapman *et al*., 1987; Pearson and Rosenberg, 1978; BPTCP, 1996; Tetra Tech, 1990; Milbrink, 1980; Raman, 1995; Holte *et al*., 1996). Another polychaete, *Streblospio benedicti*, has been found to tolerate hydrocarbon contamination (Levin *et al*., 1996; Chandler *et al*., 1997; Chapman *et al*., 1987; Pearson and Rosenberg, 1978; Dauer, 1993; BPTCP, 1996; Bridges *et al*., 1994). Polychaetes in the family *Dorvilleidae* and *Eteone* sp. are present in polluted waters and can often be found along with *Capitella* and *Streblospio* (Pearson and Rosenberg, 1978; Thompson, 1982; Milbrink, 1980; Tetra Tech, 1990). The oligochaete *Limnodrilus hoffmeisteri* was shown to be tolerant of various types of contaminants including high sediment concentrations of pyrene and phenanthrene (Lotufo and Fleeger, 1996; Simpson *et al*., 1993; Lang and Reymond, 1996; Matagi, 1996; Lafont *et al*., 1996; Martinez and Levinton, 1996; Montuelle *et al*., 1997; Peterson *et al*., 1996; Dauer, 1993; Pearson and Rosenberg, 1978). References for nematodes included variable conclusions; one article showed that they were tolerant to PAHs, while another showed they were intolerant to cadmium, and a third showed that different species had variable tolerances to contamination (Carman *et al*., 1995; Chandler *et al*., 1994; Hansen *et al*., 1996; Peterson *et al*., 1996).

Contaminant intolerant species include most amphipod crustaceans and some harpactacoid copepods which are highly sensitive to toxic chemicals (Peterson *et al*., 1996; DeWitt *et al*., 1988; Word *et al*., 1977; Swartz *et al*., 1994). *Ampelisca abdita*, a dominant amphipod in the San Francisco Estuary, is quite sensitive to contamination (Ferraro and Cole, 1997; Swartz *et al*., 1994). Other amphipod species, such as *Corophium acherusicum*, are also good indicators of uncontaminated environments (Tetra Tech, 1990; Pearson and Rosenberg, 1978; Flemer *et al*., 1997; Ferraro and Cole, 1997; Swartz *et al*., 1994). Unlike most other amphipods, *Grandidierella japonica* is tolerant of contamination (Ferraro and Cole, 1997; Swartz *et al*., 1994; Carr *et al*., 1996). Since amphipods are dominant members of all major assemblages in the Estuary (Table 4.1), they are very good candidates for ambient reference indicators.

Echinoderms, especially brittlestars, occur in the Central Bay and are also very sensitive to contamination (Thompson, 1982; Peterson *et al*., 1996; Milbrink, 1980; Word *et al*., 1977; Swartz *et al*., 1986). Based on examination of RMP data collected to date, echinoderms do not inhabit sites where the salinity is below 15 psu. Therefore, echinoderms would only be useful ambient reference indicators for the Central Bay assemblages.

The introduced Asian clam *Potamocorbula amurensis* is often dominant in the Estuary. Studies by the U.S. Geological Survey have shown that it is sensitive to metals contamination (Parchaso *et al*., 1997; Thompson *et al*., 1996; Brown and Luoma, 1995). Several articles about *Corbicula fluminea* suggested it is useful for bioaccumulation studies, but they were inconclusive in characterizing it as a potential benthic indicator (Hayward *et al*., 1996; Moulton *et al*., 1996; Foe and Knight, 1986). However, it appears that the larvae are adversely affected by contaminants (Boltovskoy *et al*., 1997).

Abundances of some higher taxa have been used as indicators. Proportions of oligochaetes (small worms) and chironomids (aquatic insects) have been used to characterize freshwater communities where they generally increase in abundance with increased contamination (Canfield *et al*., 1994; 1996). Oligochaetes of the family *Tubificidae* are generally classified as contaminant tolerant indicators, but some genera are

Table 4.2. List of indicator species.

Contamination Tolerant Indicators (more abundant under impacted conditions) n = 58

Armandia brevis
Aulodrilus limnobius
Aulodrilus pluriseta
Branchiura sowerbyi
Capitella "capitata"
Chironomus attenuatus
Cladotanytarsus sp. A
Cryptochironomus sp. A
Cryptochironomus sp. B
Cryptotendipes sp. A
Demicryptochironomus sp. A
Dero digitata
Dorvillea rudolphi
Dorvilleidae
Dorvilleidae sp. A
Einfeldia sp. A
Endochironomus sp. A
Eteone lighti
Eteone spilotus
Euphilomedes carcharodonta
Glycinde armigera
Grandidierella japonica
Harnischia curtilamellata
Heteromastus filiformis
Heteromastus filobranchus
Heteromastus spp.
Hydrobaenus sp. A
Ilyodrilus templetoni
Leitoscoloplos spp.
Limnodrilus hoffmeisteri
Limnodrilus udekemianus
Mediomastus spp.
Microtendipes sp. A
Molgula manhattensis
Monodiamesa sp. A
Mysella tumida
Neanthes succinea
Nephtys caecoides
Nephtys cornuta
Nephtys cornuta franciscana
Ophidonais serpentina
Ophiodromus pugettensis
Paracladopelma sp. A
Paraprionospio pinnata
Paratendipes sp. A
Polydora ligni
Polydora socialis
Polypedilum sp. A
Prionospio cirrifera
Procladius sp. A
Psectrocladius sp. A
Pseudopolydora kempi
Quistadrilus multisetosus
Stictochironomus sp. A
Streblospio benedicti
Tanytarsus sp. A
Theora lubrica
Xenochironomus xenolabis

OLIGOCHAETA—12% of individuals and 6% of chiromomid individuals indicate a "clean site".
CHIRONOMIDAE—Number of genera increase with increased pollution.
COPEPODA/NEMATODA—Ratio increases with increased organic enrichment.

Contamination Intolerant Indicators (found under unimpacted conditions) n = 61

Ampelisca abdita
Ampelisca macrocephala
Ampelisca spp.
Amphiodia digitata
Amphiodia spp.
Amphipholis spp.
Amphipoda
Amphiurid sp. A
Ampithoe spp.
Ampithoe valida
Aoridae
Caprella californica
Caprella equilibra
Caprella mendax
Caprella natalensis
Caprella spp.
Caprellidea
Corbicula fluminea
Corophium acherusicum
Corophium alienense
Corophium heteroceratum
Corophium insidiosum
Corophium oaklandense
Corophium spinicorne
Corophium spp.
Corophium stimpsoni
Crangonyx sp. A
Cryptomya californica
Dulichia monocantha
Elasmopus antennatus
Ericthonius brasiliensis
Ericthonius hunteri
Ericthonius spp.
Eudorella pacifica
Gammarus daiberi
Gnathopleustes pugettensis
Grandifoxus grandis
Hyalella azteca
Ischyrocerus sp.
Jassa marmorata
Listriella goleta
Lumbrineris luti
Melita dentata
Metacaprella anomala
Microdeutopus schmitti
Monoculodes spinipes
Ophionereis eurybrachyplax
Ophiuroidea
Ophiuroidea C
Orchestoidea columbiana
Paradexamine spp.
Paraphoxus milleri
Phoronis spp.
Photis brevipes
Photis spp.
Podoceridae
Podocerus spongicolus
Protomedeia penates
Rhepoxynius tridentatus
Stenothoe spp.
Synchelidium shoemakeri

CRUSTACEA—Total number decreases with increase in Cd.

For a list of identified tolerant and intolerant taxa with references, please contact SFEI, Richmond, CA directly.

contaminant intolerant; for example *Spirosperma* and *Varichaetadrilus pacificus* (Canfield *et al.*, 1994). The genus *Pristina* (oligochaete family *Naididae*) was also cited as being intolerant to industrial pollution (Lafont *et al.*, 1996). Oligochaetes are found throughout the Estuary although their abundance increases at freshwater sites. Chironomids are restricted to freshwater (<2 psu) and thus, would only be good indicators in the Fresh Brackish assemblage. The relative proportions of copepods to nematodes has also been used. The proportion increases with increased contamination (Peterson *et al.*, 1996).

It is not obvious how to apply the information about each indicator species. Generally, no guidelines exist as to the exact abundance of an indicator that would distinguish impacted from unimpacted sites. The percentage of all impacted or unimpacted indicator taxa or abundances identified could be used. However, since information was not found for all species collected in the Estuary, those estimates would be imprecise.

Other commonly used biological indicators are the number of taxa, total abundances, and total biomass of a sample (Pearson and Rosenberg, 1978; Swartz *et al.*, 1986). However, the use of those variables has several problems in their application. First, there are no guidelines as to which exact values one should expect from an ambient reference site (although once reference sites are identified using other indicators, ranges could be calculated as described in the discussion section). More importantly, those indicators are not usually linearly related to contamination (including organic enrichment). Instead, biological indicators, such as the number of taxa, total abundance, and biomass, often are higher in locations where there is moderate contamination. This phenomenon is known as “intermediate disturbance” and has also been observed in tropical rain forests and coral reefs where other types of disturbance have a similar effect (Connell, 1986). Intermediate disturbance is an initial response to environmental disturbances such as the influx of effluent which might contain both nutrients and contaminants. Under such conditions, it is believed that nutrient benefits dominate over contaminant effects (provided that the contamination is not too high) and benthic populations increase and diversify (Figure 4.19). At some threshold along the contamination gradient, contaminant effects become too great and the community begins to decline. Where non-linear responses occur, a biological indicator could have the same value at an unimpacted and an impacted site (Figure 4.19), an undesirable quality for an indicator. At severely impacted sites, very low numbers of species and abundance would be expected.

Discussion

The Benthic Pilot Study data and the literature review have provided information about many of the species that inhabit San Francisco Bay and whether they might serve as indicators of unimpacted ambient reference conditions or indicators of contamination impacts. The types and number of taxa, total abundances, and the number of indicator taxa should reveal information about the condition of sediments without making any *a priori* assumptions based on the sediment contamination found at a site.

Based on our literature review and current understanding of changes in the benthic community response to contamination in the San Francisco Estuary, several benthic variables are being evaluated as candidate indicators of ambient reference conditions:

- amphipod abundances (except *G. japonica*),
- echinoderm abundances (where salinity is above 15 psu),
- abundances of unimpacted indicator taxa.

Several other variables are being evaluated as candidate indicators of impacted conditions:

- elevated abundances of oligochaetes,
- elevated abundances of chironomids (where salinity is below 2 psu),
- abundances of impacted indicator taxa.

The selection of appropriate benthic indicators for the Estuary should consider whether candidate indicators actually respond to changes in contami-

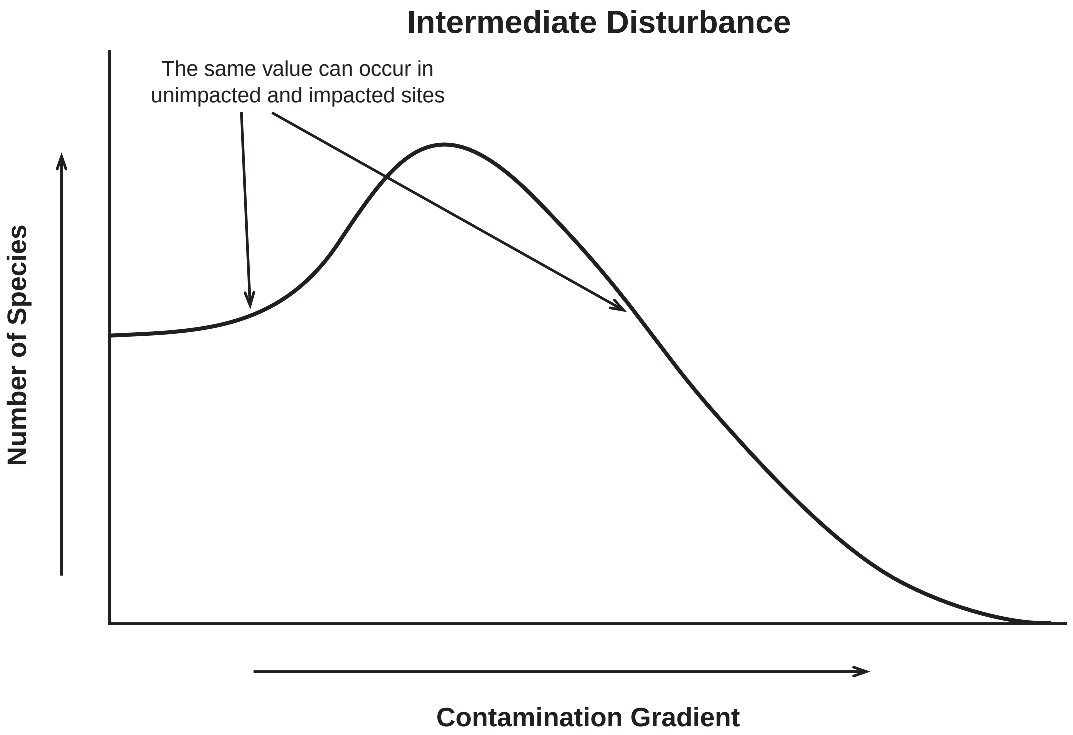

Figure 4.19. An example of intermediate disturbance effects on the number of species as contamination increases.

nation, but the RMP has apparently not sampled any severely contaminated sites. These phenomena need to be understood before indicators can be used. Analyses conducted to date have shown that understanding some of the indicators responses is complicated. Some examples of unresolved issues are listed below.

- What proportion of taxa indicative of impacted conditions would make a sample “significantly” different from ambient reference conditions?
- At Redwood Creek, echinoderms are collected in some samples but not others, although the salinity and sediment-type is similar. Does that reflect contaminant effects or life history phenomenon?
- What triggered the large influx of the amphipod *Corophium ascherusicum* in August 1995 in the Central Bay and their subsequent demise?

Most investigators have used numerical approaches to create a “benthic index” that is calibrated to distinguish impacted from unimpacted samples (O’Connor and Swanson, 1982; Word *et al*., 1977; Tetra Tech, 1990; Weisberg *et al*., 1992; Smith *et al*., 1988). A benthic index was used in the BPTCP for San Francisco Bay samples based on the presence or absence of several benthic indicator species (Hunt *et al*., 1998).

Another approach, based on the range of reference values, has been used for both sediment chemistry and toxicity in the Estuary (see articles by Hunt *et al*. and Gandesbery *et al*. in this report). Typically, a test sample may be considered significantly different from a reference condition if the value of an indicator (e.g., number of amphipods) is outside of a chosen percentile reference confidence limit. Any percentile could be chosen and is a subjective decision. But, there must be some justification for choosing a specific percentile. Alternatively, the simple range of amphipod abundance at ambient reference sites could be used, but there is no statistical confidence associated with a simple range.

The use of tolerance limits for a set of benthic indicators is being evaluated. However, preliminary calculations have shown that in most cases, the number of samples used as ambient reference samples for each assemblage is too low to yield useful tolerance limits. Additionally, more information about contaminated samples is needed. Additional information will facilitate the identification of suitable benthic indicators.

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Bay Protection and Toxic Cleanup Program: Studies to Identify Toxic Hot Spots in the San Francisco Bay Region

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Introduction

The Bay Protection and Toxic Cleanup Program (BPTCP) was established by the California State Legislature in 1989 with four major goals:

1. Provide protection of present and future beneficial uses of the bay and estuarine waters of California.
2. Identify and characterize toxic hot spots.
3. Plan for toxic hot spot cleanup or other remedial actions.
4. Develop prevention and control strategies for toxic pollutants that will prevent creation of new toxic hot spots or the perpetuation of existing ones within the State's bays and estuaries.

These goals are being addressed by each of California's coastal Regional Water Quality Control Boards. The San Francisco Bay Regional Board's (Regional Board) activities under the BPTCP have included completion of the Pilot Regional Monitoring Program as a precursor to the current Regional Monitoring Program (RMP), continued participation in the RMP, completion of a fish tissue study that identified contaminant concentrations sufficient to trigger a health advisory on consumption of Bay fish, and completion of baywide sediment assessments to identify toxic hot spots. The sediment quality assessments have been described in two recently released reports: *Evaluation and Use of Sediment Reference Sites and Toxicity Tests in San Francisco Bay,* and *Sediment Quality and Biological Effects in San Francisco Bay* (Hunt *et al*., 1998a, 1998b). Both are available from the Bays and Estuaries Unit, Division of Water Quality, State Water Resources Control Board. Together they describe a phased approach using reference site comparisons and a suite of biological and chemical measurements to screen numerous sites in the region and provide information that can be used by the Regional Board to identify locations requiring cleanup, source control, or other remedial action.

The objectives, methods, and findings of these studies are summarized here. Major parts of the reference site study were described in the *RMP 1995 Annual Report* (SFEI, 1996), so the present summary will focus on the results of reference envelope statistical analyses that used reference site data to calculate tolerance limits for comparison with test site results. In addition to toxicity tolerance limits, tolerance limits for concentrations of sediment-associated chemicals were also evaluated and reported to the Regional Board, and the results of that analysis are also briefly summarized below.

Reference Site Study

Study Objectives

To date, the primary focus of the BPTCP has been the identification of toxic hot spots, which can be defined as localized areas where elevated concentrations of toxic pollutants are found in association with adverse biological impacts. Implicit in the definition of a toxic hot spot is the assumption that pollution in a localized area is worse than in surrounding areas, either in the same water body or in the region where the hot spot exists. The goal of the San Francisco Bay sediment reference site study was to adequately characterize ambient conditions in the Bay to provide a standard against which to compare measurements from sites being investigated as possible hot spots. However, since program goals are to manage the

State's bays and estuaries to promote environmental quality, it is not sufficient to simply characterize the "average" condition of a water body, but instead the goal of the study was to characterize the "optimal ambient conditions" currently existing. Therefore, the study focused on the identification and evaluation of sediment reference sites, the least polluted fine-grained sediment sites that could be found in San Francisco Bay with reasonable sampling effort. Reference site evaluations were based on criteria established by reviewing relevant scientific literature and consulting with the BPTCP Scientific Planning and Review Committee.

To meet this goal and to support continuing BPTCP investigations, the study focused on four objectives:

1. Identify and evaluate sediment reference sites in San Francisco Bay.
2. Evaluate appropriate sediment toxicity test methods for use in San Francisco Bay.
3. Evaluate a statistical method (the "reference envelope approach") that uses toxicity test data from reference sites to establish relative standards against which to compare results from test sites.
4. Investigate the use of toxicity identification evaluations (TIEs) in determining the causes of toxicity at sites with both high and low concentrations of measured pollutants.

The results of investigations to address objectives 1, 2, and 4 were discussed in the *RMP 1995 Annual Report* (SFEI, 1996). But the statistical method used to calculate reference envelope tolerance limits underwent significant re-evaluation to address issues regarding the effects of combined spatial and temporal variation, and tolerance limit results were not available at that time. Therefore, the evaluation of the reference envelope approach is summarized below.

Reference Sites and Reference Envelope Approach

The study evaluated data from five specified reference sites in San Francisco Bay, plus data from three RMP sites that satisfied the reference site criteria (see Figure 4.20). The sites were Island #1 and Tubbs Island (in San Pablo Bay), Paradise Cove (in Central San Francisco Bay), and a northern and southern site in the South Bay. Three stations (field replicates) were established at each of these sites. The RMP sites used in the reference envelope calculations were Pinole Point (in San Pablo Bay), Horseshoe Bay (in Central San Francisco Bay), and San Bruno Shoal (in the South Bay). Surveys were conducted during three separate seasons, late summer 1994 and late winter/early spring 1994 and 1995. The RMP sites were sampled in winter and summer from 1993 to 1997. A total of 61 reference site samples were used to establish a population of reference site toxicity values (the "reference envelope") that could be used to determine tolerance limits against which to compare the results of test sites in future sediment toxicity surveys. This statistical method is described briefly below.

The "reference envelope" approach was developed to provide an appropriate statistical method for determining whether conditions at test sites were significantly worse than those in the surrounding area. This objective is different from that of determining absolute sample toxicity. Rather than comparing results of test samples with laboratory controls using laboratory replicate variance as the statistical test variance component, the reference envelope method establishes tolerance limits based on test results from reference site samples. Tolerance limits are calculated to identify samples significantly more toxic than a chosen proportion of the reference site distribution, and statistical significance is determined using variation among reference site results. In this way, the method considers all relevant sources of variation that could affect comparisons between sites, such as variation in time and space, the interaction of time and space components, and variation between replicates (the error term). If natural factors such as grain size vary among reference sites or between surveys, then the effects of these factors are accounted for in the analysis. Any additional toxicity is assumed (statistically) to be caused by anthropogenic constituents of the test sample.

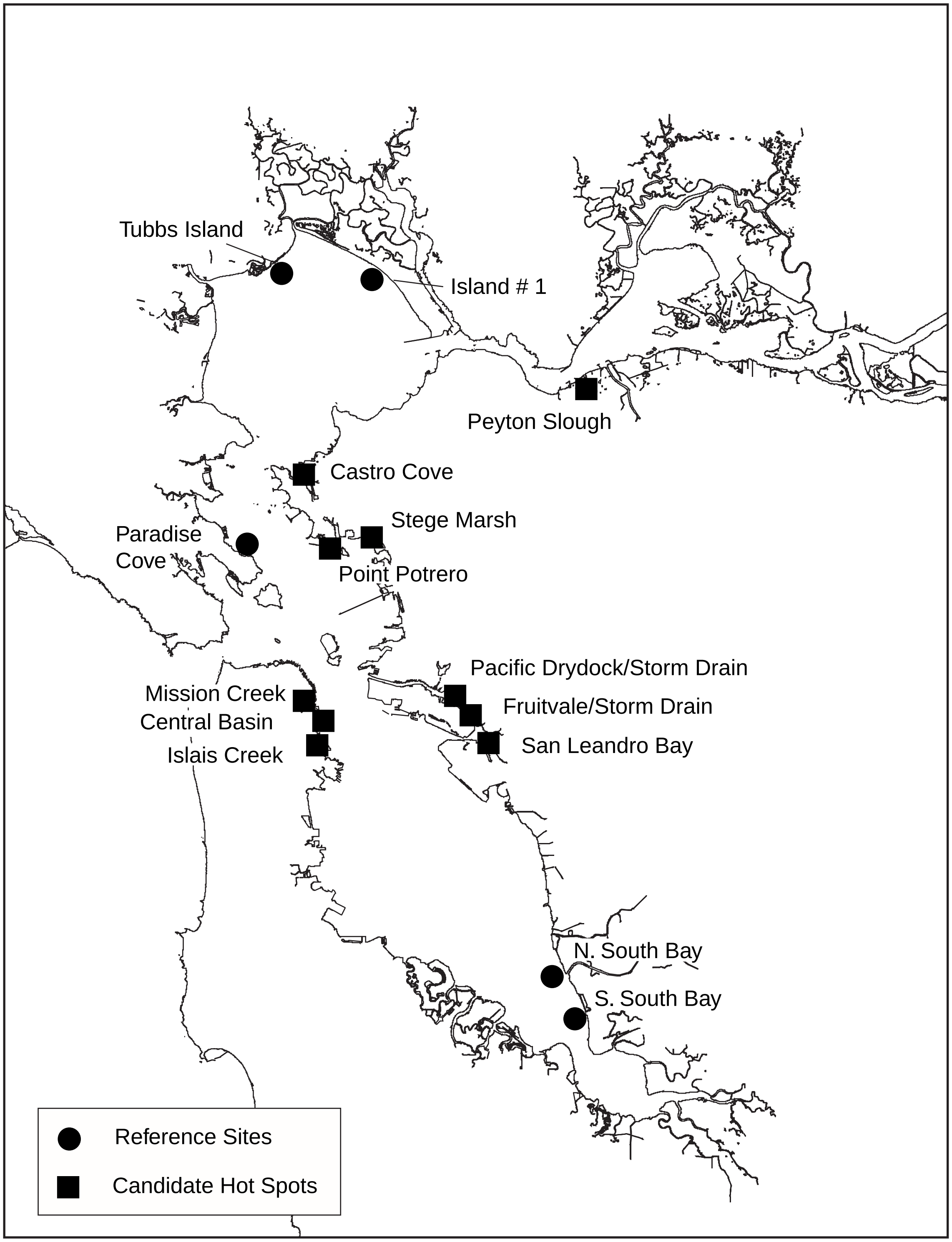

Figure 4.20. BPTCP reference sites and hot spots.

Results of the Reference Envelope Evaluation of Toxicity Data

As described in the report, the calculation of tolerance limits was affected by a number of factors, including data distribution, occurrence of outliers, method of calculation, and reference envelope “p” values. The “p” value is the proportion of the reference site distribution selected for the tolerance limit. For example, a “p” value of 10 would set the tolerance limit such that any sample with a test result below the limit would be as toxic or more toxic than the worst 10% of samples expected in the water body characterized by the reference sites.

Tolerance limits were highest when calculated from data with high mean values and low variability among reference sites. The sea urchin embryo/larval development test in porewater had the highest tolerance limits. For example, the tolerance limit for sea urchin larval development in pore water at a “p” value of 10 was 94.3% (Table 4.3). Porewater samples exhibiting lower rates of larval development would be considered in the worst 10% of the reference distribution, or lower. Such high tolerance limits are indicative of consistently high reference site values, but do not necessarily indicate that the level of response was biologically significant. In such cases, we would recommend deferring to a “detectable difference” criterion based on test minimum significant difference (MSD) values (such as described by Thursby *et al*., 1997). On the other hand, data sets with relatively low values and high variability often produced tolerance limits that were very low or negative. Toxicity test standards below zero clearly have no utility, and these data cannot be used in this approach. Solid-phase sediment tests using the amphipods *Eohaustorius* and *Ampelisca* had tolerance limits ranging from 55% to 78% of control values (for “p” values of 1 to 20; Table 4.3).

As mentioned above, this study also evaluated three methods for calculating tolerance limits. Two of the methods were appropriate for studies in which all data are collected at the same time. These two methods used conventional formulae and statistical tables. The third method was appropriate for the BPTCP program, which analyzed samples collected from multiple sites at multiple times. This method required extensive

Table 4.3. Tolerance limits for four toxicity test protocols. Data are survival or normal larval development as a percentage of test control values. The “p” value indicates the percentile of the reference distribution used to generate the tolerance limit (see text). All limits were calculated based on an alpha level of 0.05.

p Value	*Eohaustorius*	*Ampelisca*	Sea Urchin Embryo/Larval Development	
			Porewater	Sediment Water Interface
1%	58.7	54.7	89.9	79.4
2%	61.5	59.1	90.9	81.4
3%	63.3	61.6	91.7	82.6
4%	64.2	63.7	92.2	83.5
5%	65.5	65.3	92.7	84.3
6%	66.7	66.6	93.2	85.0
7%	67.5	67.9	93.7	85.5
8%	68.2	68.9	93.9	86.0
9%	68.8	69.9	94.2	86.4
10%	69.5	70.9	94.3	86.7
12%	70.6	72.5	94.7	87.4
14%	71.5	73.9	95.2	88.0
16%	72.2	75.1	95.5	88.6
18%	72.8	76.3	95.8	89.2
20%	73.4	77.5	96.0	89.6

development for the study, and relied on bootstrap simulations in the calculation of tolerance limits.

Appropriate application of the reference envelope approach and the resulting tolerance limits will depend on professional judgment in determining the quality of the reference database, selection of "p" values, and suitability to the goals of the investigation. This method can effectively distinguish impacted sites from optimal ambient conditions if those conditions are well characterized and the assumptions of the method are met. Reference site databases with less than about six values probably cannot produce acceptable tolerance limits, and tolerance limits based on less than twenty reference site values should be applied with caution. In some cases, entire water bodies may be polluted to the extent that optimal ambient conditions are not a sufficient standard for comparison, and other methods would need to be applied to measure and improve environmental quality.

Results of this study indicate that the reference sites evaluated were not pristine, but had relatively low concentrations of pollutants, and probably approximated optimal ambient conditions for fine-grained sediments in San Francisco Bay. Many of the toxicity test protocols produced distributions of reference site data that could be used to calculate reasonable toxicity tolerance limits. Successful application of this information for monitoring activities will require continued sampling of reference sites coincident with monitoring surveys, and thoughtful selection of reference envelope "p" values, based on careful consideration of data quality and study objectives.

Results of the Reference Envelope Evaluation of Chemistry Data

Tolerance limits were calculated for a number of chemicals, based on the distribution of sediment chemical concentrations measured at reference sites in San Francisco Bay (Smith, 1997, report to the Regional Board). The chemical tolerance limits were calculated to provide 95% certainty that measured concentrations exceeding the tolerance limit would be as high or higher than expected of the highest 15% of samples from reference sites. This reflects the "p" value of 0.85 selected by the Regional Board staff when they derived threshold values for ambient concentrations of these chemicals in their assessments of test sites (Gandesbery and Hetzel, 1998). Concentrations above the tolerance limits could therefore be assumed to be elevated relative to ambient conditions in the Bay. No assumptions were made about the relationship between the tolerance limit concentrations and their potential for biological effects; the chemical tolerance limits were simply descriptive of chemical concentrations found at reference sites.

These chemical tolerance limits were not used in the identification of toxic hot spots, but they were listed in the San Francisco Bay BPTCP report. Two points regarding the chemical tolerance limits are worth noting here. First, for the majority of chemicals for which San Francisco Bay reference tolerance limits were derived, the tolerance limits were much lower than concentrations at a similar percentile of the BPTCP statewide database, and were also much lower than concentrations usually associated with biological effects, as indicated by ERM (Effects-Range Median) values. Second, the nickel concentration at the 85th percentile of the San Francisco Bay reference site distribution (the tolerance limit) was higher than the 90th percentile for all BPTCP samples statewide, many of which were collected to characterize potentially polluted sites. The elevated nickel concentrations throughout the Bay are probably the result of local geologic abundance and human-enhanced transport of this element, though localized nickel concentrations may also be due to municipal, industrial, or urban non-point sources.

Studies to Identify Toxic Hot Spots

The focus of BPTCP sediment monitoring in San Francisco Bay has been to conduct sediment quality assessments in several phases: 1) previous information on water and sediment quality was evaluated by reviewing approximately 100 relevant reports; 2) a large number of Bay and wetland sites were surveyed in the Pilot Regional Monitoring Program (PRMP), which also included a methods validation study along a pollution gradient; 3) the reference site study evaluated appropriate sediment reference sites and toxicity tests; 4) approximately 127 stations from throughout the region (selected on the basis of previous information and PRMP results) were screened for sediment toxicity and/or chemistry; and 5) a number of sites that exhibited toxicity and/or elevated chemistry were resampled for additional biological and chemical analyses to confirm previous results. This confirmation survey incorporated three components commonly known as the sediment quality triad: toxicity testing, chemical measurement, and benthic community analysis. Additional samples were collected at selected confirmation sites to estimate the bioavailability of sediment-associated chemicals.

Study Design

During the screening phase of the study, 127 stations that had been identified in previous investigations were screened for sediment toxicity. Since funding constraints precluded comprehensive assessments at each screening site, toxicity testing was used as the primary screening tool. Toxicity tests were used because they are direct, precise indicators of the integrated effects of sediment contaminants, and they provide information about biological impacts of pollutants, information difficult to discern solely from chemical measurements. Generally, two toxicity tests were used at each screening site: a solid-phase sediment test with benthic amphipods, and a sediment porewater test using developing embryos of sea urchins. As methodological improvements were incorporated during the study, some screening samples were tested with sea urchins exposed to the sediment-water interface (SWI), rather than porewater.

After reviewing the screening data and information from previous studies, twelve sites were resampled during the confirmation phase of the study. These sites were analyzed with the sediment quality triad, including two toxicity tests, sediment chemistry, and benthic community analysis. Ten samples from these sites were also analyzed for bioaccumulation, using 28-day laboratory exposures with the clam *Macoma nasuta*. A total of 46 samples were screened for a broad suite of trace metal and organic compounds, and a total of 143 samples were analyzed for mercury and PCBs, chemicals that were identified as elevated in fish tissues in the Bay (SFBRWQCB *et al.*, 1995) and were the subject of a fish consumption health advisory. An additional 15 sites were resampled and tested with sea urchin larvae in sediment-water interface exposures, because their screening samples exhibited toxicity only in sea urchin porewater tests that were accompanied by elevated sulfide or ammonia concentrations.

In order to provide additional information about potential toxic hot spots, linear transects (gradients) were sampled at some confirmation sites to evaluate relationships between sediment chemistry and biological effects. Phase I sediment toxicity identification evaluations (TIEs) were conducted at two sites, and an abbreviated sediment-water interface TIE was conducted at a third site to investigate possible causes of sediment toxicity.

Results of Sediment Assessments

Through the screening and confirmation process, this study identified several highly polluted locations that exhibited adverse biological effects. The study also indicated that 21% of all samples tested were toxic to amphipods, 31% of porewater samples were toxic to sea urchin embryos, and 33% were toxic to sea urchin embryos exposed at the sediment-water interface. Statistical analyses indicated a number of chemicals that were both correlated with biological effects and found at concentrations exceeding sediment quality guideline values.

A number of sites had numerous chemicals with concentrations above sediment quality guideline values and significant biological effects. These sites were categorized based on the magnitudes of chemical concentrations and effects. The sites exhibiting highest chemical concentrations and greatest biological effects included: Stege Marsh, Mission Creek, Islais Creek, Point Potrero (notable for extremely high PCB and mercury concentrations), Pacific Drydock, Castro Cove, Peyton Slough, and San Leandro Bay.

Principal components analyses (PCA) indicated that sediment quality guideline quotient means (ERMQs) and the number of chemicals exceeding guideline values both covaried negatively with biological indicators (increasing concentration of chemical mixtures associated with decreasing biological function). Individual chemicals or chemical classes identified by PCA that also exceeded guideline values and were significantly correlated with adverse biological effects included: total chlordanes and 2-methylnaphthalene (with amphipod toxicity); cadmium, copper, silver, and zinc (with sea urchin porewater toxicity); and cadmium, copper, and zinc (with sea urchin SWI toxicity).

Sediment quality guidelines (such as ERMs) have been derived empirically from a large number of studies nationwide to indicate chemical concentrations often associated with adverse biological effects. The use of guideline values allows simple comparisons of sample concentrations to those observed in numerous other studies. This comparison is useful for perspective, but does not necessarily indicate that chemicals with concentrations above guideline values are responsible for any observed impacts. Only site-specific investigations, using TIEs and other toxicological methods, can determine causal relationships. In the present study, numerous chemicals were found at concentrations exceeding guideline (ERM) values. Of these, chlordanes, PCBs, DDTs, PAHs, dieldrin, copper, mercury, lead, and zinc were commonly found above ERMs. Hexachlorobenzene and chlorpyrifos, for which ERM values have not yet been derived, were often found at concentrations above the 90th percentile of the statewide BPTCP sediment chemistry database. Combined concentrations of chemical mixtures were high at many sites, with 9 sites having mean ERM quotients above the 95th percentile of the statewide BPTCP database.

In tests of ten samples from the Bay, exposed clams accumulated elevated tissue concentrations of nine chemicals or chemical classes: copper, lead, total chlordanes, total DDTs, dieldrin, total PCBs, LMW PAHs, HMW PAHs, and total PAHs. The identification of these chemicals was dependent on the particular samples tested, the analyte list, the physiology of the clam *Macoma nasuta*, and the 28-day exposure period of the laboratory tests.

The data provided in the report represent a significant body of information to assist in management efforts to identify and remediate toxic hot spots in San Francisco Bay. A number of sites were identified as having elevated pollutant concentrations and severe biological impacts. Determination of spatial extent and development of information relevant to pollutant source control will require additional investigation at many sites. A number of other sites demonstrated elevated chemical concentrations without severe acute toxicity, and still other sites had toxic sediment without having elevated concentrations of measured chemicals. These sites may warrant further studies of chronic effects and/or investigations to determine the likely causes of observed biological impacts.

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Ambient Concentrations of Toxic Chemicals in San Francisco Bay Sediments: Summary[1]

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Introduction

In this article, we present results of a method that computes the upper threshold for ambient concentrations of chemical elements and compounds in San Francisco Estuary sediments. In light of the work described below, the staff of the San Francisco Bay Regional Water Quality Control Board (Regional Board) would consider chemical constituents at concentrations equal to or below this upper threshold as ambient values.

Background

Scientists have studied sediments in San Francisco Bay and other estuaries for many decades. Yet despite significant effort on a national level, only general guidance has been available for assessing contaminated sediments and dredged material quality. This project was intended to support the Regional Board in its work in the area of assessment and management of contaminated sediments. To better evaluate polluted sites, Regional Board staff need data on ambient concentrations of chemicals in sediments. For instance, sediments at a given site in and along the Bay margin are often scrutinized for elevated concentrations of elements, compounds, or classes of compounds. The thresholds presented below can be used to determine whether sediments have chemical concentrations greater than that of the current Bay ambient condition.

Ambient Values

Although Bay sediments can be severely polluted, such as those found at a state-listed “toxic hot spot”, more often Bay sediments are moderately contaminated. Since San Francisco Bay sediments are not totally free of anthropogenic pollutants, ambient concentrations for these compounds may be higher than that in pre-industrial sediments (background concentration). It is therefore important to define the typical range of concentrations that one would expect to find in ambient sediments.

It is often crucial to know how chemical concentrations in a given sediment sample compare to those in the rest of the Bay. This is especially true for habitat restoration projects where a newly restored intertidal wetland would be subject to an influx of suspended sediments from the daily tides. A restored wetland surface will have concentrations at least as high as ambient levels because the new marsh substrate will be comprised of sediment deposited by resuspension from ambient sources.

Background Values

The concentrations of chemicals in sediments prior to the region’s industrialization are often relevant to sediment investigations. These pre-industrialization concentrations are referred to as “background”. However, industrial activities carried out

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[1] This is a summary of the Staff Report: Ambient Concentrations of Toxic Chemicals in San Francisco Bay Sediments available from the Regional Board (SFBRWQCB, 1998). See Document Availablility at the end of this article.

during and after the late nineteenth century have had a profound deleterious effect on much of the San Francisco Estuary. Industrial discharges continued uncontrolled until the enactment of the Clean Water Act in the 1970s. Since then, point source discharges of contaminants have steadily decreased. Current factors controlling chemical contamination of surficial sediments are point and non-point discharges, atmospheric deposition, bioturbation, and resuspension of sediments by wave and current action.

Recent analysis of deep sediment cores by the United States Geological Survey (USGS) has provided valuable information on pre-industrial levels of several metals: copper, lead, mercury, silver, and zinc (Hornberger *et al.*, in press). Other metals in that report include chromium, nickel, and vanadium. Hornberger found background metal concentrations in deeper, pre-industrialized sediments to be lower than those in the surficial (ambient) sediments.

Data Sources and Considerations

Data used to calculate ambient sediment concentrations were collected as part of the Regional Monitoring Program for Trace Substances (RMP) and the Bay Protection and Toxic Cleanup Program (BPTCP). Sediments used in the ambient analysis were collected from sites consistently shown to be representative of the cleanest portions of the Bay (Table 4.4). The sampling stations are located away from point and non-point pollution sources. The data used in this analysis were gathered from the 1991 Pilot RMP, ongoing RMP, and the BPTCP's 1995 Reference Site study. The survey stations where sediments were collected for chemical analyses are all within the San Francisco Estuary. The data used in the statistical analyses consisted of 81 records for PAHs, PCBs, heavy metals and metalloids, and selected chlorinated pesticides. Other analytes were not analyzed due to the low number of detections. The station names along with the sampling dates are listed in Table 4.4. River stations (noted as "BG") are located within the Central Valley RWQCB's jurisdiction. In the Pilot RMP, some of the Bay stations were located near potential sources of contamination (e.g., marinas); these were removed from the database prior to analysis. The "marsh" stations from the Pilot RMP were not included in this database and the available database for "marsh" sediments was not sufficiently large to warrant a separate analysis.

Sediment Dynamics / Sample Type

In shallow areas with fine-grained sediments, there is typically a loose or "fluff" layer that hovers over the firm sediments. The sediment samples discussed herein likely include a portion that is periodically resuspended or recently deposited. Resuspension of fine-grain material by wind-waves is a dominant force in shallower regions, while current-driven bed-load transport of coarse material is common in the deep channels (Schoellhamer and Burau, 1996). Data for this project were obtained from sediment samples taken from the upper five centimeters of the benthic substrate.

Removal of Outliers

Outliers were removed to prevent skewed results based upon only one or a few values. Outliers were determined by visual observation of scatter plots and searching for obvious breaks in the data clusters (Smith and Riege, 1998). This process removed data from 19 stations.

Statistical Approach for the Determination of Ambient Threshold Values

The following summary presents a brief overview of the statistical data analysis employed in the determination of ambient concentrations. For a complete description of the statistical methods employed, the reader is referred to Smith and Riege (1998).

Chemical analyses of sediments from relatively clean locations yield a wide range of concentrations for each element or compound. The aim of the statistical analyses was to define a concentration at the upper end of this data range to serve as

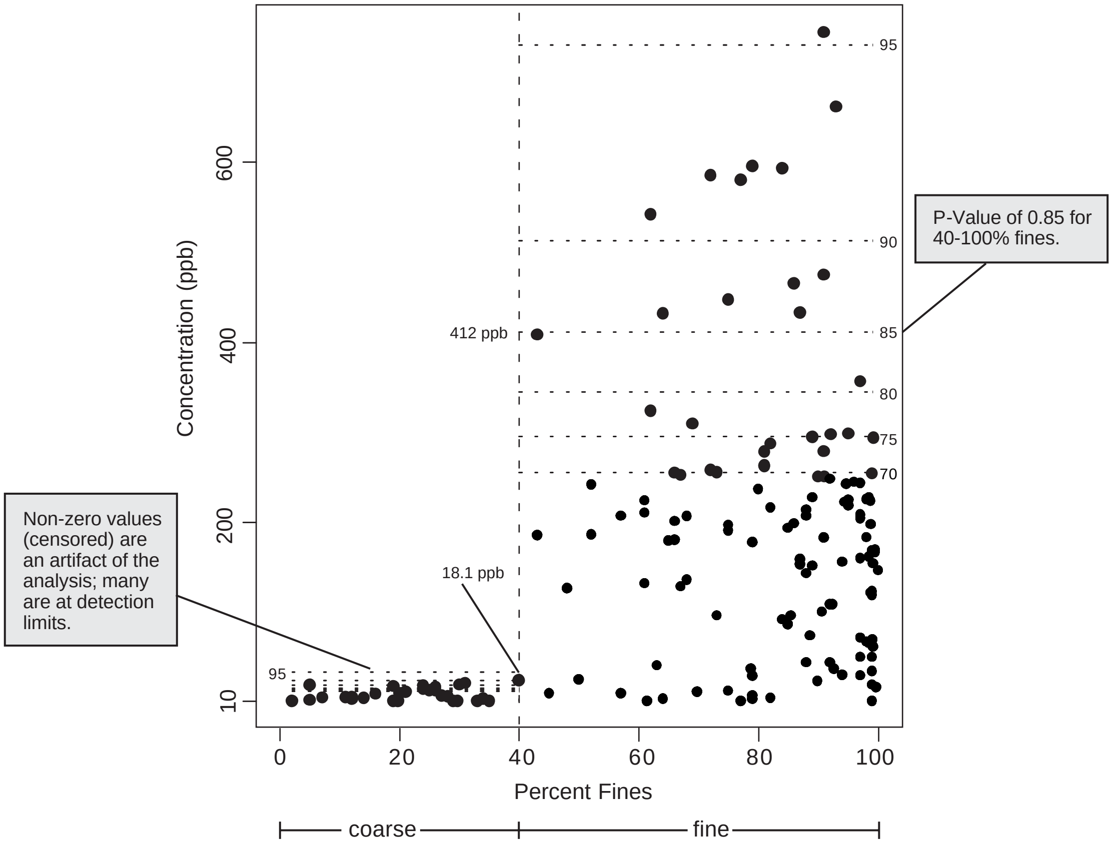
Table 4.4. Stations-Surveys. The numbers in the cells of the table indicate the number of field or location replicates taken. Blank cells indicate no data.

Location	Station #	Site	Data Source	8/91	3/92	4/92	5/92	3/93	9/93	2/94	4/94	8/94	2/95	3/95	4/95	8/95
South Bay	20013	N. South Bay Ref.	REFERENCE SURVEY											3		
South Bay	20014	S. South Bay Ref.	REF SURV											3		
South Bay	BA20	Extreme South Bay	BPTCP SEDQUAL 3	1	1											
South Bay	BA21	South Bay	SFB RMP					1	1	1		1	1			1
South Bay	BA30	Dumbarton Bridge	SFB RMP	1	1			1	1	1		1	1			1
South Bay	BB15	San Bruno Shoal	SFB RMP							1		1	1			1
South Bay	BB30	Oyster Point	SFB RMP					1	1	1		1	1			1
South Bay	BB70	Alameda	SFB RMP							3		3	1			1
Central Bay	BC10	Yerba Buena Island	BPTCP SEDQUAL 3	1	1											
Central Bay	BC11	Yerba Buena Island	SFB RMP					1	1	1		1	1			1
Central Bay	BC21	Horseshoe Bay	SFB RMP					1	1	3		3	1			1
Central Bay	BC31	Richardson Bay	BPTCP SEDQUAL 3		1											
Central Bay	BC32	Richardson Bay	SFB RMP					1	1	1		1	1			1
Central Bay	BC41	Point Isabel	SFB RMP					1	1	1		1	1			1
Central Bay	BC50	Staufer	BPTCP SEDQUAL 3	1	1											
Central Bay	BC60	Red Rock	SFB RMP							1		1	1			1
North Bay	BD15	Petaluma River	SFB RMP										1			1
North Bay	BD20	Petaluma River Lt. 18	BPTCP SEDQUAL 3	1	1											
North Bay	BD22	San Pablo Bay	SFB RMP					1	1	1		1	1			1
North Bay	BD30	Pinole Point	BPTCP SEDQUAL 3	1	1											
North Bay	BD31	Pinole Point	SFB RMP					1	1	1		1	1			1
North Bay	BD40	Davis Point	BPTCP SEDQUAL 3	1												
North Bay	BD41	Davis Point	SFB RMP					1	1	3		3	1			1
North Bay	BF10	Pacheco Creek	SFB RMP	1		1		1	1	1		1	1			1
North Bay	BF20	Grizzly Bay	BPTCP SEDQUAL 3	1		2										
North Bay	BF21	Grizzly Bay	SFB RMP													
North Bay	BF40	Honker Bay	SFB RMP													
River	BG20	Sacramento River	SFB RMP													
River	BG21	Sacramento River In Sherman Lake	BPTCP SEDQUAL 3	1		1		1	1	1		1	1			1
River	BG30	San Joaquin River	SFB RMP					1	1	1		1	1			1
River	BG31	San Joaquin River At Kimball Island South	BPTCP SEDQUAL 3	1												
River	BG32	San Joaquin River At Kimball Island Southwest	BPTCP SEDQUAL 3			1										
North Bay	GD12	Pt. Pinole pilings, shallow	BPTCP SEDQUAL 3				5									
Central Bay	SF01-1	Paradise Cove	REF SURV								3			1		
North Bay	SF02-3	San Pablo Bay-Island #1	REF SURV								3				1	
North Bay	SF03-1	San Pablo Bay-Tubbs Is.	REF SURV								3				1	

an upper threshold for distinguishing between concentrations representing ambient versus contaminated conditions. One way to accomplish this is to define the threshold as a percentile of the distribution. For example, one could define the 85th percentile as the threshold. Here 85% of the data values would fall below the threshold value, and 15% would fall above the threshold. Since a relatively small set of ambient data was available, the percentiles of the underlying distribution of ambient sediment concentrations had to be estimated. The uncertainty in the estimate is a function of the sample size. To incorporate the uncertainty in the estimate of the threshold percentile, tolerance intervals were computed instead of the percentiles. A tolerance interval is the confidence interval bound of a percentile. The confidence interval bound of the mean is widely used and understood. The tolerance interval is similar except that it represents the confidence interval for a percentile instead of the mean of a distribution. Figures 4.21 and 4.22 show the tolerance intervals of selected percentiles for two different distributions.

The size of the confidence interval around the threshold percentile is related to the value chosen for the parameter a, where the size of the confidence interval in percent is 100(1-a). Thus, if one chose the 85th percentile as the threshold and a = 0.05, the upper tolerance interval bound is the upper bound of the 95% confidence interval of the 85th percentile of the ambient concentrations for the chemical in question. If the statistical assumptions associated with the method are correct, the tolerance interval bound would be expected to cover the 85th percentile 95% of the time.

For this project, the 85th percentile was selected as the threshold concentration with an



P-Value of 0.85 for 40-100% fines.

Non-zero values (censored) are an artifact of the analysis; many are at detection limits.

Figure 4.21. Example of a scatter plot for PAHs. Shows Benzo(a)pyrene range of P-values. Break on X-axis indicates a change in sample population. Note: not all contaminants exhibit a sharp break at 40% fines.

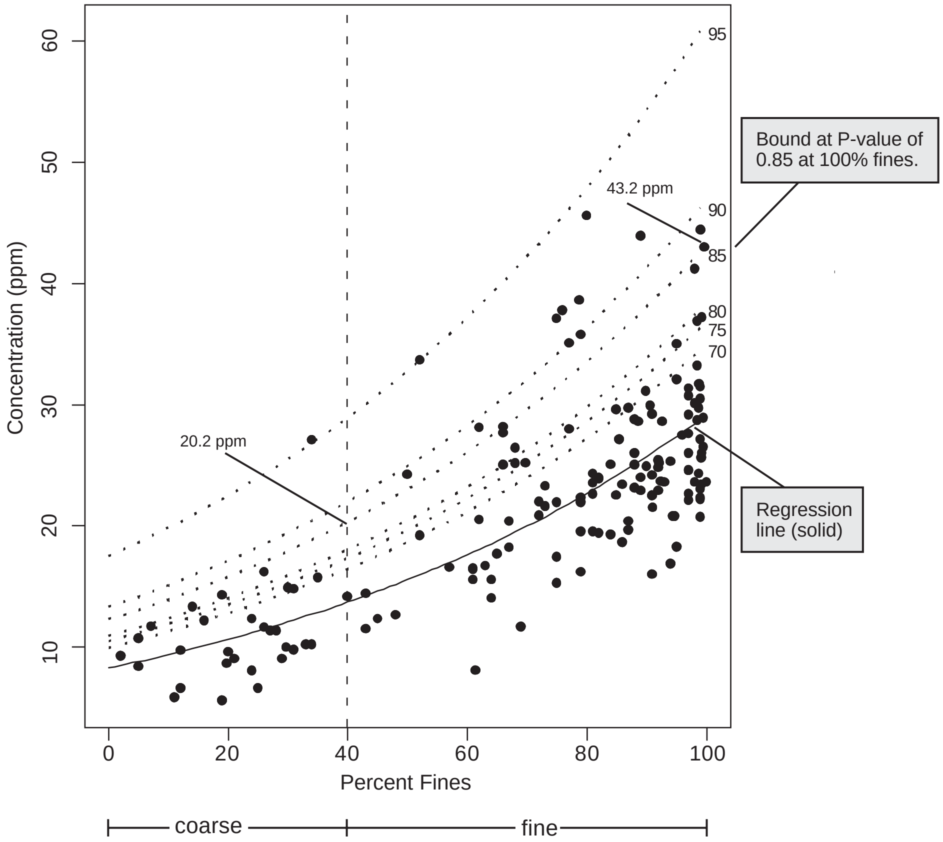


Figure 4.22. Example of a scatter plot for metals. Shows lead concentration change as a function of percent fines.

α = 0.05 used as the tolerance interval bounds. For all chemicals, the tolerance interval bounds are reported for 40% fines and 100% fines. For PCBs, pesticides and metals, this is a somewhat conservative procedure in that the chemical concentrations tend to increase monotonically with finer sediment texture. Tolerance interval bounds at 40% and 100% will be the highest bounds for coarse and finer sediments, respectively. The results are presented in this manner to avoid presenting multiple, continuously changing bounds as a function of particle size.

Parametric tolerance intervals are used when the data fit a normal distribution or when the data can be transformed to a normal distribution. Otherwise, non-parametric tolerance intervals are used. In this project, both approaches were used, depending on the observed distribution of the data sample. The statistical models are described in Smith and Riege (1998).

Several physical and chemical factors, such as total organic carbon, particle surface area, and particle size distribution, are known to correlate with chemical concentrations in sediments. These factors must be considered when defining ambient concentrations. Grain size, as measured by the percent fine, was selected as the main co-factor for the data analysis, as it is easily measured, there is a known interrelationship of other factors with grain size, and there is a lack of data for many other parameters.

After analysis of the distributions with respect to particle size, three statistical models were employed. For the PAHs, two thresholds were computed, one for coarse sediments (0–40% fines) and one for finer sediments (>40% fines). The concentrations of pesticides, metals, and PCBs tended to increase monotonically with decreasing particle size. Tolerance interval bounds around regression lines were used to account for the particle size-concentration relationship.

Results

The results of the analysis of tolerance intervals at the 85th percentile and $\alpha = 0.05$ are presented in Table 4.5. The statistical analyses and the results for other tolerance intervals can be found in Smith and Riege (1998).

Discussion and Recommendations

We recommend that the ambient level threshold for routine use be based upon the bound for the 85th percentile as derived for sediments at the 100% fines level (Table 4.5). Most projects subject to regulatory scrutiny involve fine-grained sediments (e.g., dredging projects and military base closure). Therefore, the thresholds for fine material should prove more often useful to various agencies. Coarse material analytical results should be compared to the ambient value for coarse sediments. Given the uncertainties of the data, it is appropriate that the threshold values for metals, chlorinated hydrocarbons, and pesticides be based upon the upper bound for coarse or fine-grained sediment. Coarse-grained ambient sediments are essentially devoid of chlorinated compounds.

In various site-specific sediment investigations, we have seen concentrations of chlorinated organic compounds (e.g., PCB, DDT) above the ambient upper thresholds. Some of these investigations were conducted in locations that are well offshore and removed from suspected sources. The fact that these sites have chlorinated organic compounds above ambient levels is, in some cases, a reflection of the relatively low detection limits used in the monitoring programs. In other words, the detection of the chlorinated organic compounds is at, or near, the limit of detection, and the occurrence of such compounds in offshore sediments is heterogeneous. Therefore, the comparison of project sediments to ambient thresholds for compounds, such as PCBs and HCHs, will be essentially a comparison to non-detection. This is a contrast to the detection of heavy metals and PAHs, which are more widely distributed and have ambient thresholds well above routine detection limits.

For comparative purposes, we have also included effects range levels (ERL, ERM) in Table 4.5 (Long *et al*., 1995). The ambient threshold is the point at which one can say with confidence that a given concentration is either within the ambient (reference) population or elevated above it. The threshold is not a sort of average around which there is a region of uncertainty (error bar); rather, it is the edge of the reference envelope. Also, the ambient thresholds do not speak to the potential toxicity of these chemicals at low levels. The biological risk associated with these chemicals at ambient levels is a question outside the scope of this project. However, sediments that are swept into dredged channels or onto newly formed marsh surfaces would be expected to contain chemical concentrations similar to the ambient concentrations presented in this report.

Several metals were found at levels exceeding guidelines and thresholds (e.g., ERLs). In some cases, for example nickel, this is partially due to the mineralogy of the parent geologic material found in the Estuary's watershed. In other cases, such as mercury, its occurrence is mostly the result of anthropogenic activities. Metal concentrations may be even higher in certain locations due to parent geologic materials. For example, mercury concentrations are elevated in North Bay tributaries as compared to the mid-Bay stations used in this study. We found the threshold in fine sediment for mercury to be 0.43 ppm. However, sediment samples taken in the Napa River and Novato Creek watersheds show that mercury can be in the 2 ppm to 4 ppm range (Regional Board Case Files: Corps of Engineers, Dredging applications, Napa River Flood Control Project). These data are not covered in our analysis.

The ambient concentration plots and thresholds should be used for evaluations, and when possible, in concert with other measurements and endpoints. If toxicity testing or bioassay data is available, those data should also be considered during the decision-making process. In cases where there is little reason to suspect polluted sediments, these ambient thresholds may prove

Table 4.5. Sediment Thresholds.

Analyte	ERL (dry wt.)	ERM (dry wt.)	SF Estuary Sediment Ambient Concentration (dry wt.) [p=.85]	
			<40 % fines	40–100 % fines
Metals (ppm) (HNO3/HCl Digestion)				
Arsenic	13.5	15.3	8.2	70
Cadmium	0.25	0.33	1.2	9.60
Chromium	91.4	112	81	370
Copper	31.7	68.1	34	270
Lead	20.3	43.2	46.7	218
Mercury	0.25	0.43	0.15	0.71
Nickel	92.9	112	20.9	51.6
Selenium	0.59	0.64		
Silver	0.31	0.58	1	3.7
Zinc	97.8	158	150	410
Organic Compounds (ppb)				
Chlordanes, total	0.42	1.1		
Dieldrin	0.18	0.44		
HCH, total	0.31	0.78		
HCB, total	0.19	0.48		
DDTs, total of 6 isomers	2.8	7	1.58	46.1
PCBs, total	5.9	14.8	22.7	180
PCBs, total (SFEI 40 list)	8.6	21.6		
1-Methylnaphthalene	6.8	12.1		
1-Methylphenanthrene	4.5	31.7		
2,3,5-Trimethylnaphthalene	3.3	9.8		
2,6-Dimethylnaphthalene	5	12.1		
2-Methylnaphthalene	9.4	19.4	70	670
Acenaphthene	11.3	26.6	16	500
Acenaphthylene	2.2	31.7	44	640
Anthracene	9.3	88	85.3	1100
Benz(a)anthracene	15.9	244	261	1600
Benzo(a)pyrene	18.1	412	430	1600
Benzo(b)fluoranthene	32.1	371		
Benzo(e)pyrene	17.3	294		
Benzo(g,h,i)perylene	22.9	310		
Benzo(k)fluoranthene	29.2	258		
Biphenyl	6.5	12.9		
Chrysene	19.4	289	384	2800
Dibenz(a,h)anthracene	3	32.7	63.4	260
Fluoranthene	78.7	514	600	5100
Fluorene	4	25.3	19	540
Indeno(1,2,3-c,d)pyrene	19	382		
Naphthalene	8.8	55.8	160	2100
Perylene	24	145		
Phenanthrene	17.8	237	240	1500
Pyrene	64.6	665	665	2600
High molecular weight PAHs, total	256	3060	1700	9600
Low molecular weight PAHs, total	37.9	434	552	3160
PAHs, total	211	3390	4022	44792

most useful as a "first-level screen" in the decision-making process. In this way, ambient concentrations can serve to define what is "elevated" relative to the ambient sediments distributed throughout the Bay. For projects involving sediment concentrations well above the ambient thresholds, more sophisticated measurements of toxicity and estimates of bioavailability should be considered.

It is believed that the ambient values presented in this report will be representative of conditions in San Francisco Bay for a number of years. The RMP data collected over a four-year period shows that the concentrations of contaminants in sediments at these mid-Bay sites do not change substantially from one year to the next. For this reason we recommend that the database be updated and the thresholds recalculated on a triennial basis.

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Document Availability

Documents that this article are based upon (listed below) are available from the San Francisco Bay Regional Water Quality Control Board office and can be found on the Regional Board Web Page at: http://www.rwqcb2.com/

San Francisco Bay Regional Water Quality Control Board, Staff Report: Ambient Concentrations of Toxic Chemicals in San Francisco Bay Sediments, May 1998.

Smith, R.W. and L. Riege. 1998. San Francisco Bay Sediment Criteria Project: Ambient Analysis Report.

Further Investigations of Classes of Compounds Associated with Sediment Toxicity at Regional Monitoring Program River Stations

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Introduction

Since the San Francisco Regional Monitoring Program (RMP) sampling began in the winter of 1993, three stations have exhibited consistent toxicity to bivalves and intermittent toxicity to amphipods. Significant toxicity to bivalves has been detected in all but one of the sediment elutriate samples from the Grizzly Bay, Sacramento River, and San Joaquin River stations. As part of a RMP Special Study, Phase I toxicity identification evaluations (TIEs) were conducted in August 1996 to better characterize potential causes of toxicity. Abbreviated TIEs were also conducted on August 1997 river samples to characterize chemicals responsible for toxicity to bivalve embryos exposed at the sediment-water interface (SWI). TIE results and measurements of trace metals in sediment elutriates indicated trace metals were a potential cause of toxicity in sediment elutriates from Grizzly Bay and San Joaquin River. Phase I TIE manipulations suggested an organic chemical might be the source of toxicity in Sacramento River sediment.

The three stations in question are essentially freshwater stations, although there is some tidal influence in Grizzly Bay. Because RMP samples have been tested with marine/estuarine species (i.e., bivalves), sediment elutriates are prepared by mixing the sediments with water at the test salinity of 28‰. It is not clear what effect elution of freshwater sediment with higher saline water has on chemical bioavailability or sediment toxicity. Part of the previous investigation included sediment elutriate toxicity tests with the freshwater cladoceran, *Ceriodaphnia dubia*. No adverse acute effects of the river sample elutriates were observed using *Ceriodaphnia*.

Tests conducted on samples from the three stations prior to this portion of the study are summarized in Table 4.6. As part of continuing research into the causes of toxicity at these stations, additional Phase I and Phase II TIE manipulations were conducted in April 1998 using the bivalve larval development test (*Mytilus galloprovincialis*). Based on the results of the previous tests, the current TIEs emphasized treatments that would mitigate toxicity of divalent metals. Additional manipulations included a combined EDTA/C18 column treatment, sodium thiosulfate treatment, and a cation exchange column treatment. Trace metals were also measured in unfiltered elutriate samples.

Investigations into metal toxicity also include an ongoing study of cupric ion concentrations in overlying water from SWI exposures from the three sites. Copper concentrations in sediment elutriates are within the range toxic to bivalves, and sample pH suggested ionic concentrations might be elevated in these samples. Sediment-water interface exposures were conducted simultaneously with the TIEs. Free copper ion concentrations were measured in overlying water from these exposures by determining copper complexation. The analytical technique employed uses flow injection analysis with chemiluminescent detection of a reaction between a copper-binding ligand and titrated copper (Zamzow, 1997). These analyses have so far produced cupric ion concentrations for two of the samples. Additional analyses will be conducted on spiked seawater samples in order to create a cupric ion dose-response curve

Table 4.6. Summary of testing conducted on River stations during 1996–1997.

Station	Test	Date	Result
Grizzly Bay (BF21)	*Mytilus* w/ 28‰ water elutriate	August 1996	0% normal survival at 100% elutriate
	Phase I TIE on elutriate w/ *Mytilus*	August 1996	EDTA treatment significantly mitigated toxicity in 50% elutriate.
	SWI w/ *Mytilus*	August 1996	65% normal survival
	SWI w/ *Mytilus*	August 1997	19% normal survival
	SWI with EDTA w/ *Mytilus*	August 1997	76% normal survival, a significant reduction in toxicity with EDTA treatment.
	Ceriodaphnia with freshwater elutriate	August 1997	100% survival
Sacramento River (BG20)	*Mytilus* w/ 28‰ water elutriate	August 1996	0% normal survival at 100% elutriate
	Phase I TIE on elutriate w/ *Mytilus*	August 1996	Column treatment significantly mitigated toxicity in 50% elutriate.
	SWI w/ *Mytilus*	August 1996	15% normal survival
	SWI w/ *Mytilus*	August 1997	57% normal survival
	SWI with EDTA w/ *Mytilus*	August 1997	57% normal survival
	Ceriodaphnia with freshwater elutriate	August 1997	100% survival
San Joaquin River (BG30)	*Mytilus* w/ 28‰ water elutriate	August 1996	0% normal survival at 100% elutriate
	Phase I TIE on elutriate w/ Mytilus	August 1996	No significant mitigation of toxicity in any TIE treatments.
	SWI w/ *Mytilus*	August 1996	46% normal survival
	SWI w/ *Mytilus*	August 1997	28% normal survival
	SWI with EDTA w/ *Mytilus*	August 1997	60% normal survival, a significant reduction in toxicity with EDTA treatment.
	Ceriodaphnia with freshwater elutriate	August 1997	100% survival

for *Mytilus* larval development. Using the dose-response information, we will be able to determine if free copper ions were present at toxic concentrations in these samples.

Methods

Sample Preparation

All toxicity testing and sample manipulations were conducted at the Marine Pollution Studies Laboratory at Granite Canyon (MPSL). Elutriate solutions were prepared by adding 200 grams of sediment to 800 mL of Granite Canyon seawater in each of 4 clean 1-liter borosilicate glass jars with Teflon®-lined lids (1:4 volume to volume ratio; U.S. EPA/ACOE, 1991). These mixtures were shaken vigorously for 10 seconds, then allowed to settle for 24 hours (Tetra Tech, 1986). The resulting supernatant was siphoned off for use in toxicity testing, TIE manipulations, and chemical analyses.

Trace metals were measured in unfiltered elutriate samples by Mark Stephenson and Jon Goetzl at the Department of Fish and Game Trace Metals Analytical Facility in Moss Landing. The analysis method was Inductively Coupled Plasma Mass Spectrometry (U.S. EPA method 1638).

Toxicity Identification Evaluations

Phase I TIE manipulations followed methods described by U.S. EPA (1996). A brief description of the treatments follows. Filtration (0.45 µm) removed contaminants associated with particles. Sample aeration was used to assess volatile constituents such as sulfide. Two different concentrations of EDTA were used to assess toxicity due to divalent cations. C18 solid-phase extraction columns were used to remove non-polar organic compounds. The C18 column was then eluted with methanol, and the eluate was added back to clean dilution water to determine if C18-bound organics were toxic. A combination C18 column/EDTA treatment was used to remove mixtures of organic and metal contaminants. A cation exchange column was used to remove metal contaminants that were then eluted with acid and added back to clean dilution water for confirmation testing. All column samples were pre-filtered (0.45 µm) so particulate-associated contaminants did not interfere with the interpretation of the results. Graduated pH adjustments (7.9, 8.1, and 8.4) were used to assess toxicity of ionic constituents such as ammonia. The addition of piperonyl butoxide (PBO) was used to test for the presence of metabolically activated pesticides such as diazinon.

Each manipulation was conducted on five concentrations of sediment elutriate from each station and a control. Controls consisted of Granite Canyon seawater and served as blanks for TIE treatments. TIE results were compared using analysis of variance between treatments within each elutriate concentration. Treatments were considered significantly different from the baseline treatment at $p < 0.05$.

Sediment-Water Interface Exposures (after Anderson *et al.*, 1996)

Intact un-homogenized sediment cores were sampled directly from a modified van Veen grab sampler during routine sediment sampling for the RMP. Cores were brought back to the laboratory on ice, prepared for testing by slowly adding 300 mL of overlying seawater, and equilibrated overnight under gentle aeration. Before test initiation, 25-mm mesh screen tubes were inserted into the core tubes containing the sediment, so that the screen was positioned about 1 cm above the sediment. Approximately 200 mussel embryos were pipetted into the screen tubes and exposed for 48 hours. Tests were terminated by removing the screen tube and rinsing larvae into vials that were fixed with 5% formalin. All normally developed larvae were counted in each test container to determine the percentage of embryos that developed into live normal larvae. This value was determined by dividing the observed number of normal D-shaped prodisoconch larvae at the end of the test by the mean number of live embryos inoculated at the beginning of the test. Sediment-water interface exposures were conducted concurrently with Phase I TIE manipulations. Water samples for cupric ion analysis were collected from overlying water of additional replicate cores.

Results

Elutriate Chemistry

As of this writing, bulk phase sediment chemistry had not yet been analyzed on the 1998 RMP samples. A survey of chemistry from 1996 indicates that there were exceedances of effects range low (ERL; Long *et al.*, 1995) values for arsenic, chromium, copper, and mercury, but no exceedances of effects range median (ERM) values at any of the River sites, with the exception of nickel. Nickel concentrations exceeded the ERM on every sampling occasion. It should be noted that there is low confidence in the current nickel guideline (Long *et al.*, 1995). There were no exceedances of either ERL or ERM values for PAHs, PCBs, or pesticides. Although analysis of selected metals in unfiltered 1998 elutriates showed concentrations well below the effect limits for silver, cadmium, and zinc, the total copper concentrations exceeded the EC_{50} value of 7.13 (Table 4.7, MPSL unpublished data).

TIE Results

TIE treatments were conducted on six concentrations of sediment elutriate. Because significant toxic responses and toxicity mitigation generally occur within one or two concentrations of elutriate, data are represented graphically only for concentrations where treatments mitigated toxicity (Figures 4.23 through 4.25). Results from the cation column eluate are not presented because this treatment had 0% survival due to over-acidification.

Unionized ammonia concentrations were below the effects threshold, but some pH levels were outside the acceptable range. Initial baseline pH values for Grizzly Bay and San Joaquin River were below the tolerance threshold for *Mytilus*. However, pH could not have been the only cause of toxicity because other treatments with higher pH values had similar toxic responses. Baseline concentrations of hydrogen sulfide were above the

Table 4.7. Results of metals analysis for elutriate samples. [a] Martin *et al.*, 1981; [b] MPSL, unpublished data.

Metal (mg/L)	Grizzly Bay (BF21)	Sacramento River (BG20)	San Joaquin River (BG30)	*Mytilus* EC_{50}
Ag	0.55	0.069	0.056	14[a]
Al	5.8	14.3	7.6	
As	44.2	33.2	29.6	
Cd	1.77	1.45	0.51	3890[b]
Cr	8.9	15.9	21.2	
Cu	9.60	9.10	7.54	7.13[b]
Fe	19.9	47.3	144.0	
Mn	22640	12459	26028	
Ni	10.9	18.7	23.7	
Pb	0.47	0.46	0.34	
Zn	19.3	13.3	15.0	175[a]

effect limits for *Mytilus* (0.0053 mg/L, Knezovich *et al.*, 1997), but there was no mitigation of toxicity in the aeration or graduated pH manipulations, which would be expected if sulfide were the sole cause of toxicity.

In all samples the column eluate treatment showed significantly greater normal larval development relative to the baseline treatment indicating that non-polar organic chemicals were not eluted from the C18 column.

Grizzly Bay (BF21) TIE

Several treatments significantly reduced toxicity of the 25% concentration of this elutriate sample (Figure 4.23). Filtration, both EDTA treatments, the C18 column with and without EDTA, and the cation column treatments were all significantly different from the baseline treatment. Samples that were passed through the column treatments were all filtered. The C18 treatments were not significantly different from the filtration treatment, indicating that the pre-filtration step probably caused the reduction in toxicity in these treatments. The C18 column can also remove metal chelates that are relatively non-polar (U.S. EPA, 1991). The pre-filtered cation column treatment was significantly different from the filtration treatment indicating that it had further reduced toxicity beyond the filtration step. Reduction of toxicity by the cation column as well as the two EDTA treatments, suggests that divalent cations contributed to the toxicity in this sample.

Sacramento River (BG20) TIE

Toxicity was significantly reduced in the 25% concentration by the filtration treatment, both EDTA treatments, the sodium thiosulfate treatment, the C18 column, and the cation column (Figure 4.24a). Removal of toxicity with the EDTA treatments and the cation column suggest that divalent cations might be a cause of toxicity. Removal of toxicity with the sodium thiosulfate treatment suggests removal of an oxidant or metal. Sodium thiosulfate is a strong chelator of copper, cadmium, mercury, and silver chlorides (Hockett and Mount, 1996). Removal of toxicity by the filtration treatment, along with the pre-filtration steps of the column treatments suggest that contaminants might also be particle-bound, but when the 50% elutriate concentration is examined (Figure 4.24b), toxicity was significantly mitigated by both C18 column treatments and not the filtration treatment. Although the C18 column removed some toxicity, no compounds were eluted off the column in toxic concentrations.

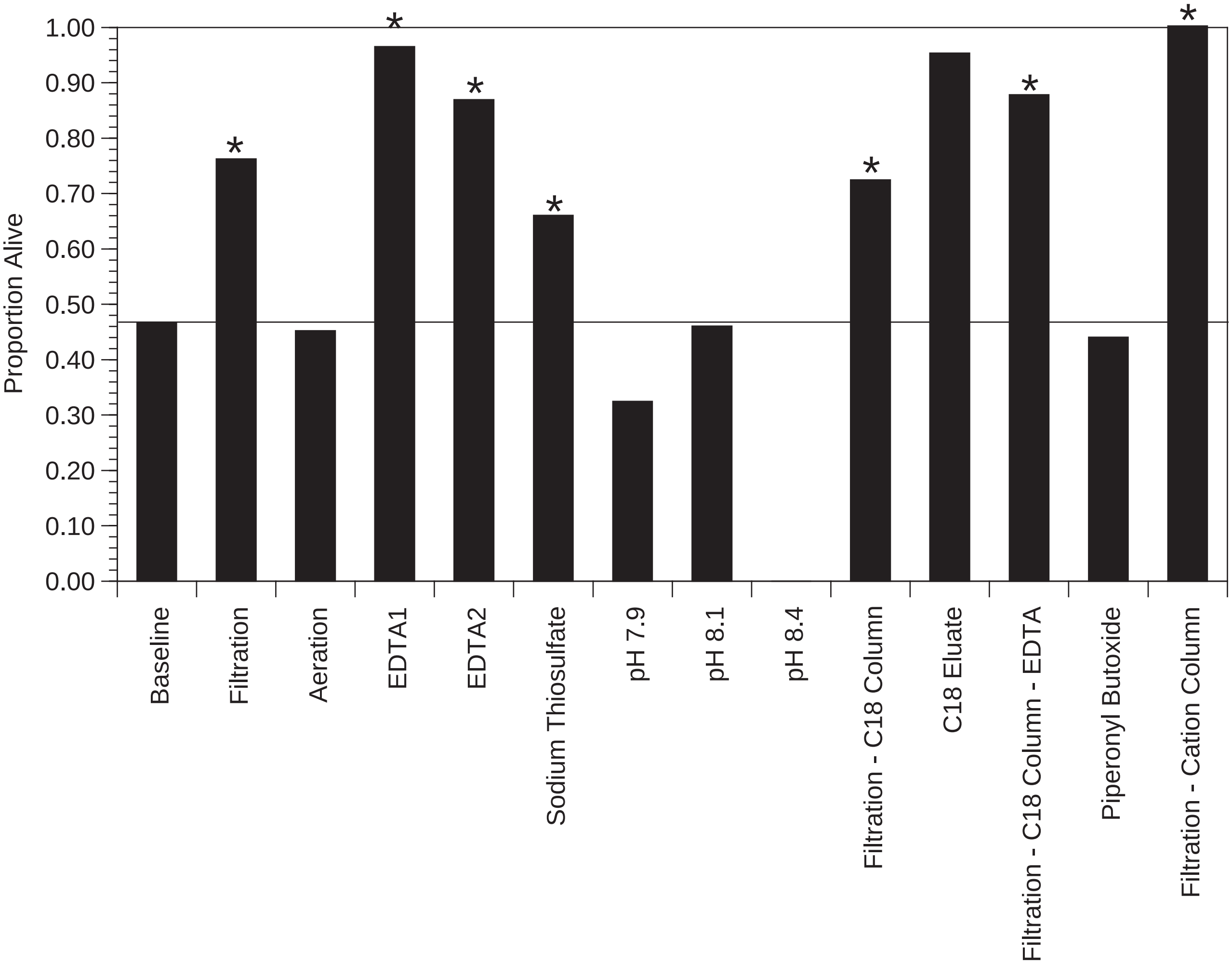

Figure 4.23. Results of TIE manipulations on 25% sediment elutriate from Grizzly Bay. * indicates a significant reduction of toxicity compared to baseline treatment.

San Joaquin River (BG30) TIE

The C18 column treatment and the cation column treatment significantly mitigated toxicity (Figure 4.25a). Although the filtration treatment and the EDTA treatments removed some toxicity, the differences were not statistically significant. The combined C18 column/EDTA treatment did not remove toxicity. The pre-filtration step of the column treatments might be a factor in contaminant removal, but the additional removal of toxicity by the cation column in the 50% elutriate concentration suggests divalent cations as a source of toxicity (Figure 4.25b). Partial reduction of toxicity by EDTA supports this hypothesis.

Sediment-Water Interface (SWI) Tests

In addition to sediment elutriate toxicity tests, mussel embryos were exposed to intact sediment cores collected from the River stations. In these SWI exposures, embryos are exposed in screen tubes on top of the sediment in order to investigate the toxicity of fluxed chemicals to an epibenthic organism. Previous SWI exposures at the River stations have detected significant toxicity to mussel embryos (Table 4.6). Toxicity of the sediment overlying water was reduced in these experiments with the addition of EDTA to the overlying water, indicating divalent metals were responsible for the observed abnormal

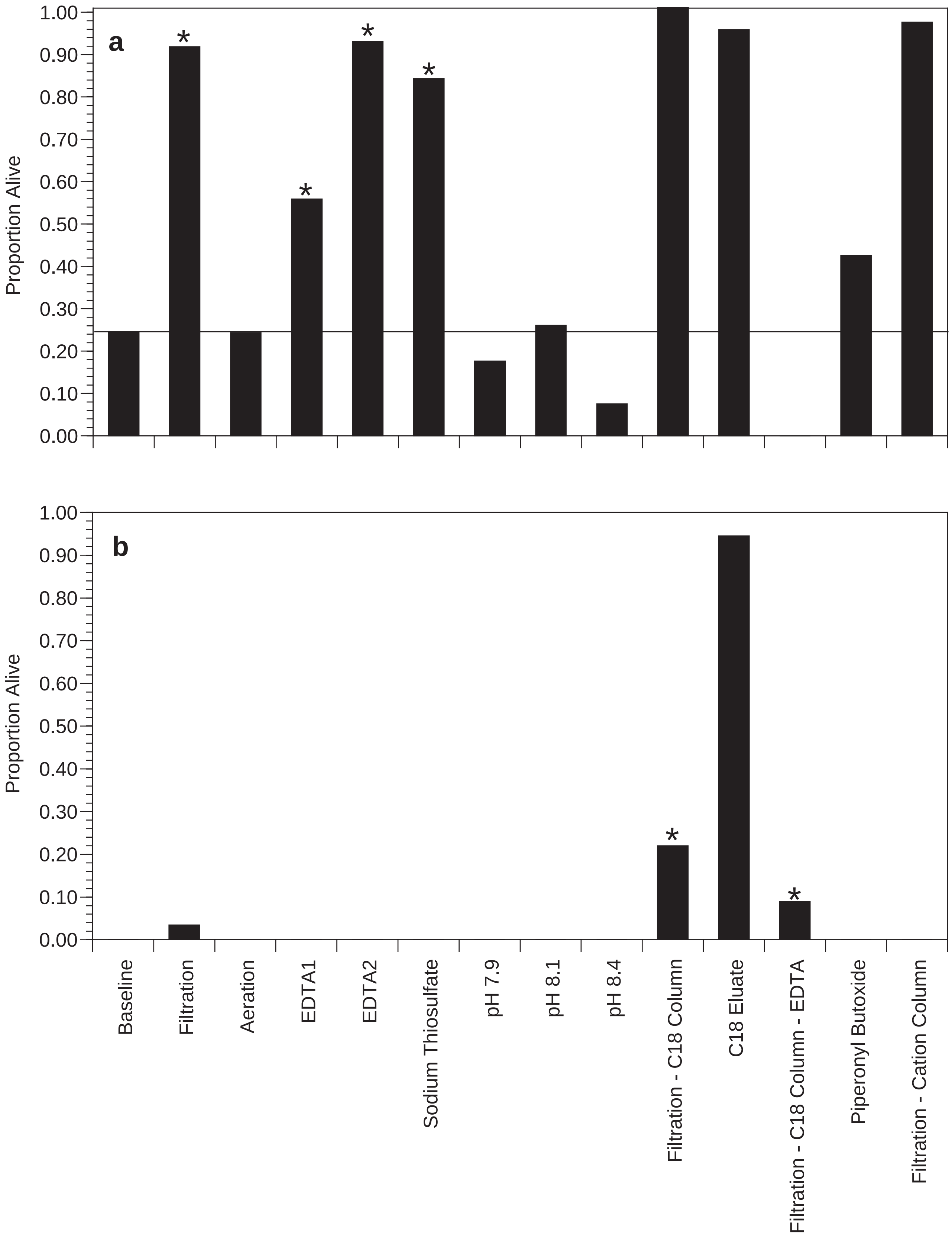

Figure 4.24a and b. Results of TIE manipulations on 25% and 50% sediment elutriate from Sacramento River. * indicates a significant reduction of toxicity compared to baseline treatment.

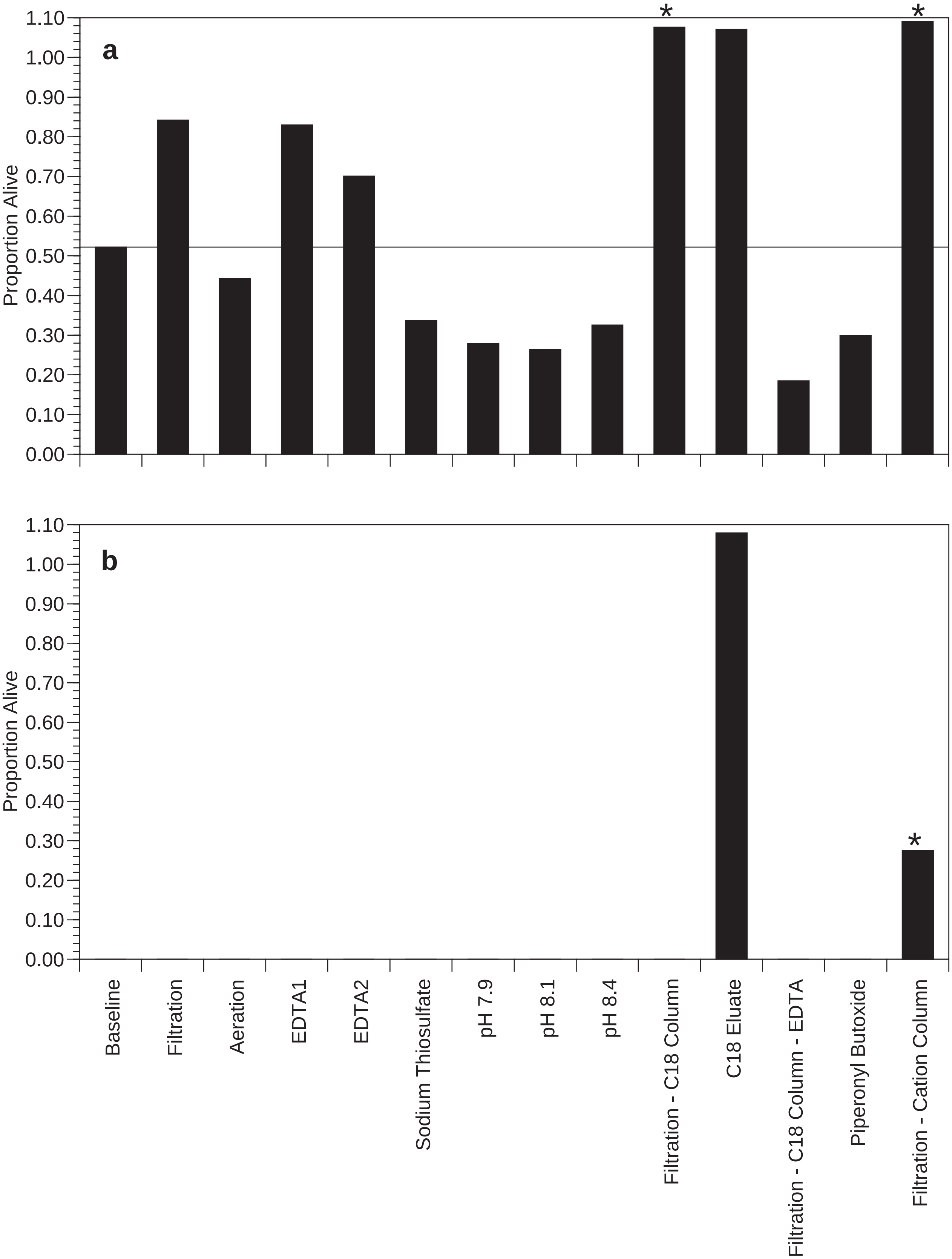

Figure 4.25a and b. Results of TIE manipulations on 25% and 50% sediment elutriate from San Joaquin River. * indicates a significant reduction of toxicity compared to baseline treatment.

development. Additional SWI exposures were conducted in the current study to confirm that fluxed chemicals were toxic to mussel embryos. Sediment overlying water in cores from the River stations again demonstrated significant toxicity in the April 1998 sampling period.

Chemical analyses of sediment elutriates have indicated that copper concentrations are within the range toxic to mussel embryos at these stations. In the current experiments, sediment overlying water from SWI cores was sampled to measure cupric ion concentrations. Cupric ion concentrations in 2 of 3 river samples were successfully determined using flow injection analysis coupled with chemiluminescence detection. These concentrations will be compared to results of laboratory dose-response experiments designed to determine the concentration of cupric ion toxic to mussel embryo-larval development. These experiments will allow us to determine if cupric ion activity in sediment overlying water exceeds the toxicity threshold for *Mytilus* embryos.

Discussion and Conclusions

Sediment elutriates and sediment-water interface exposures from the three River stations were all significantly toxic. Toxicity identification evaluation (TIE) treatments designed to mitigate metals toxicity reduced toxicity in all three samples. C18 solid-phase extraction also reduced toxicity in the Sacramento River sample, indicating non-polar organics may have contributed to toxicity. Although some toxicity was mitigated by the C18 column in the Sacramento River TIE, past bulk phase chemistry data for RMP Sacramento River sediment samples show low levels of measured organic contaminants. The pH value of Grizzly Bay and San Joaquin River elutriate samples were low enough to cause the observed toxicity at these sites, but manipulations of sample pH would have mitigated toxicity if pH was the only factor contributing to sample toxicity. Toxicity was also observed in SWI exposures where overlying water pH was within tolerance limits.

Previous chemical analyses of sediment elutriate samples indicated that metal concentrations were below the effect thresholds of the test organism. Samples from the current study contained concentrations of copper that were above the lowest observed effect concentration (LOEC) of 7 µg/L (MPSL, unpublished data). Other metals may have contributed to toxicity through additivity. Combinations of certain metals have been shown to be additive in their toxicity. Masnado *et al.* (1995) found that combinations of metals including cadmium, chromium, copper, nickel, and zinc with concentrations below National Pollutant Discharge Elimination System (NPDES) water quality permit limits were toxic to *Ceriodaphnia dubia*. The additive, synergistic, and antagonistic effects of metals on larval invertebrates is the subject of a current State Water Board study at MPSL.

The current TIE manipulations, combined with past experiments with Phase I TIEs and SWI exposures (Table 4.6), indicate divalent cations are the likely cause of toxicity at the three river delta sites. EDTA and the cation column treatments successfully removed toxicity to some degree in all three samples. The C18 column also removed toxicity from the Sacramento River sample. The additional study of cupric ion concentrations in sediment overlying water samples will help to confirm the role of cupric ions in river sediment toxicity. Because the influence of salinity manipulation is still unclear, additional experiments will also be conducted on freshwater elutriate, including cupric ion analysis, additional toxicity tests with freshwater organisms, and trace metal analyses of freshwater elutriates.

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Sediment Monitoring Discussion

Sediment contaminant concentrations measured in the San Francisco Estuary exhibit considerable variability depending on the sites and times at which they were sampled. That variability reflects the proximity to the sources of contamination, the biogeochemical interactions between the dissolved and particulate phases in water and bedded sediments of the Estuary, and sediment transport mechanisms such as deposition and resuspension. Because all of those factors affect sediment concentrations measured by the RMP, the concentrations reported only provide information about the status of sediments at the times and locations collected. Understanding the differences in concentrations among the stations and Estuary reaches, or between sampling periods and over several years, requires some knowledge about the factors listed above, but much of that information is not known. Sediment transport mechanisms are well illustrated in the 1997 RMP sediment data: flood flows in January (see article by Cloern *et al.* in *Chapter 3: Water Monitoring*) produced observable changes in RMP sediment concentrations and trends. RMP sediment monitoring does provide reliable measurements of sediment contamination that reflect the most recently deposited sediments and may be used to track trends in the concentrations over time

Patterns in Sediment Contamination in 1997

As in past years, concentrations of most contaminants were highest in the Southern Sloughs and South Bay than in the other Estuary reaches. Average concentrations of chromium, cadmium, lead, mercury, nickel, selenium, zinc, and chlordanes were highest in sediments of the Southern Sloughs, PAHs were highest in the South Bay, and PCBs were highest in the Southern Sloughs and South Bay. In contrast, arsenic was highest in the Central Bay, and copper and total DDTs were highest in the Northern Estuary. Concentrations at the sandy sediment sites were generally lower than at the muddy sediment sites.

The February samples were collected following the flood flows of January 1997. Only mercury concentrations were generally higher throughout the Estuary in February than in August. However, several contaminants (e.g., copper, lead, mercury, selenium, and PAHs) had obviously elevated concentrations at the San Joaquin River (BG30) in February. Conversely, arsenic, chromium, cadmium, and selenium were usually higher in August than in February, whereas all other contaminants showed no obvious seasonal trends.

Another way to examine the effects of the flood flows on sediment concentrations is by examining the RMP trends plots (Figures 4.17 and 4.18). Flood flow effects may be observed as either changes in the average, or increases in the range of values plotted for each contaminant in each reach. Copper and PAHs at the River sites were most obviously increased from past values. Cadmium, chromium, nickel, chlordanes, and DDTs showed increases in the range of values for the South Bay (includes data from the Southern Sloughs). In contrast, arsenic appeared to be below previous values in the Northern Estuary and Central Bay.

The patterns described above indicate that flood flows may elevate some contaminants, but not others. Those patterns are most obvious at sites nearest the major tributaries to the Estuary. Where concentrations were elevated, it is assumed that sediment-associated contaminants were flushed into the Bay by the flows. Conversely, lower concentrations following the floods suggest that those contaminants were not associated with the sediments that came in with the flood. The possible role of resuspension and mixing of existing sediments during flood flows is not known.

Comparisons to Sediment Quality Guidelines

Sediment quality guidelines (SQGs) are concentration values that help interpret RMP results. Since there are no formal regulatory sediment contaminant guidelines, several different sets of guidelines may be used to evaluate monitoring results from several perspectives (Table 4.8).

The USGS's sediment coring data provide historic concentrations of several trace elements. Prior to the gold rush and subsequent industrialization in the region, sediments reflected natural concentrations of trace elements present in the earth's crust. There were no synthetic pesticides or chlorinated hydrocarbons (Venkatesan *et al.*, 1999), and very low levels of petroleum hydrocarbons from combustion of natural materials and peat degradation (Pereira *et al.*, 1999). Obviously, Bay concentrations will never return to those levels, but this knowledge provides an important historical perspective against which to evaluate current Bay conditions.

RMP sediment data have been compared to the Effects-Range guidelines (see *Sediment Introduction*). Those guidelines are effects-based and may be used to evaluate the potential for biological effects. New information about interpreting the Effects-Range guidelines show that for amphipod bioassays, when one or more contaminants exceed their ERL values, 38% of the samples were toxic. When more than 14 ERLs were exceeded, or more than 4 ERMs were exceeded, more than half of the tests were toxic (Long *et al.*, 1998).

Most of the 1997 RMP sediment samples had multiple ERL exceedances, and at least 1 ERM exceedance (Table 4.9a and 4.9b), which suggests a potential for ecological effects. Arsenic, chromium, copper, mercury, nickel, and HPAHs most frequently exceeded ERLs. Nickel always exceeded its ERM and mercury exceeded the ERM at Guadalupe River in the Estuary Interface Study in February. Horseshoe Bay (BC21) and San Pablo Bay (BD22) exceeded numerous PAH ERLs in February.

Another set of SQGs was recently developed by the SFBRWQCB for the San Francisco Estuary (see the article by Gandesbery *et al.* in this Chapter). Ambient Sediment Concentration (ASC) values were based on the 85th percentile of reference or ambient Bay concentrations. Therefore, they reflect an upper limit for ambient or current "background" concentrations. As shown on Table 4.10a and 4.10b, most 1997 RMP samples exceeded at least some of the ASC values. Samples from San Bruno Shoal (BB15), Point Isabel (BB41), and Davis Point (BD41) in February, and Oyster Point (BB30) in August were all within the ASC guidelines. Interestingly, the San Bruno Shoal (BB15) and Yerba Buena Island (BC11) samples from August had numerous ASC exceedances. Sites in the Southern Sloughs, Coyote Creek (BA10), Horseshoe Bay (BC21), San Pablo Bay (BD22), Pinole Point (BD31), and San Joaquin River (BG30) also had numerous concentrations above the ASC guidelines. Chromium and nickel were the most frequently exceeded contaminants, but several individual PAH compounds also exceeded the ASC guidelines.

Effects of Sediment Contamination

The effects of sediment contamination are monitored by the RMP using sediment bioassays and through the Benthic Pilot Study. Sediments may also affect contaminant concentrations in fish (see article by Davis *et al.* in *Chapter 6: Pilot and Special Studies*) and bivalve tissues. There was no toxicity from the sandy sediments at Davis Point (BD41) and Red Rock (BC60), and none at Horseshoe Bay (BC21) and San Bruno Shoal (BB15). However as in previous years, many sediment samples were toxic to amphipods and bivalve embryos. Half of the amphipod bioassays indicated toxicity. Toxicity occurred in samples from both seasons at Napa River (BD50), Yerba Buena Island (BC11), Alameda (BB70), Redwood Creek (BA41), South Bay (BA21), and San Jose (C-3-0). Those results differed from previous years in that more of the South Bay samples were toxic. There was also toxicity to bivalve embryos at 36% of the sites. In 1997, both samples from Coyote Creek (BA10) were toxic, and as in past years, all samples from the Rivers (BG20, BG30), Grizzly Bay (BF21), and Napa River (BD50) were toxic as well.

RMP investigators continue to study the cause of the observed toxicity. For the amphipod test, mixtures of contaminants in sediments was shown to be highly associated with toxicity in most samples (Thompson *et al.*, 1996). The mean ERM quotient (mERMq) is a cumulative ERM index

Table 4.8. Sediment quality guidelines for evaluation of chemical concentrations in sediment. . = no value available

Parameter	unit (dry wt)	ERL[1]	ERM[1]	ASC[2]-sandy <40% fines	ASC[2]-muddy >40% fines	Amphipod AET[3]	Bivalve AET[3]	Background Concentrations (Baywide ranges)[4, 5]	
								Total	Near Total
Arsenic	mg/kg	8.2	70	13.5	15.3	.	.	.	.
Cadmium	mg/kg	1.2	9.6	0.25	0.33	6.7	9.6	.	.
Chromium	mg/kg	81	370	91.4	112	270	.	110 - 170	70 - 120
Copper	mg/kg	34	270	31.7	68.1	1300	390	20 - 55	20 - 41
Mercury	mg/kg	0.15	0.71	0.25	0.43	2.1	0.59	.	0.05 - 0.05
Nickel	mg/kg	20.9	51.6	92.9	112	.	.	70 - 100	50 - 100
Lead	mg/kg	46.7	218	20.3	43.2	660	660	20 - 40	10 - 20
Selenium	mg/kg	.	.	0.59	0.64	.	.	.	.
Silver	mg/kg	1	3.7	0.31	0.58	5.9	0.56	0.1 - 0.1	0.1 - 0.1
Zinc	mg/kg	150	410	97.8	158	960	1600	60 - 70	50 - 100
Total HPAHs	µg/kg	1700	9600	256	3060	69000	17000	.	.
Fluoranthene	µg/kg	600	5100	78.7	514	30000	2500	.	.
Perylene	µg/kg	.	.	24	145	.	.	.	.
Pyrene	µg/kg	665	2600	64.6	665	16000	3300	.	.
Benz(a)anthracene	µg/kg	261	1600	15.9	244	5100	1600	.	.
Chrysene	µg/kg	384	2800	19.4	289	9200	2800	.	.
Benzo(b)fluoranthene	µg/kg	.	.	32.1	371	.	.	.	.
Benzo(k)fluoranthene	µg/kg	.	.	29.2	258	.	.	.	.
Benzo(b,k)fluoranthene	µg/kg	.	.	.	.	7800	3600	.	.
Benzo(a)pyrene	µg/kg	430	1600	18.1	412	3000	1600	.	.
Benzo(e)pyrene	µg/kg	.	.	17.3	294	.	.	.	.
Dibenz(a,h)anthracene	µg/kg	63.4	260	3	32.7	540	230	.	.
Benzo(g,h,i)perylene	µg/kg	.	.	22.9	310	1400	720	.	.
Indeno(1,2,3-c,d)pyrene	µg/kg	.	.	19	382	1800	690	.	.
Total LPAHs	µg/kg	552	3160	37.9	434	24000	5200	.	.
1-Methylnaphthalene	µg/kg	.	.	6.8	12.1	.	.	.	.
1-Methylphenanthrene	µg/kg	.	.	4.5	31.7	.	.	.	.
2,3,5-Trimethylnaphthalene	µg/kg	.	.	3.3	9.8	.	.	.	.
2,6,-Dimethylnaphthalene	µg/kg	.	.	5	12.1	.	.	.	.
2-Methylnaphthalene	µg/kg	70	670	9.4	19.4	.	.	.	.
Naphthalene	µg/kg	160	2100	8.8	55.8	2400	2100		
Acenaphthylene	µg/kg	44	640	2.2	31.7	1300	.	.	.
Acenaphthene	µg/kg	16	500	11.3	26.6	2000	500	.	.
Fluorene	µg/kg	19	540	4	25.3	3600	540	.	.
Phenanthrene	µg/kg	240	1500	17.8	237	6900	1500	.	.
Anthracene	µg/kg	85.3	1100	9.3	88	13000	960	.	.
Total PAHs	µg/kg	4022	44792	211	3390	.	.	36 - 931	
p,p'-DDE	µg/kg	2.2	27	.	.	15	.	.	.
DDD	µg/kg	.	.	.	.	43	.	.	.
DDT	µg/kg	.	.	.	.	.	.	.	.
Total DDTs	µg/kg	1.58	46.1	1.58	46.1	.	.	.	.
Total Chlordanes	µg/kg	0.5	6	0.42	1.1	.	.	.	.
Dieldrin	µg/kg	0.02	8	0.18	0.44	.	.	.	.
Endrin	µg/kg	.	.	.	.	.	.	.	.
TOTAL PCBs (NIST 18)	µg/kg	.	.	5.9	14.8	3000	1100	.	.
Total PCBs	µg/kg	22.7	180	8.6	21.6	3000	1100	.	.

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[1] Long *et al.*, 1995.
[2] Gandesbery, 1998; Smith and Riege, 1998.
[3] Barrick *et al.*, 1988.
[4] Hornberger *et al.*, 1999.
[5] Pereira *et al.*, 1999.

Table 4.9a. Sediment trace element concentrations above Effects-Range guidelines during the wet- and dry-sampling periods in 1997. See Table 4.8. ● = above ERL, ◆ = above both the ERL and ERM, - = data not available.

			Ag		As		Cr		Cu		Hg		Ni		Zn	
	Code	Station	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
Estuary Interface	BW10	Standish Dam					●	●		●		●	◆	◆		
	BW15	Guadalupe River				●	●	●	●	●	◆	●	◆	◆	●	●
Southern Sloughs	C-1-3	Sunnyvale		-			●	●		●	●	●	◆	◆		●
	C-3-0	San Jose		●			●	●		●	●	●	◆	◆		●
South Bay	BA10	Coyote Creek		-			●	●	●	●	◆	●	◆	◆	●	
	BA21	South Bay		-			●	●	●	●	●	●	◆	◆		
	BA30	Dumbarton Bridge		-			●	●	●	●	●	●	◆	◆		
	BA41	Redwood Creek		-		●	●	●	●	●	●	●	◆	◆		
	BB15	San Bruno Shoal		-			●	●			●	●	◆	◆		
	BB30	Oyster Point		-			●	●	●		●		◆	◆		
	BB70	Alameda		-			●	●	●	●	●	●	◆	◆		
Central Bay	BC11	Yerba Buena Island		-		●	●	●		●	●	●	◆	◆		
	BC21	Horseshoe Bay		-			●	●	-		●		◆	◆		
	BC32	Richardson Bay		-	●	●	●	●	●	●	●	●	◆	◆		
	BC41	Point Isabel		-		●	●	●	●	●	●	●	◆	◆		
	BC60	Red Rock	-	-		●		●	-				◆	◆		
Northern Estuary	BD15	Petaluma River		-		●	●	●	●	●	●	●	◆	◆		
	BD22	San Pablo Bay		-	●	●	●	●	●	●	●	●	◆	◆		
	BD31	Pinole Point		-	●	●	●	●	●	●	●	●	◆	◆		
	BD41	Davis Point		-				●					◆	◆		
	BD50	Napa River		-	●	●	●	●	●	●	●	●	◆	◆		
	BF10	Pacheco Creek		-				●	-				◆	◆		
	BF21	Grizzly Bay		-	●	●	●	●	●	●	●	●	◆	◆		
	BF40	Honker Bay		-	●		●	●	●	●	●	●	◆	◆		
Rivers	BG20	Sacramento River	-	-				●	-				◆	◆		
	BG30	San Joaquin River		-	●		●	●	●		●		◆	◆		

that reflects additive concentrations of mixtures of contaminants. In the 1997 results, mERMq values below about 0.2 were usually not toxic, and mERM quotients above about 0.25 usually were toxic (Table 4.11), although samples from Coyote Creek (BA10) and Grizzly Bay (BF21) in August, 1997 had mERMq values above 0.3 and were not toxic. While they were not tested, samples from the Estuary Interface Study in Coyote Creek (BA10) and elsewhere had mERMq values that would suggest they were toxic.

For the bivalve embryos, dissolved metals (divalent cations) in sediment elutriates at the Rivers (BG20, BG30) and Grizzly Bay (BF21) were probably responsible for the observed toxicity. At the Sacramento River site (BG20), organics were also implicated.

Investigations into sediment contaminant effects on benthos are continuing under the RMP Benthic Pilot Study, but analysis is not yet complete. Our preliminary results, however, indicate that most RMP sites are inhabited by many species characteristic of unimpacted conditions. In order to demonstrate a benthic response to contamination, the Bay Protection and Toxic Cleanup Program samples, which included several impacted sites (Hunt *et al.*, 1998) has been added to the RMP database. Next year's Annual Report will include complete benthic assessments.

Table 4.9b. Sediment trace organic concentrations above Effects-Range guidelines during the wet- and dry-sampling periods in 1997. See Table 4.8. ● = above ERL, ◆ = above both the ERL and ERM, - = data not available.

			2-Methylnaphthalene		Acenaphthene		Acenaphthylene		Anthracene		Benz(a)anthracene		Benzo(a)pyrene		Dibenz(a,h)anthracene		Dieldrin		Fluoranthene		Fluorene		Phenanthrene		Total Chlordanes (SFEI)		Pyrene		Total DDTs		Total HPAHs		Total LPAHs		Total PAHs		Total PCBs	
	Code	**Station**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**
Estuary Interface	BW10	Standish Dam																●							◆	◆			◆	●							●	●
	BW15	Guadalupe River		●																		●			●	●			●	●				●			●	
Southern Sloughs	C-1-3	Sunnyvale		-		-		-		-		-		-		-		-		-		-		-	●	-		-	●	-		-		-		-		-
	C-3-0	San Jose																							●	●			●	●							●	●
South Bay	BA10	Coyote Creek																							◆	●			●	●							●	
	BA21	South Bay																							●				●	●		●						
	BA30	Dumbarton Bridge																							●				●	●	●	●						●
	BA41	Redwood Creek																								●			●	●		●						
	BB15	San Bruno Shoal																											●	●								
	BB30	Oyster Point							●												●								●		●							
	BB70	Alameda								●												●		●					●	●		●		●				●
Central Bay	BC11	Yerba Buena Island																								●			●	●								●
	BC21	Horseshoe Bay			●		●		●		●										●		●						●	●	●		●		●			
	BC32	Richardson Bay				●																							●	●		●						
	BC41	Point Isabel																							●				●	●		●						
	BC60	Red Rock																	-				-				-		●	●								
Northern Estuary	BD15	Petaluma River																											●	●								
	BD22	San Pablo Bay			●				●		●		●		●			●	●		●		●				●		●	●	●	●	●		●			
	BD31	Pinole Point			●												●				●				●				●	●								
	BD41	Davis Point																		-			-	-			-											
	BD50	Napa River																								●			●	●								
	BF10	Pacheco Creek																						-					●	●								
	BF21	Grizzly Bay																						-					●	●								
	BF40	Honker Bay																							●	●			●	●								
Rivers	BG20	Sacramento River																						-					●									
	BG30	San Joaquin River																						-														

Table 4.10a. Sediment trace element concentrations above Ambient Sediment Criteria (ASC; Smith and Riege, 1998) during the wet- and dry-sampling periods in 1997. See Table 4.8. ▲ = above ASC, - = data not available.

			Ag		Cd		Cr		Cu		Hg		Ni		Pb		Zn	
	Code	Station	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
Estuary Interface	BW10	Standish Dam			▲			▲	▲				▲	▲	▲			
	BW15	Guadalupe River	▲				▲	▲			▲	▲	▲	▲	▲		▲	▲
Southern Sloughs	C-1-3	Sunnyvale		-				▲						▲				▲
	C-3-0	San Jose	▲	▲	▲	▲	▲	▲		▲		▲	▲	▲	▲		▲	▲
South Bay	BA10	Coyote Creek		-	▲		▲	▲		▲	▲	▲	▲	▲		▲	▲	▲
	BA21	South Bay		-			▲	▲			▲		▲					
	BA30	Dumbarton Bridge		-			▲	▲										
	BA41	Redwood Creek		-			▲	▲										
	BB15	San Bruno Shoal		-														
	BB30	Oyster Point		-														
	BB70	Alameda		-			▲	▲					▲					
Central Bay	BC11	Yerba Buena Island		-				▲		▲						▲		▲
	BC21	Horseshoe Bay		-		▲									▲			
	BC32	Richardson Bay		-			▲	▲										
	BC41	Point Isabel		-				▲										
	BC60	Red Rock		-				▲	-					▲				
Northern Estuary	BD15	Petaluma River		-			▲	▲			▲		▲	▲				
	BD22	San Pablo Bay		-				▲										
	BD31	Pinole Point		-	▲		▲	▲		▲			▲	▲				▲
	BD41	Davis Point		-				▲	-									
	BD50	Napa River		-		▲	▲	▲					▲	▲				
	BF10	Pacheco Creek		-				▲										
	BF21	Grizzly Bay		-			▲	▲					▲	▲				
	BF40	Honker Bay		-	▲		▲	▲					▲	▲				
Rivers	BG20	Sacramento River		-				▲	-									
	BG30	San Joaquin River		-	▲		▲	▲	▲		▲				▲		▲	

Summary of Sediment Conditions in the Estuary

One of the most commonly used methods of assessing sediment condition is to consider information about sediment contamination, toxicity, and benthos together: the Sediment Quality Triad (Long and Chapman, 1985; Chapman *et al.*, 1997). While each of the three components individually provide information about sediments, it is the "weight of evidence" using all three components that creates an overall assessment of sediment condition. At this point, the RMP has good information on the first two components, although bioassays are not conducted at all sites; benthic assessments are being developed. Summary information about sediment contamination and sediment toxicity for each site is shown in Table 4.11.

According to the information presented in this Chapter, sediment contaminant concentrations in the San Francisco Estuary were often above levels known to cause effects at most of the RMP sites. The highest concentrations of most contaminants were at the Estuary Interface sites, the Southern Sloughs, and in the South Bay. Sediments at many sites were toxic to either amphipods or bivalve embryos. Toxicity was most pronounced and occurred most frequently in the Suisun Bay (BF10, BF20, BF30) and Rivers (BG20, BG30) sites, and in the South Bay, although Redwood Creek (BA41) was most toxic to amphipods. The flood flows of January 1997 appeared to generally elevate sediment concentrations in the February samples, especially near the major tributaries, and the incidence of toxicity was also greater than in August.

Table 4.10b. Sediment trace organic concentrations above Ambient Sediment Criteria (ASC; Smith and Riege, 1998) during the wet- and dry-sampling periods in 1997.
See Table 4.8. ▲ = above ASC, - = data not available

			1-Methylnaphthalene		1-Methylphenanthrene		2,3,5-Trimethylnaphthalene		2,6-Dimethylnaphthalene		2-Methylnaphthalene		Acenaphthene		Acenaphthylene		Anthracene		Benz(a)anthracene		Benzo(a)pyrene		Benzo(b)fluoranthene		Benzo(e)pyrene		Benzo(ghi)perylene		Benzo(k)fluoranthene		Chrysene	
	Code	**Station**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**
Estuary	BW10	Standish Dam			▲				▲		▲								▲		▲		▲		▲		▲				▲	
Interface	BW15	Guadalupe River		▲		▲	▲	▲		▲		▲																				
Southern	C-1-3	Sunnyvale		-	▲	-	▲	-		-		-		-	▲	-		-	▲	-	▲	-	▲	-	▲	-	▲	-		-	▲	-
Sloughs	C-3-0	San Jose		▲	▲	▲	▲	▲	▲			▲			▲	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		▲	▲	▲
South	BA10	Coyote Creek		▲		▲						▲				▲		▲		▲		▲		▲		▲		▲		▲		▲
Bay	BA21	South Bay																														
	BA30	Dumbarton Bridge																														
	BA41	Redwood Creek																														
	BB15	San Bruno Shoal		▲		▲				▲		▲				▲		▲		▲		▲		▲		▲		▲		▲		▲
	BB30	Oyster Point			▲												▲								▲							
	BB70	Alameda				▲		▲		▲								▲								▲						
Central	BC11	Yerba Buena Island				▲		▲								▲		▲		▲		▲		▲		▲		▲		▲		▲
Bay	BC21	Horseshoe Bay		▲	▲	▲	▲		▲		▲		▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		▲	▲
	BC32	Richardson Bay																														
	BC41	Point Isabel																														
	BC60	Red Rock																								▲		▲				
Northern	BD15	Petaluma River																														
Estuary	BD22	San Pablo Bay			▲		▲						▲		▲		▲		▲		▲		▲		▲	▲	▲	▲			▲	
	BD31	Pinole Point				▲							▲			▲				▲		▲		▲		▲		▲		▲		▲
	BD41	Davis Point																														
	BD50	Napa River																														
	BF10	Pacheco Creek																		▲						▲						▲
	BF21	Grizzly Bay																														
	BF40	Honker Bay																														
Rivers	BG20	Sacramento River																	▲	-	▲	-			▲		▲				▲	
	BG30	San Joaquin River			▲										▲		▲		▲		▲		▲		▲		▲		▲		▲	

Table 4.10b (continued).

			Dibenz(a,h)anthracene		Dieldrin		Fluoranthene		Fluorene		Indeno(1,2,3-cd)pyrene		Naphthalene		Perylene		Phenanthrene		Pyrene		Total Chlordanes (SFEI)		Total DDTs (SFEI)		Total HPAHs (SFEI)		Total LPAHs (SFEI)		Total PAHs (SFEI)		Total PCBs (SFEI)	
	Code	**Station**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**
Estuary	BW10	Standish Dam	▲			▲					▲		-	-	▲		▲				▲	▲	▲		▲		▲		▲		▲	▲
Interface	BW15	Guadalupe River																			▲	▲						▲			▲	▲
Southern	C-1-3	Sunnyvale	▲	-		-		-	▲	-	▲	-	-	-		-	▲	-		-	▲	-	▲	-	▲	-	▲	-	▲	-	▲	-
Sloughs	C-3-0	San Jose	▲	▲				▲	▲	▲	▲	▲	-	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
South	BA10	Coyote Creek		▲				▲		▲		▲		▲		▲		▲		▲	▲	▲		▲		▲		▲		▲	▲	▲
Bay	BA21	South Bay																			▲											
	BA30	Dumbarton Bridge		▲																												▲
	BA41	Redwood Creek																														
	BB15	San Bruno Shoal		▲				▲		▲		▲		▲		▲		▲		▲				▲		▲		▲		▲		
	BB30	Oyster Point												-													▲					
	BB70	Alameda		▲														▲										▲				▲
Central	BC11	Yerba Buena Island		▲				▲		▲		▲	-	-		▲		▲		▲		▲		▲		▲		▲		▲		▲
Bay	BC21	Horseshoe Bay	▲	▲			▲	▲	▲	▲	▲	▲	-	-	▲	▲	▲	▲	▲	▲			▲	▲	▲	▲	▲	▲	▲	▲		
	BC32	Richardson Bay											-	-																		
	BC41	Point Isabel											-																			
	BC60	Red Rock		▲			-					▲	-	-			-		-				▲	▲				▲		▲		
Northern	BD15	Petaluma River											-																			
Estuary	BD22	San Pablo Bay	▲	▲		▲	▲		▲		▲	▲	▲		▲		▲		▲						▲		▲		▲	▲		
	BD31	Pinole Point		▲	▲			▲				▲	-	-		▲		▲		▲	▲			▲		▲		▲		▲		
	BD41	Davis Point					-						-	-			-	-	-													
	BD50	Napa River												-																		
	BF10	Pacheco Creek								▲			-	-				-					▲	▲						▲		
	BF21	Grizzly Bay											-	-				-														
	BF40	Honker Bay											-	-																		
Rivers	BG20	Sacramento River	▲								▲		-	-			▲	-					▲		▲				▲			
	BG30	San Joaquin River	▲				▲		▲		▲		-	-	▲	▲	▲	-	▲						▲		▲		▲			

Table 4.11. Summary of sediment quality guideline exceedances and sediment toxicity in 1997. - = Toxicity not tested, NA = not analyzed.

				Number of Exceedances					
	Code	**Station**	**Date**	**ERL**	**ERM**	**ASC**	**mERMq**	**Toxic to Eohaustorius?**	**Toxic to Bivalve Embryos?**
Estuary Interface	BW10	Standish Dam	2/97	5	3	14	0.3966	-	-
	BW15	Guadalupe River	2/97	8	4	9	0.3873	-	-
Southern Sloughs	C-1-3	Sunnyvale	2/97	5	1	19	0.1736	-	-
	C-3-0	San Jose	2/97	5	1	27	0.2824	Yes	No
South Bay	BA10	Coyote Creek	2/97	8	3	7	0.5168	Yes	Yes
	BA21	South Bay	2/97	6	1	4	0.2852	Yes	No
	BA30	Dumbarton Bridge	2/97	7	1	1	0.2589	-	-
	BA41	Redwood Creek	2/97	5	1	1	0.2568	Yes	No
	BB15	San Bruno Shoal	2/97	7	1	0	0.2105	No	No
	BB30	Oyster Point	2/97	8	1	4	0.2407	-	-
	BB70	Alameda	2/97	5	1	2	0.2748	Yes	No
Central Bay	BC11	Yerba Buena Island	2/97	4	1	0	0.2006	Yes	No
	BC21	Horseshoe Bay	2/97	13	1	26	0.2464	No	No
	BC32	Richardson Bay	2/97	6	1	1	0.2688	-	-
	BC41	Point Isabel	2/97	6	1	0	0.2598	-	-
	BC60	Red Rock	2/97	2	1	1	0.1469	No	No
Northern Estuary	BD15	Petaluma River	2/97	5	1	3	0.3146	-	-
	BD22	San Pablo Bay	2/97	18	1	22	0.3128	-	-
	BD31	Pinole Point	2/97	10	1	6	0.3212	-	-
	BD41	Davis Point	2/97	1	1	0	0.1660	No	No
	BD50	Napa River	2/97	6	1	2	0.2884	Yes	Yes
	BF10	Pacheco Creek	2/97	2	1	1	0.1579	-	-
	BF21	Grizzly Bay	2/97	6	1	2	0.2841	Yes	Yes
	BF40	Honker Bay	2/97	7	1	3	0.2887	-	-
Rivers	BG20	Sacramento River	2/97	2	1	11	0.1900	No	Yes
	BG30	San Joaquin River	2/97	5	1	26	0.2102	No	Yes
Estuary Interface	BW10	Standish Dam	8/97	10	2	5	0.4836	-	-
	BW15	Guadalupe River	8/97	11	2	12	0.3782	-	-
Southern Sloughs	C-1-3	Sunnyvale	8/97	-	-	-	NA	-	-
	C-3-0	San Jose	8/97	9	1	34	0.4770	Yes	No
South Bay	BA10	Coyote Creek	8/97	6	1	32	0.3247	No	Yes
	BA21	South Bay	8/97	6	1	1	0.3246	Yes	No
	BA30	Dumbarton Bridge	8/97	7	1	3	0.3138	-	-
	BA41	Redwood Creek	8/97	8	1	1	0.3012	Yes	No
	BB15	San Bruno Shoal	8/97	4	1	25	0.2143	No	No
	BB30	Oyster Point	8/97	2	1	0	0.2196	-	-
	BB70	Alameda	8/97	11	1	10	0.2998	Yes	No
Central Bay	BC11	Yerba Buena Island	8/97	8	1	28	0.2637	Yes	No
	BC21	Horseshoe Bay	8/97	3	1	22	0.1858	No	No
	BC32	Richardson Bay	8/97	8	1	1	0.2775	-	-
	BC41	Point Isabel	8/97	7	1	1	0.2921	-	-
	BC60	Red Rock	8/97	4	1	9	0.2306	No	No
Northern Estuary	BD15	Petaluma River	8/97	6	1	2	0.3336	-	-
	BD22	San Pablo Bay	8/97	8	1	7	0.3103	-	-
	BD31	Pinole Point	8/97	6	1	23	0.2644	-	-
	BD41	Davis Point	8/97	2	1	1	0.1769	No	No
	BD50	Napa River	8/97	7	1	3	0.3485	Yes	Yes
	BF10	Pacheco Creek	8/97	3	1	7	0.1945	-	-
	BF21	Grizzly Bay	8/97	6	1	2	0.3324	No	Yes
	BF40	Honker Bay	8/97	6	1	2	0.3132	-	-
Rivers	BG20	Sacramento River	8/97	2	1	1	0.1984	No	Yes
	BG30	San Joaquin River	8/97	2	1	2	0.1975	No	Yes

The RMP sites are monitored to provide information on background or ambient Bay condition, and do not provide comprehensive information about all Bay sediments. Several other non-RMP studies have shown that sediment concentrations and toxicity are even higher at many locations around the Bay's margins (e.g., closing military bases, toxic hot spots). The RMP's new objective for information synthesis (see article by Hoenicke and Bernstein in *Chapter 2: Review Implementation*) encourages the summarization and integration of such information, and could be accomplished through future Special Studies.

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CHAPTER 5

Bivalve Monitoring

Bivalve Monitoring

Background

The purpose of monitoring contaminant concentrations in bivalve tissue for the RMP is two-fold. First, bivalves integrate the bioavailable portion of contaminants in the water column over time, and second, for many contaminants, bivalves are good indicators of contaminant transfer from water into the food web. Bivalves will accumulate certain contaminants in concentrations much greater than those found in ambient water (Vinogradov, 1959). This phenomenon is a result of the limited ability of bivalves to regulate the concentrations of most contaminants in their tissues. This method of active biomonitoring has been widely applied by the California State Mussel Watch Program (Phillips, 1988; Rasmussen, 1994) and others (Young *et al*., 1976; Wu and Levings, 1980; Hummel *et al*., 1990; Martincic *et al*., 1992). For reviews of bioaccumulation monitoring, see Luoma and Linville (1996) and Gunther and Davis (1997).

Bivalves were collected from sites thought to be uncontaminated and transplanted to 15 stations in the Estuary during the wet season (May) and the dry season (September; see map on the inside of the front cover). Sampling dates are listed in Table 1.2 in *Chapter 1: Introduction*. Contaminant concentrations in tissues, survival, and biological condition were measured before deployment (referred to as time zero (T-0) or background) and at the end of the 90–100 day deployment period. Because of the variability between each individual bivalve organism, composite samples of tissue were made from T-0 organisms and from surviving organisms from each deployment site (up to 45 individuals) for analyses of trace contaminants. The *Corbicula* reference site was not optimal, since initial concentrations were found to be high after changing the site from Lake Isabella to Putah Creek and a pond at UC Davis.

The effects of high short-term flows of freshwater on the transplanted bivalves west of Carquinez Strait were minimized by deploying the bivalves near the bottom where density gradients tend to maintain higher salinities. All bivalves were kept on ice after collection and deployed within 72 hours. Multiple species were deployed at several stations due to uncertain salinity regimes and tolerances. Detailed sampling and analysis methods are included in *Appendix A*. Data are tabulated in *Appendix C*.

Overall, the bivalve bioaccumulation and condition study objectives for 1997 were met, although the unusual wet season with extremely high freshwater inputs in January caused high mortality rates in *Mytilus* spp. during the winter/spring deployment.

Accumulation Factors

In addition to using the absolute tissue concentrations at the end of each deployment period and comparing them to initial tissue concentrations prior to transplanting the bivalves to the Estuary (T-0), this report uses accumulation factors (AFs) to indicate accumulation or depuration (loss of constituents from bivalve tissue) during the 90–100 day deployment period. The accumulation factor is calculated by dividing the contaminant concentration in transplants by the initial bivalve concentration at T-0. For example, an accumulation factor of 1.0 indicates that the concentration of a specific contaminant remained the same during the deployment period compared to the initial contaminant level prior to transplanting the bivalve sample to the Estuary. An AF less than 1 indicates that the bivalves decreased in contaminant concentration during the deployment period, while an AF above 1 indicates accumulation.

Guidelines

In the following figures (Figures 5.1–5.16), tissue concentrations of various trace contaminants are compared to applicable guidelines in the proposed California Toxics Rule, since these threshold levels represent the most recent and most scientifically defensible values available to date.

Tissue guidelines are expressed in ppm wet weight, while the RMP tissue data are presented as ppm dry weight. A wet-to-dry weight conversion factor of 7, based on an average of 85% moisture content in bivalves, was applied for comparisons.

Biological Condition and Survival

The biological condition (expressed as the ratio of dry tissue weight to shell cavity volume) and survival rates of transplanted bivalves following exposure to Estuary water are evidence that the animals were healthy and capable of bioaccumulation at most sites (Figures 5.17 and 5.18). However, the data on survival and condition of the transplants indicate that certain sites are generating physiological stress in the animals at certain times, which confounds the interpretation of bioaccumulation data and interferes with the bivalves' usefulness as biomonitors.

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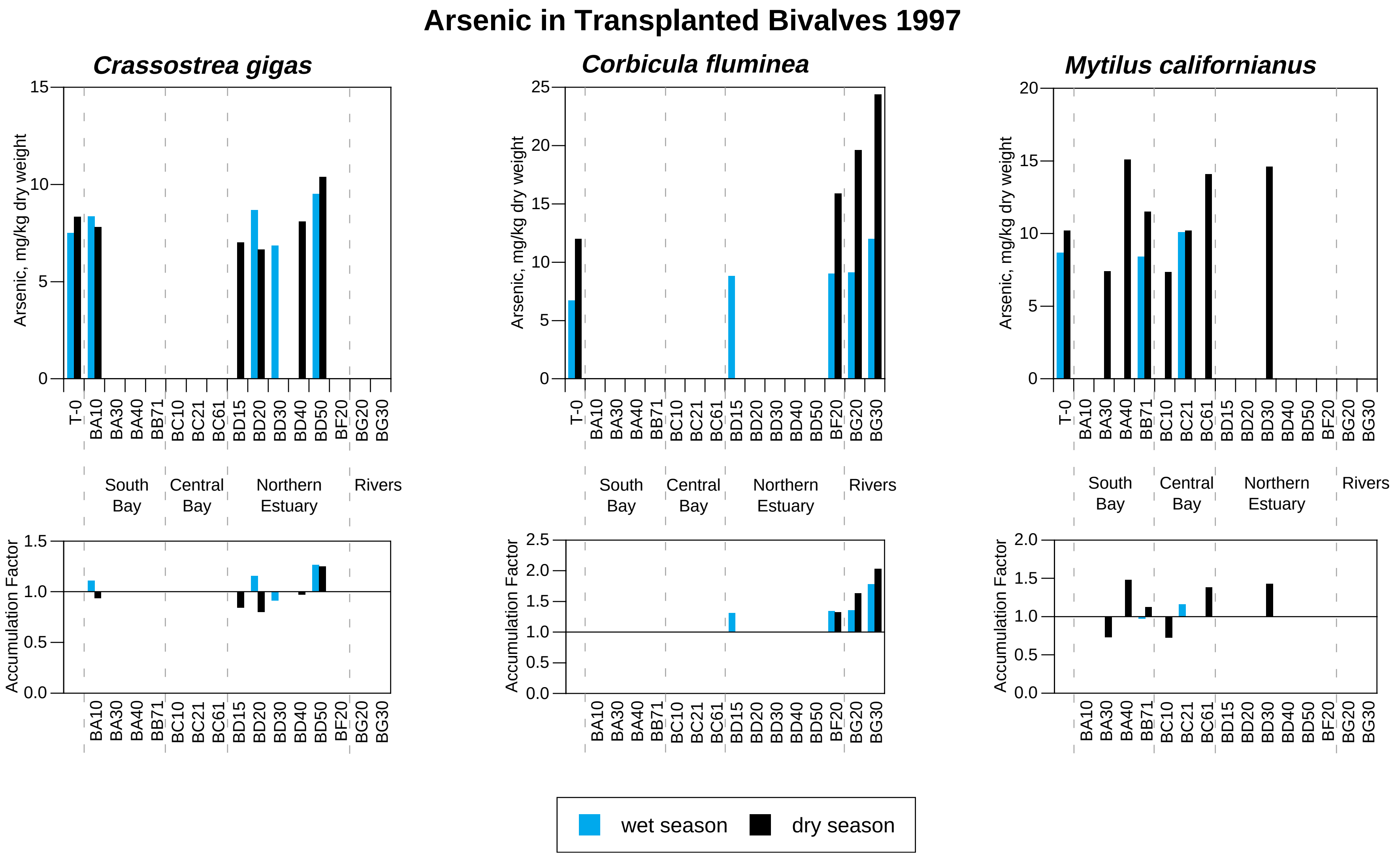


Figure 5.1. Arsenic concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.72 (depuration) to 2.0. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *C. fluminea*, at San Joaquin River (BG30) in the dry season.

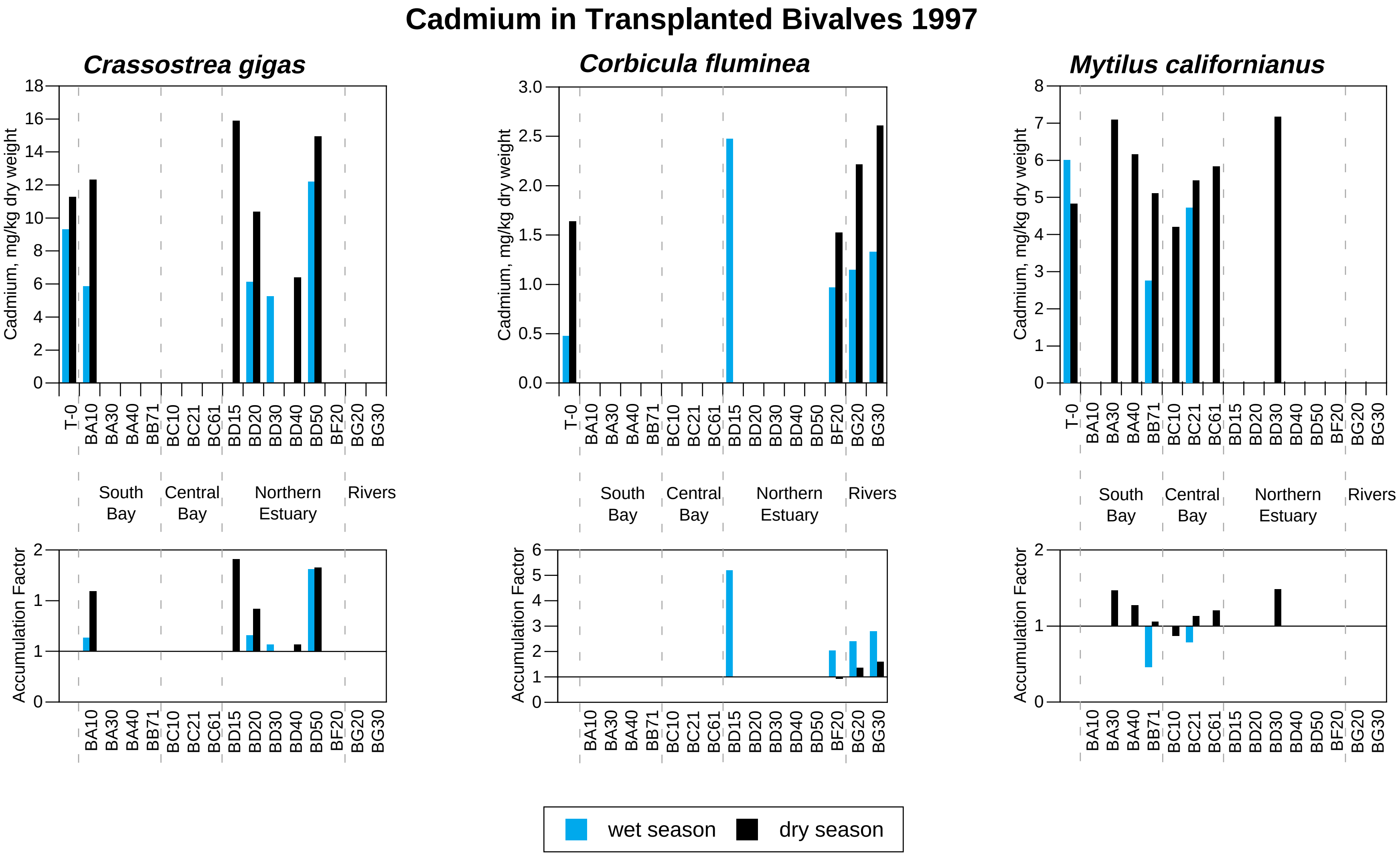


Figure 5.2. Cadmium concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.46 (depuration) to 5.2. Median concentrations were highest in *C. gigas*, intermediate in *M. californianus*, and lowest in *C. fluminea*. The highest measured concentration was in *C. gigas*, at Petaluma River (BD15) in the dry season.

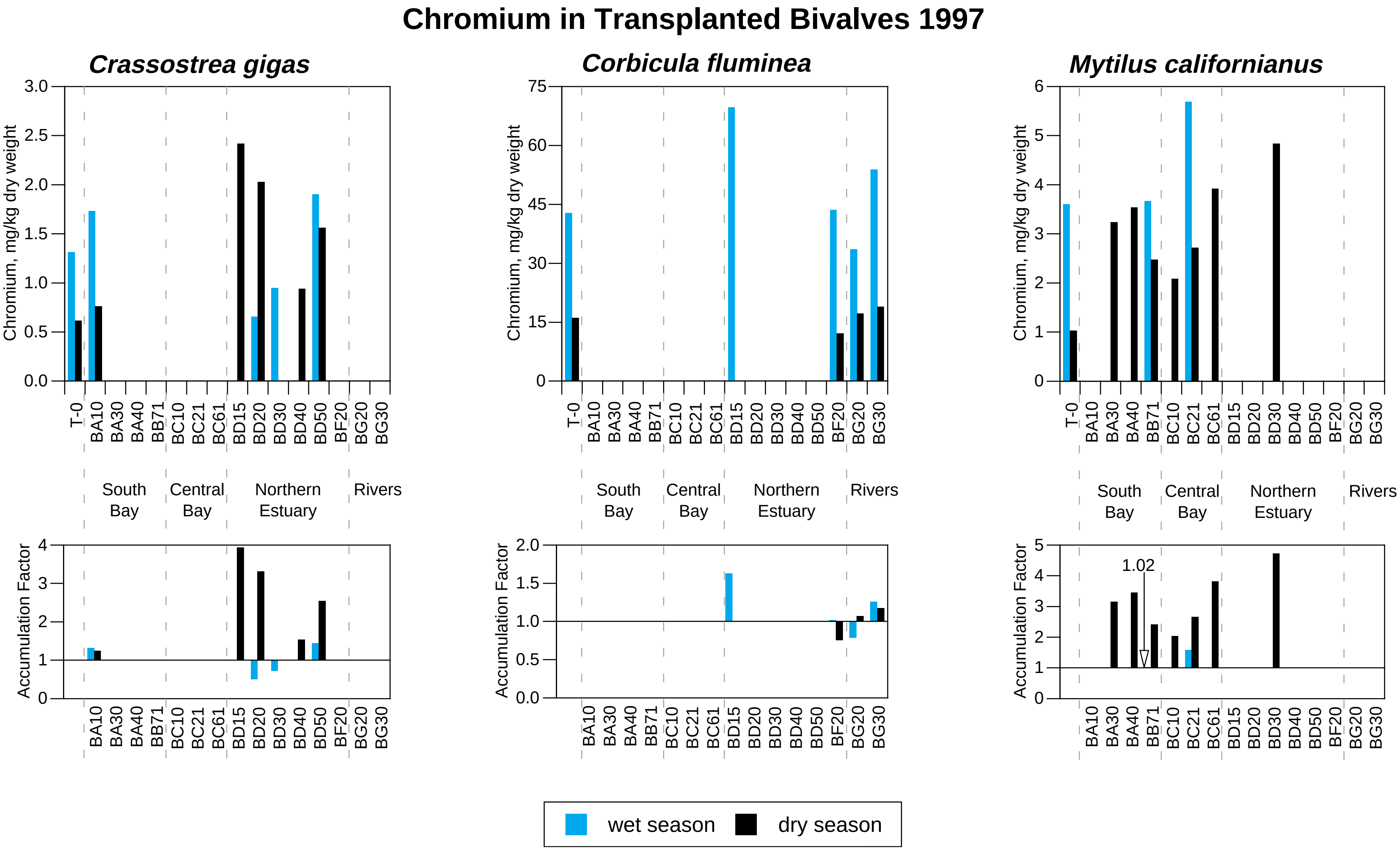


Figure 5.3. Chromium concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.5 (depuration) to 4.7. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *C. fluminea*, at Petaluma River (BD15) in the wet season.

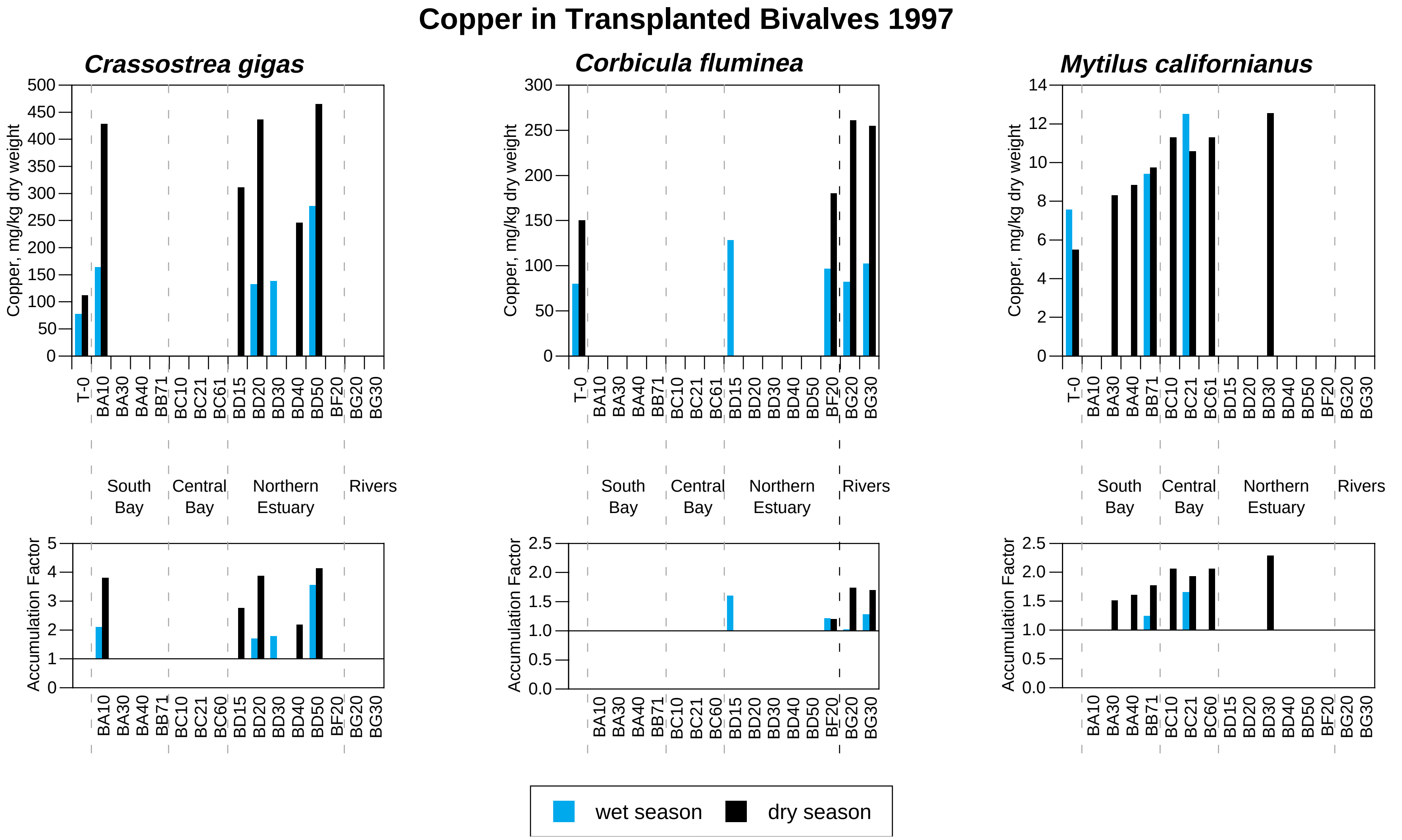


Figure 5.4. Copper concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.02 to 4.1. Median concentrations were highest in *C. gigas*, intermediate in *C. fluminea*, and lowest in *M. californianus*. The highest measured concentration was in *C. gigas*, at Napa River (BD50) in the dry season.

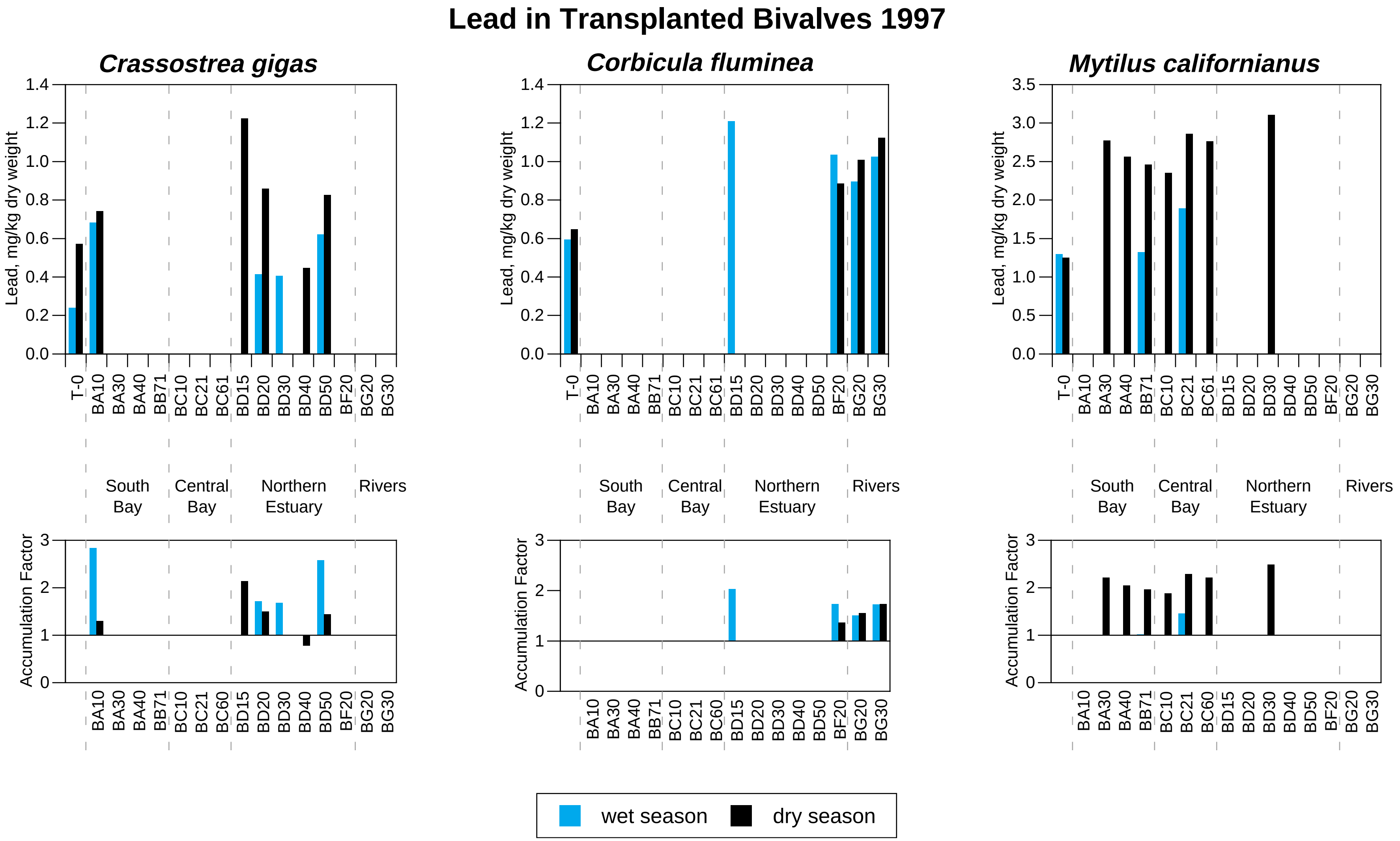


Figure 5.5. Lead concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.8 (depuration) to 2.8. Median concentrations were highest in *M. californianus*, intermediate in *C. fluminea*, and lowest in *C. gigas*. The highest measured concentration was in *M. californianus*, at Pinole Point (BD30) in the dry season.

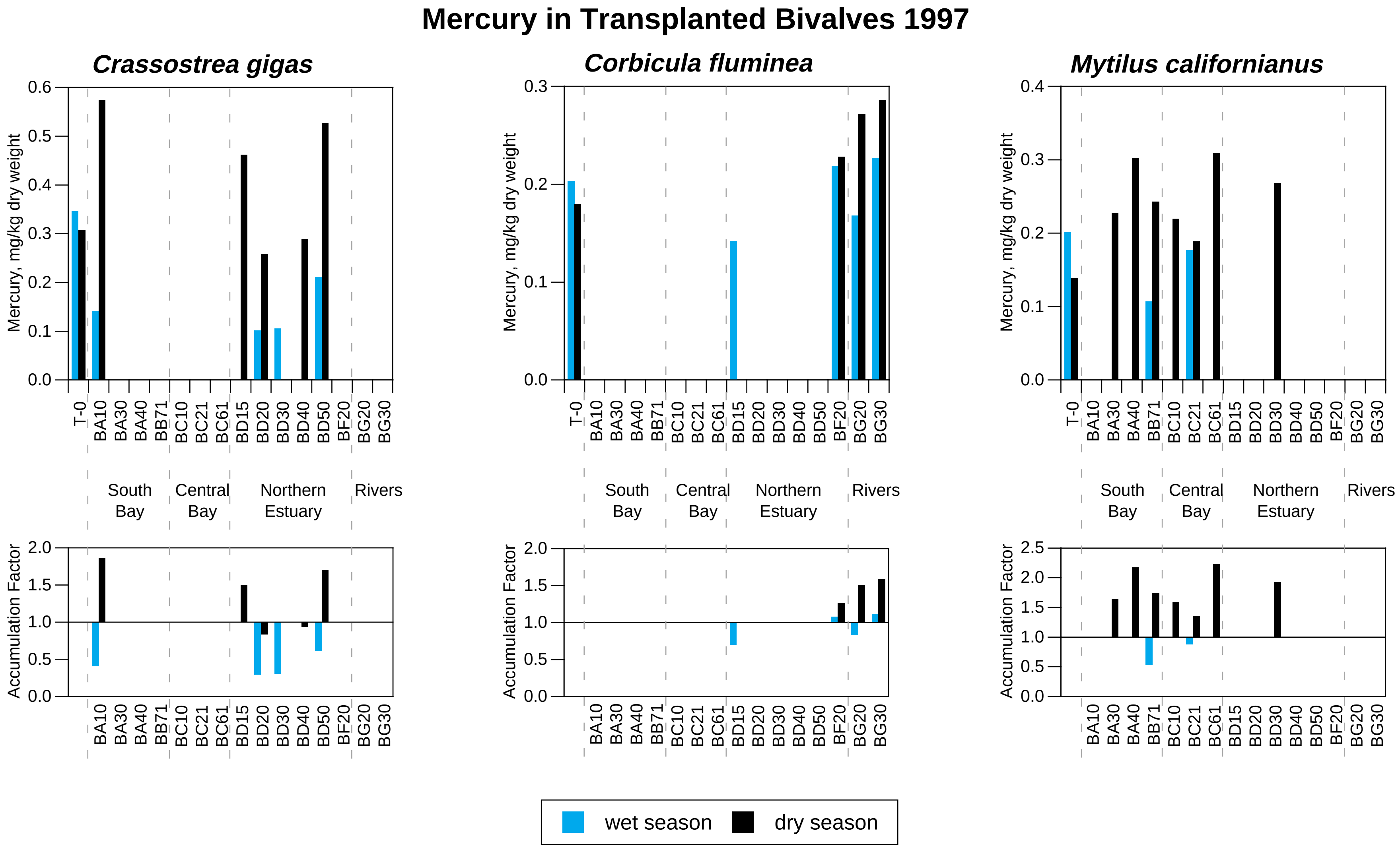


Figure 5.6. Mercury concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.3 (depuration) to 2.2. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *C. gigas*, at Coyote Creek (BA10) in the dry season. All stations had tissue concentrations much lower than the implicit tissue guideline of 7 ppm used to calculate water quality objectives in the draft California Toxics Rule.

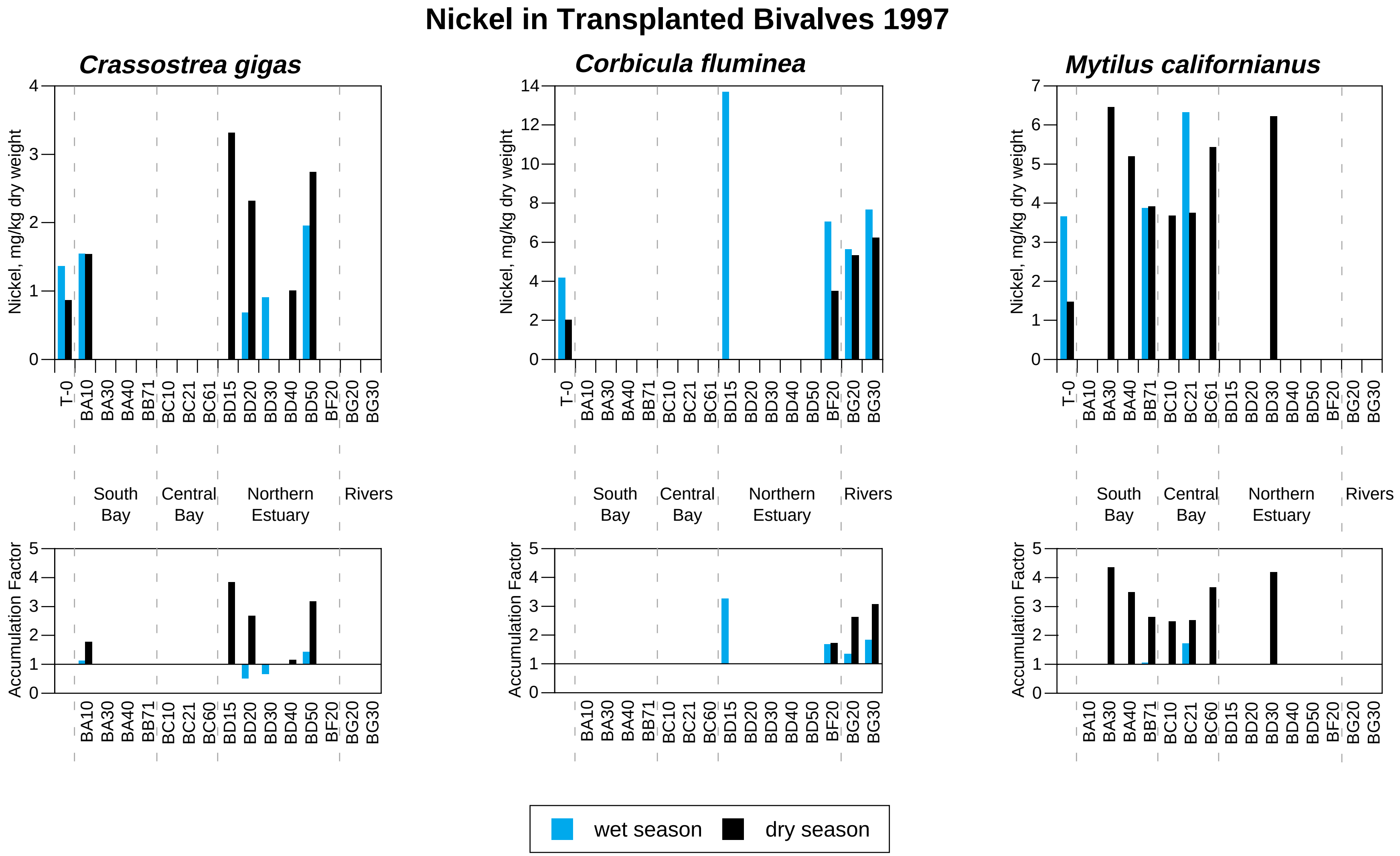


Figure 5.7. Nickel concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.5 (depuration) to 4.4. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *C. fluminea*, at Petaluma River (BD15) in the wet season. No samples exceeded the proposed California Toxics Rule's implicit tissue guideline of 215.4 ppm.

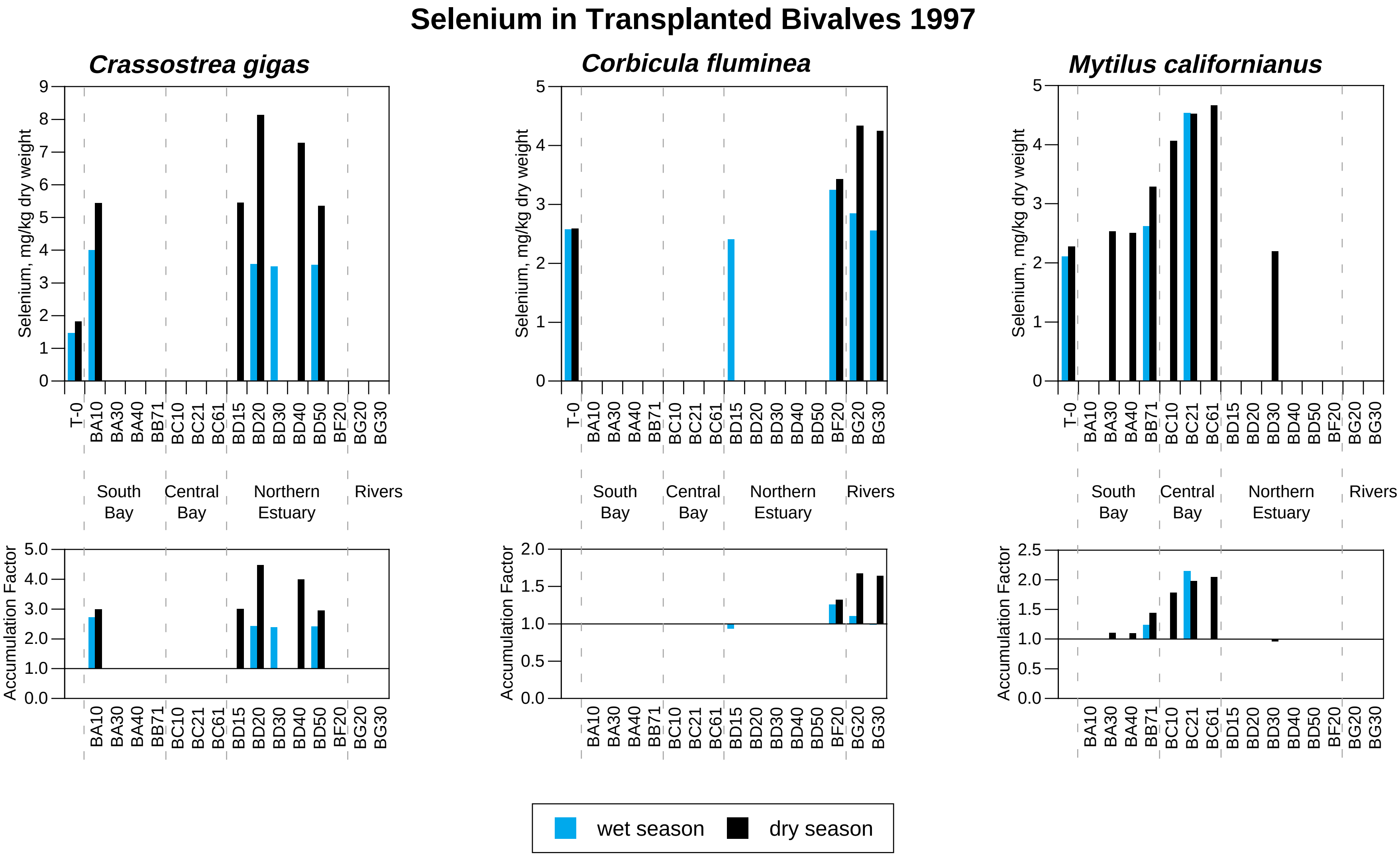


Figure 5.8. Selenium concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.93 (depuration) to 4.5. Median concentrations were highest in *C. gigas*, intermediate in *M. californianus*, and lowest in *C. fluminea*. The highest measured concentration was in *C. gigas*, at San Pablo Bay (BD20) in the dry season.

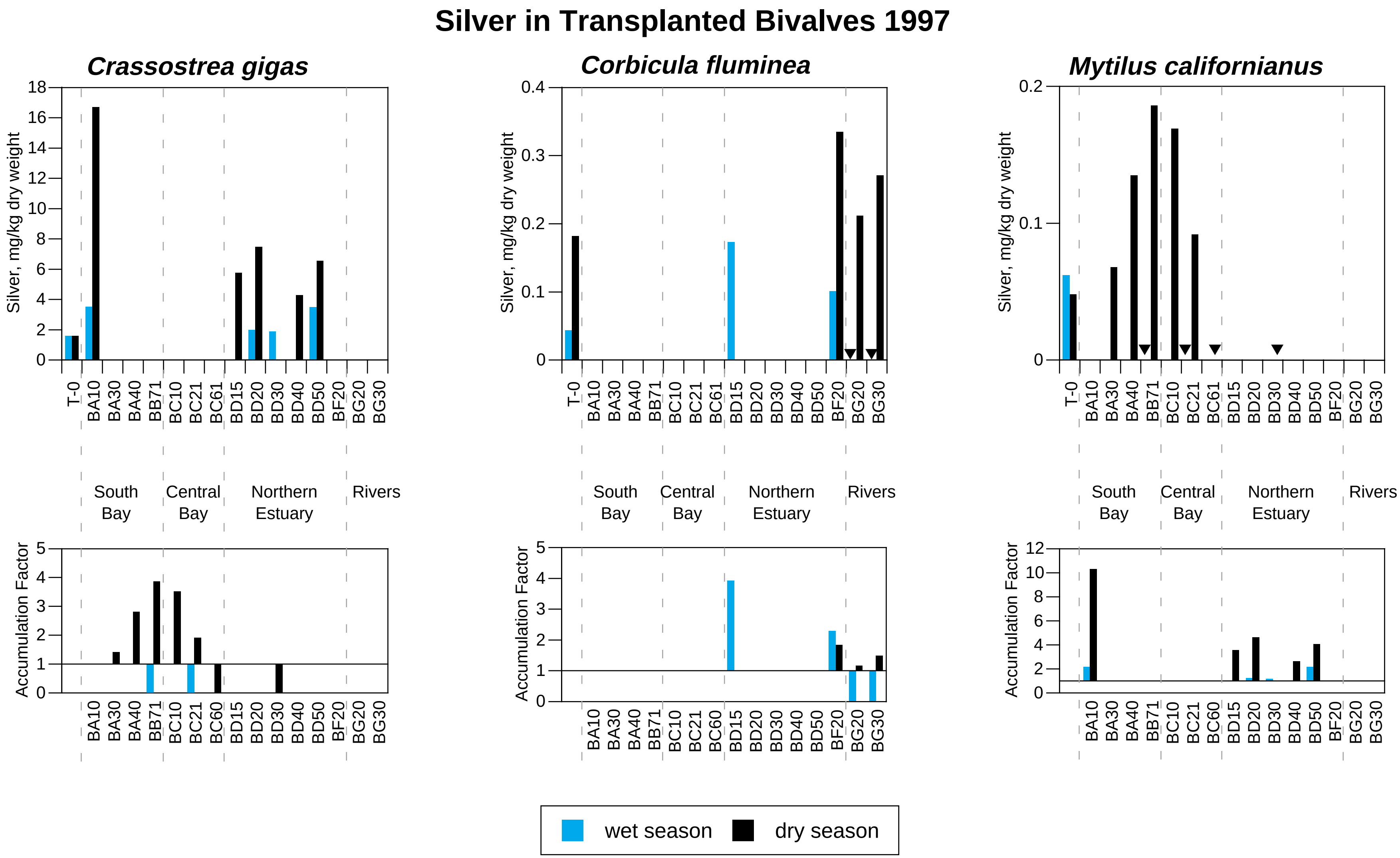


Figure 5.9. Silver concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. ▼ = not detected. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.008 (depuration) to 10.3. Median concentrations were highest in *C. gigas*, intermediate in *C. fluminea*, and lowest in *M. californianus*. The highest measured concentration was in *C. gigas*, at Coyote Creek (BA10) in the dry season. Eleven stations, including two of the reference samples, had concentrations exceeding the proposed California Toxics Rule's implicit tissue guideline of 1 ppm. For calculations, non-detects were substituted with half the target method detection (MDL) listed in the 1996 Quality Assurance Project Plan (Lowe *et al.*, 1996).

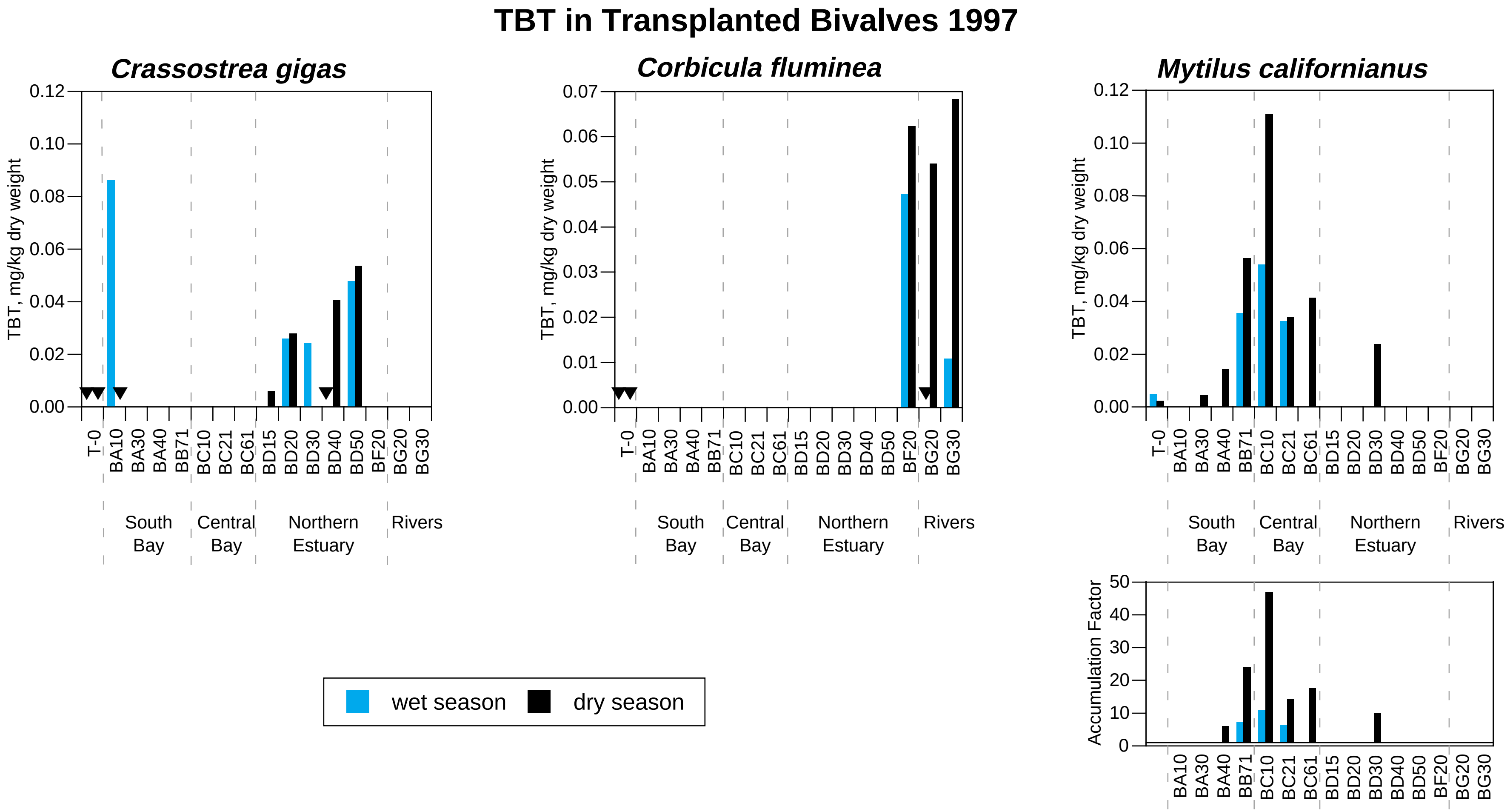


Figure 5.10. Tributyltin concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. ▼ = not detected. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.9 to 47.0. Accumulation factors were not calculated for *C. gigas* and *C. fluminea* because T-0 concentrations for both the wet and dry seasons were not detected. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *M. californianus*, at Yerba Buena Island (BC10) in the dry season.

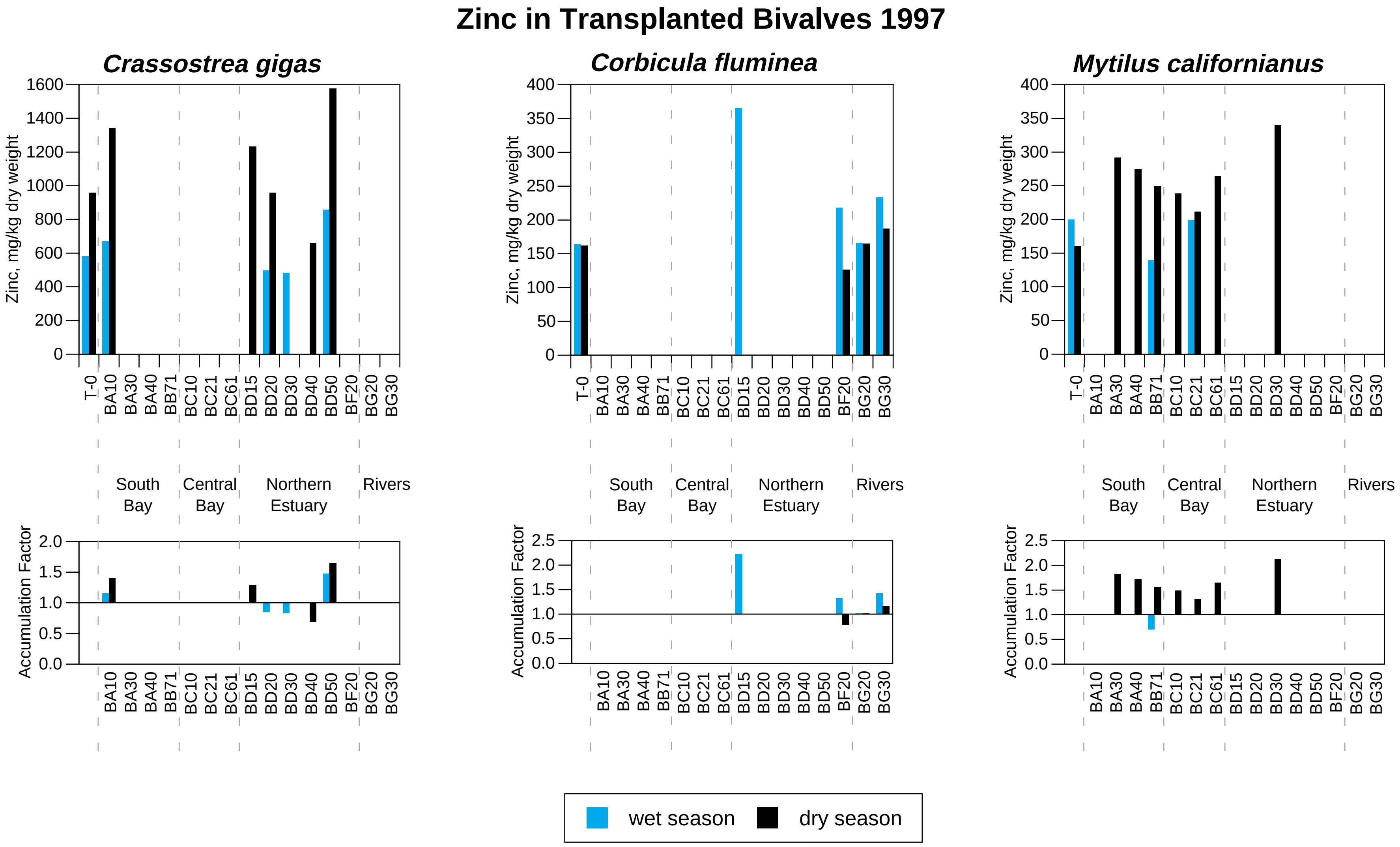


Figure 5.11. Zinc concentrations in parts per million dry weight (ppm) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.69 (depuration) to 2.2. Median concentrations were highest in *C. gigas*, intermediate in *M. californianus*, and lowest in *C. fluminea*. The highest measured concentration was in *C. gigas*, at Napa River (BD50) in the dry season.

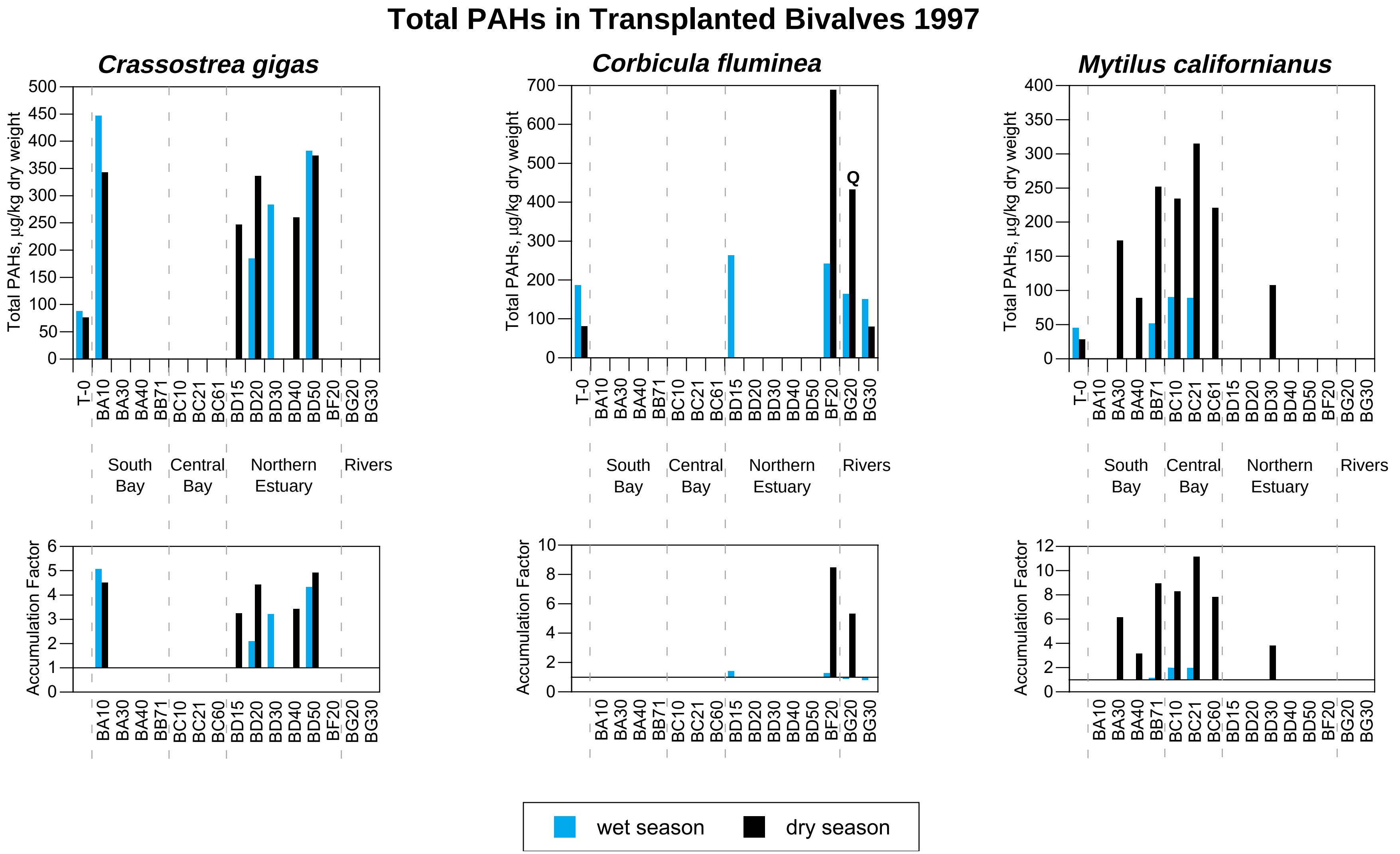


Figure 5.12. Total PAH concentrations in parts per billion dry weight (ppb) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. Q = data point outside data quality objectives. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.8 (depuration) to 11.2. Median concentrations were highest in *C. gigas*, intermediate in *C. fluminea*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea*, at Grizzly Bay (BF20) in the dry season. Implicit tissue guidelines embedded in the proposed California Toxics Rule only exist for selected PAH compounds.

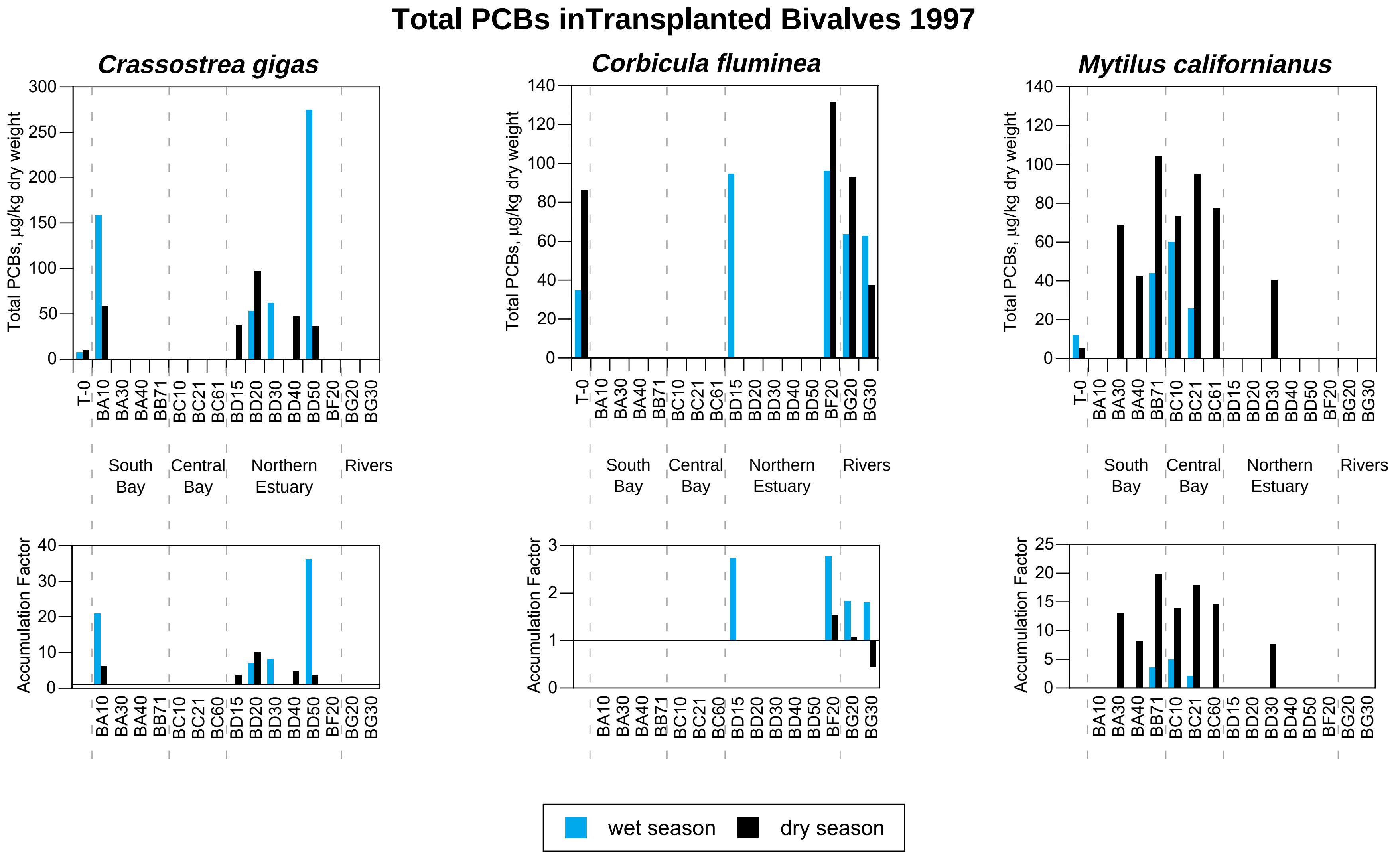


Figure 5.13. Total PCB concentrations in parts per billion dry weight (ppb) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.4 (depuration) to 36.2. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus*, and lowest in *C. gigas*. The highest measured concentration was in *C. gigas*, at Napa River (BD50) in the wet season. All samples, including reference samples, had total PCB concentrations exceeding the proposed California Toxics Rule's implicit tissue guideline of 1.4 ppb (total Aroclors).

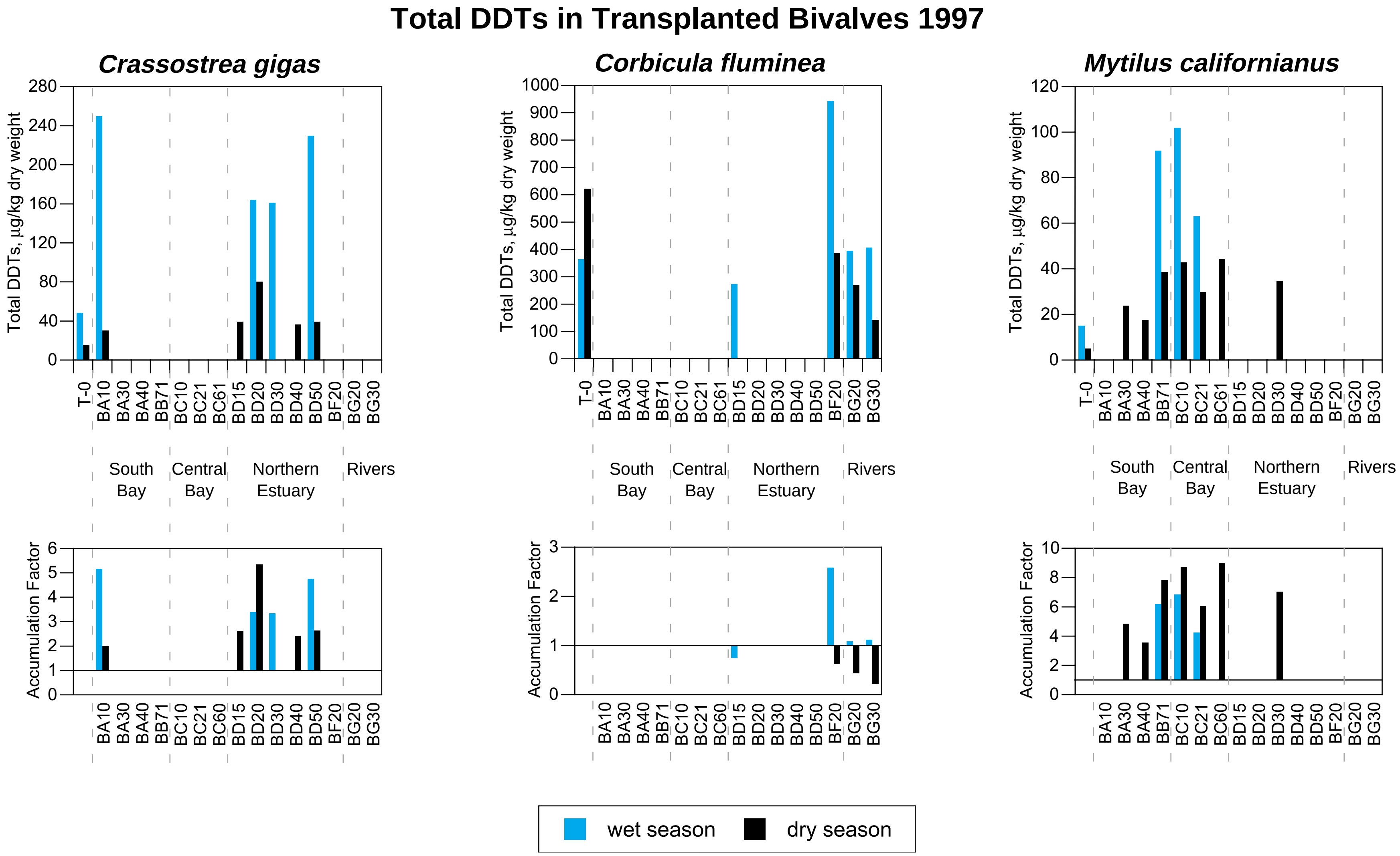


Figure 5.14. Total DDT concentrations in parts per billion dry weight (ppb) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.2 (depuration) to 9.0. Median concentrations were highest in *C. fluminea*, intermediate in *C. gigas*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea*, at Grizzly Bay (BF20) in the wet season. Sixteen samples, including three reference samples, exceeded the proposed California Toxics Rule's (CTR) implicit tissue guideline for p,p'-DDT of 3.16 ppb. All samples, including reference samples, exceeded the tissue guideline for p,p'-DDE of 3.16 ppb. Seven samples, including one reference sample, exceeded tissue guideline for p,p'-DDD of 44.9 ppb (see Table 21, *Appendix C*).

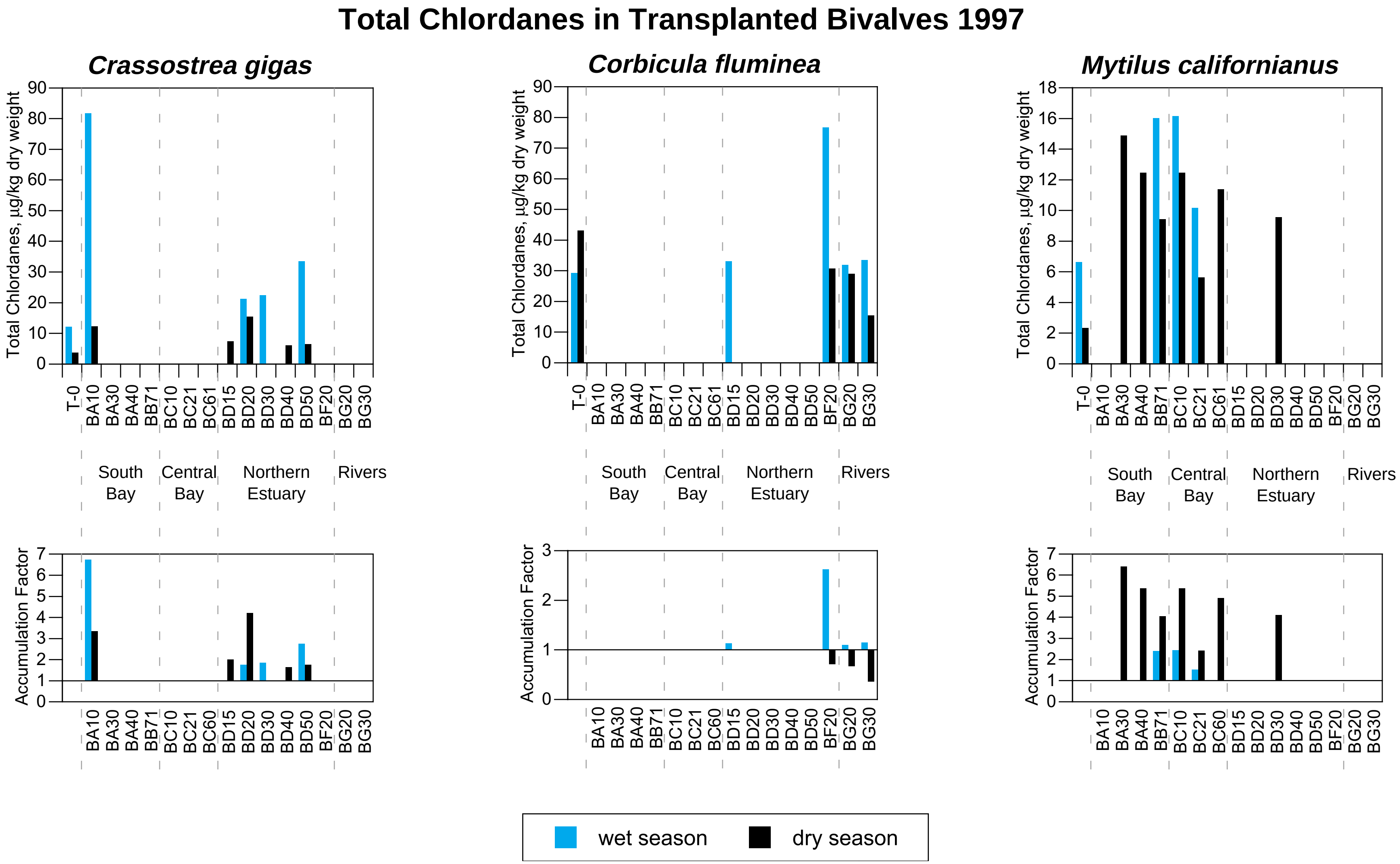


Figure 5.15. Total chlordane concentrations in parts per billion dry weight (ppb) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.4 (depuration) to 6.7. Median concentrations were highest in *C. fluminea*, intermediate in *C. gigas*, and lowest in *M. californianus*. The highest measured concentration was in *C. gigas*, at Coyote Creek (BA10) in the wet season. Twenty-five samples, including three of the reference samples, had chlordane concentrations exceeding the proposed California Toxics Rule's implicit tissue guideline of 8.3 ppb.

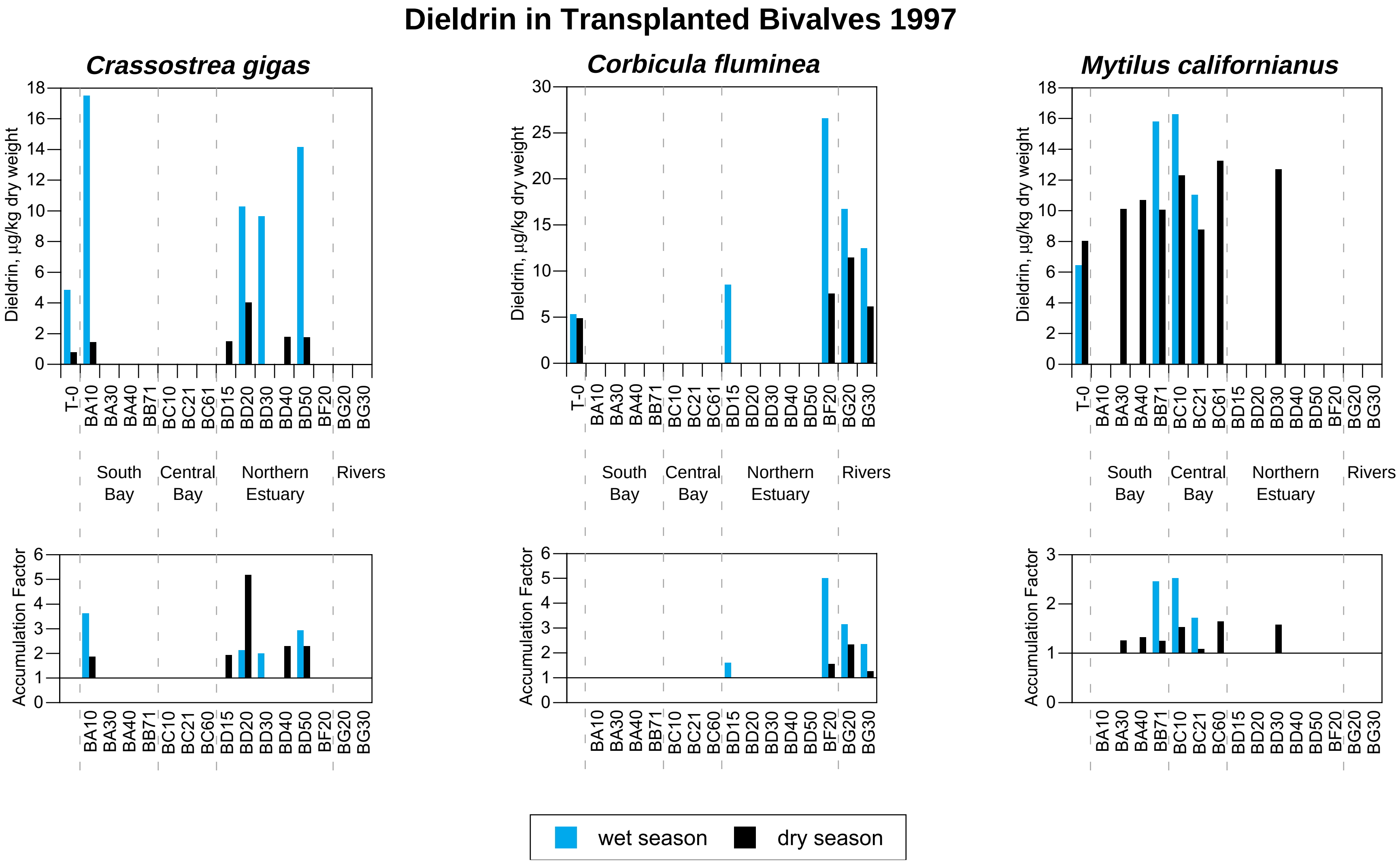


Figure 5.16. Dieldrin concentrations in parts per billion dry weight (ppb) in three transplanted bivalve species at 15 RMP stations during the wet- and dry-season sampling periods. There were no samples for Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) in the wet season due to zero percent species survival. Bivalves were not deployed at Davis Point (BD40) in the wet season. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.1 to 5.2. Median concentrations were highest in *M. californianus*, intermediate in *C. fluminea*, and lowest in *C. gigas*. The highest measured concentration was in *C. fluminea*, at Grizzly Bay (BF20) in the wet season. All samples, including the reference samples, had dieldrin concentrations exceeding the proposed California Toxics Rule's implicit tissue guideline of 0.67 ppb.

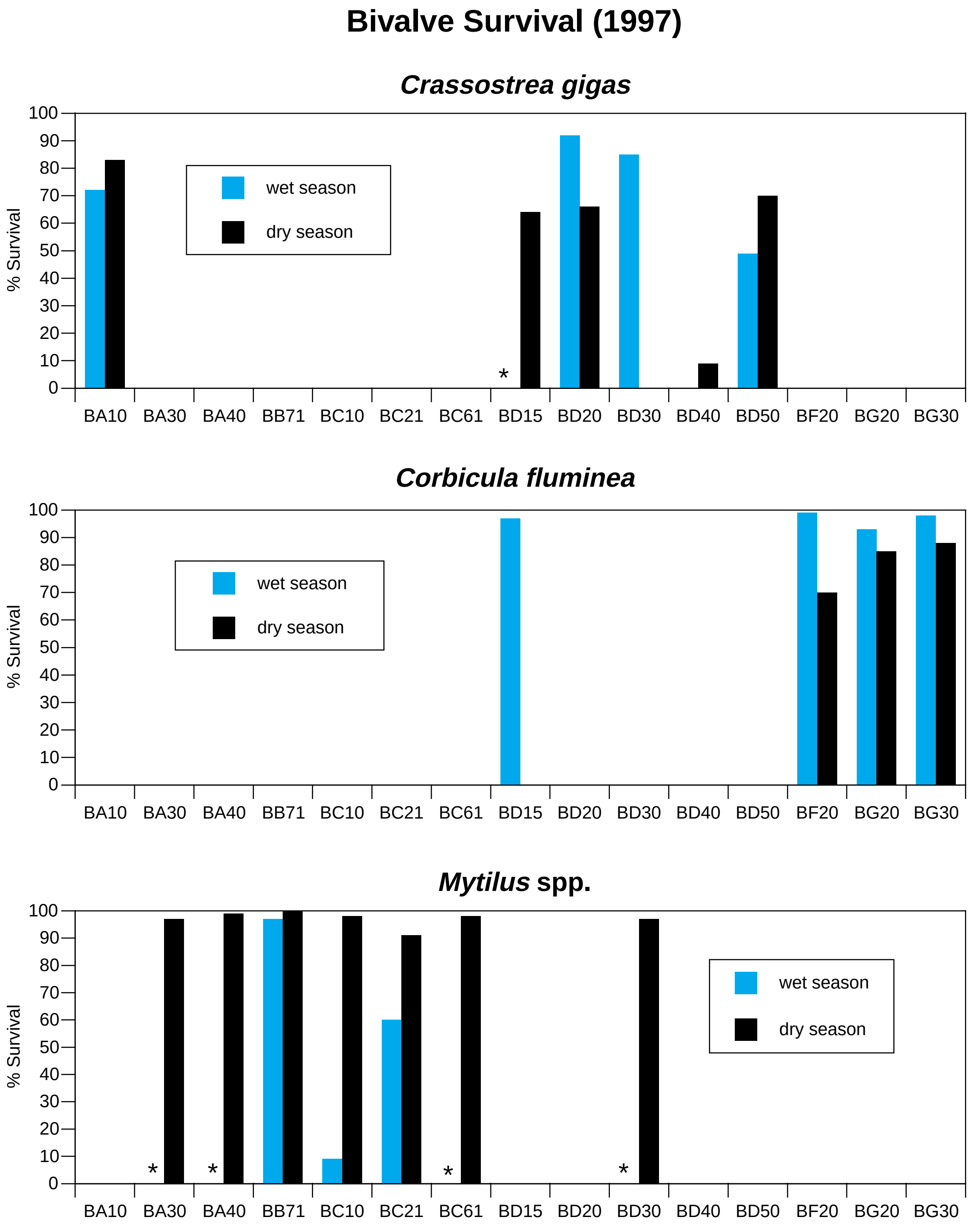


Figure 5.17. Percent survival of transplanted bivalves following exposure to Estuary conditions during the wet (May) and dry season (September) of 1997. * indicates 0% survival.

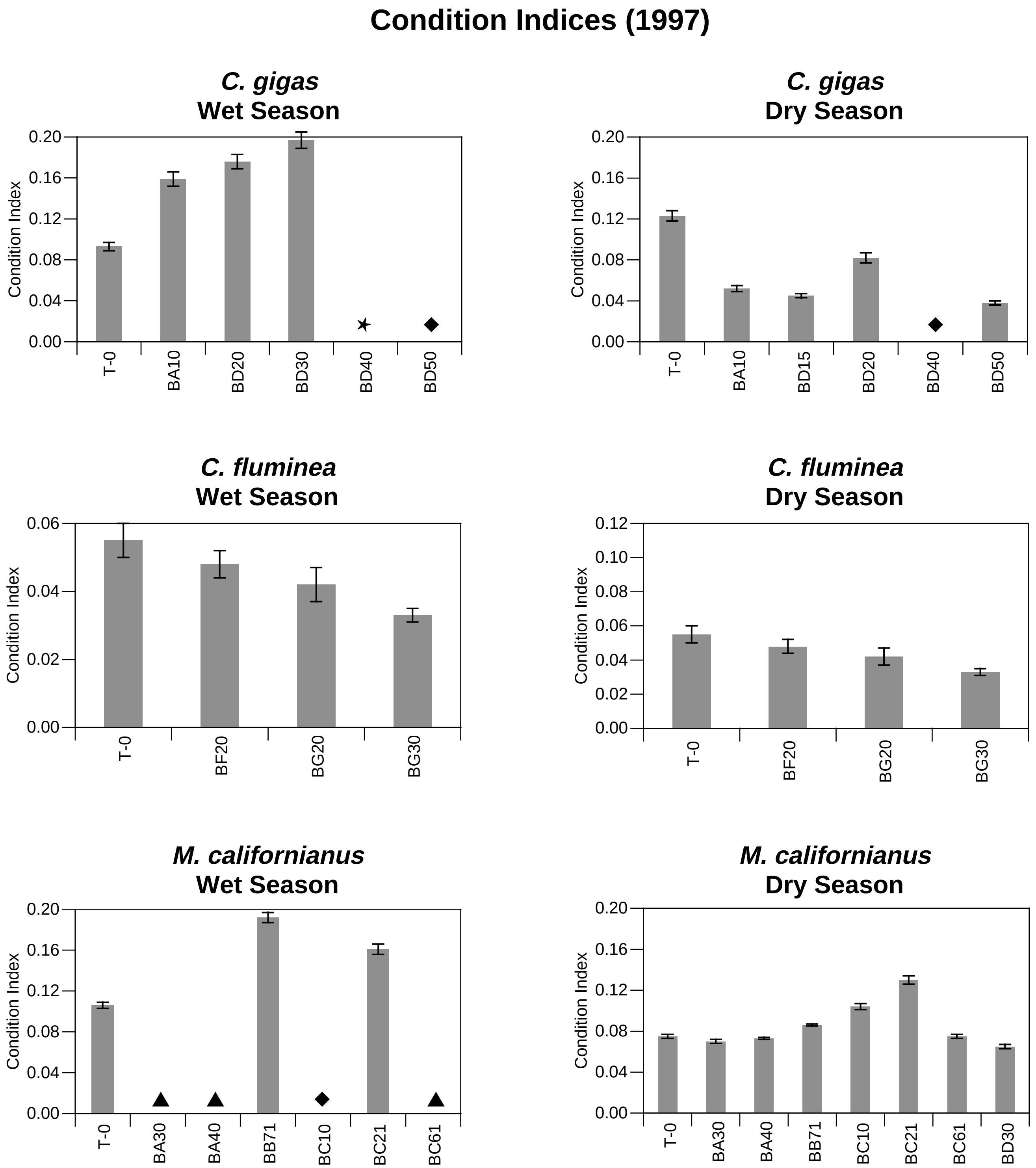


Figure 5.18. Condition indices of three species of bivalves at their original "reference" locations, prior to deployment (T-0), and at the end of their exposure to San Francisco Estuary waters (various locations) during the wet and dry seasons of 1997. Bivalves deployed at the Dumbarton Bridge (BA30), Redwood Creek (BA40), and Red Rock (BC61) stations during the wet season did not survive (indicated by ▲). Bivalves were not deployed at the Davis Point (BD50) station in the wet season (indicated by ✶). Surviving bivalves retrieved from the Napa River (BD50) and Yerba Buena Island (BC10) stations during the wet season and the Davis Point (BD40) station during the dry season were allocated to trace elements and organics analyses (indicated by ◆). Bars indicate range of values.

Bivalve Monitoring Trends

Transplanted bivalves are valuable in assessment of long-term trends because they provide an integrated measure of contamination over a three month period. This interval is more appropriate for assessment of interannual trends than the one-hour interval represented by RMP water samples or the approximate 20 year interval represented by RMP sediment samples.

This section presents plots of RMP bivalve bioaccumulation data for trace elements and trace organics from 1993 to 1997 (Figures 5.19 and 5.20). Concentrations in these plots are expressed as net bioaccumulation or depuration during the deployment period (initial concentrations prior to deployment have been subtracted from final concentrations measured after deployment). Presented in this manner, the plots are capable of showing the presence or absence of both trends and accumulation during deployment. In many cases (e.g., arsenic) there was either little accumulation or even net depuration during deployment. Mercury in clams has exhibited a consistent seasonal pattern, with higher concentrations in summer samples in all five years. The trace metals database accumulated so far is fairly noisy, and clear trends are not expected to be discernible for the near future.

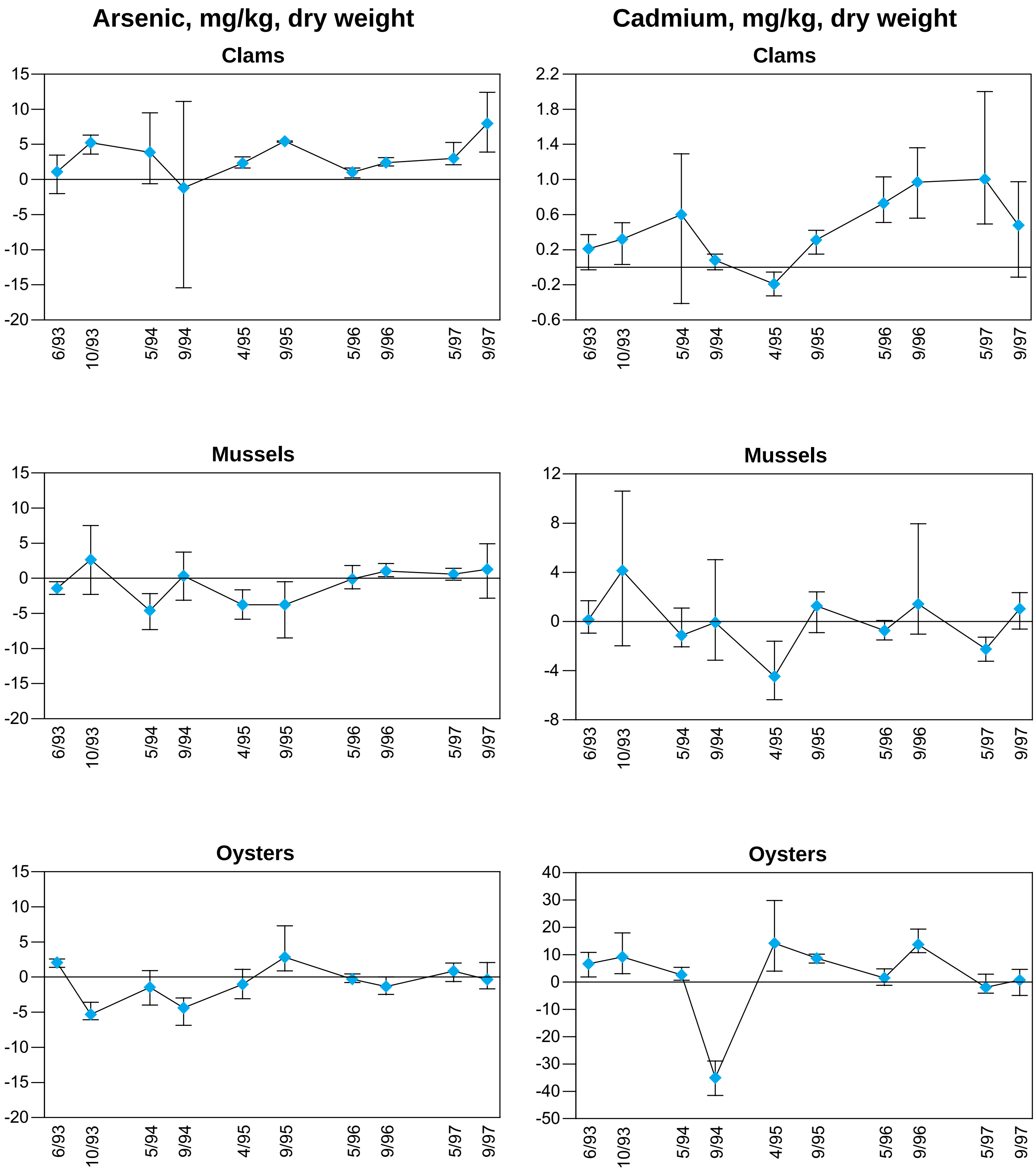


Figure 5.19. Trace element accumulation or depuration in parts per million dry weight (ppm) in three transplanted bivalve species for ten sampling periods from 1993–1997. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales.

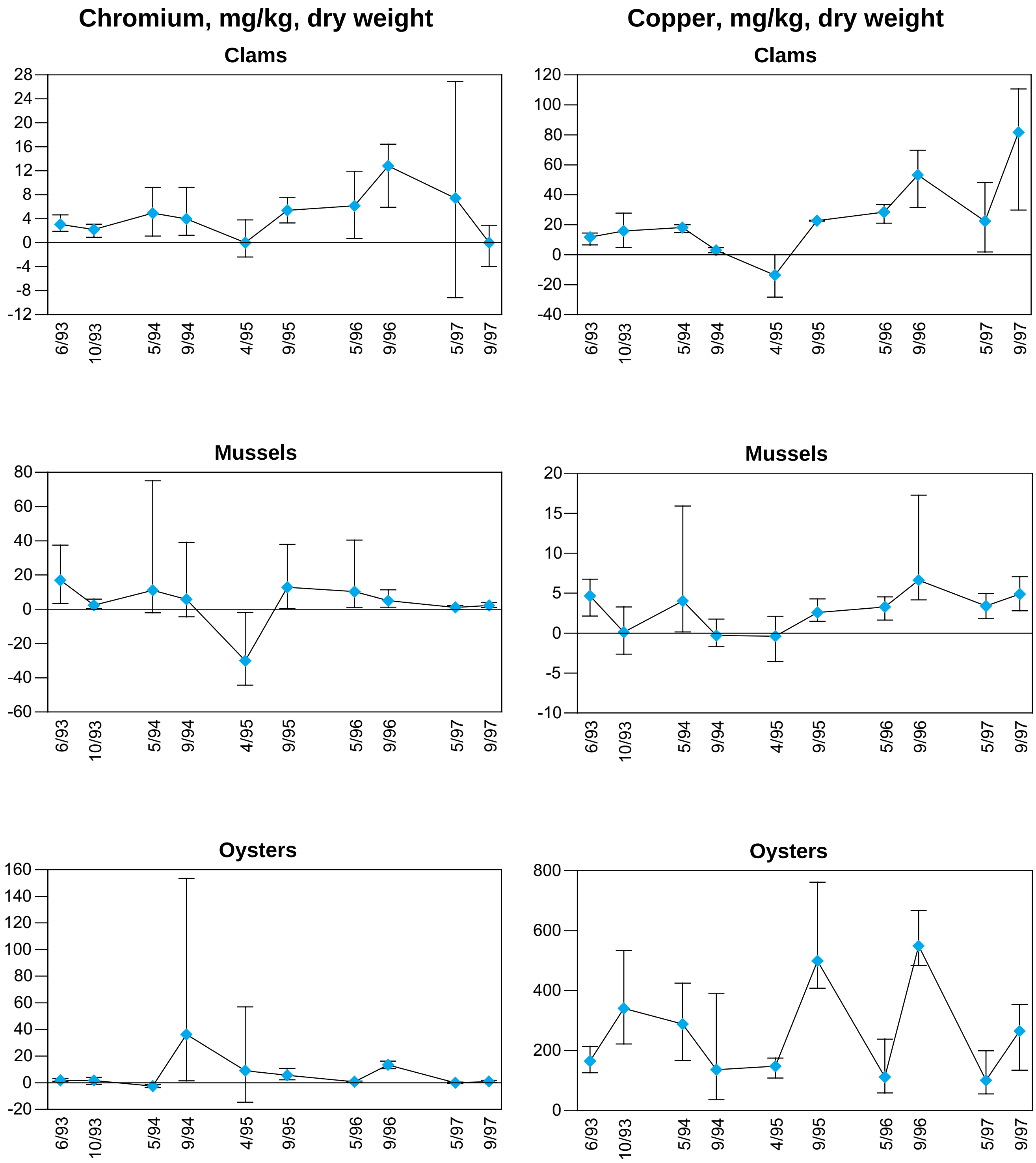


Figure 5.19 (continued). Trace element accumulation or depuration in parts per million dry weight (ppm) in three transplanted bivalve species for ten sampling periods from 1993–1997. Note different y-axis scales.

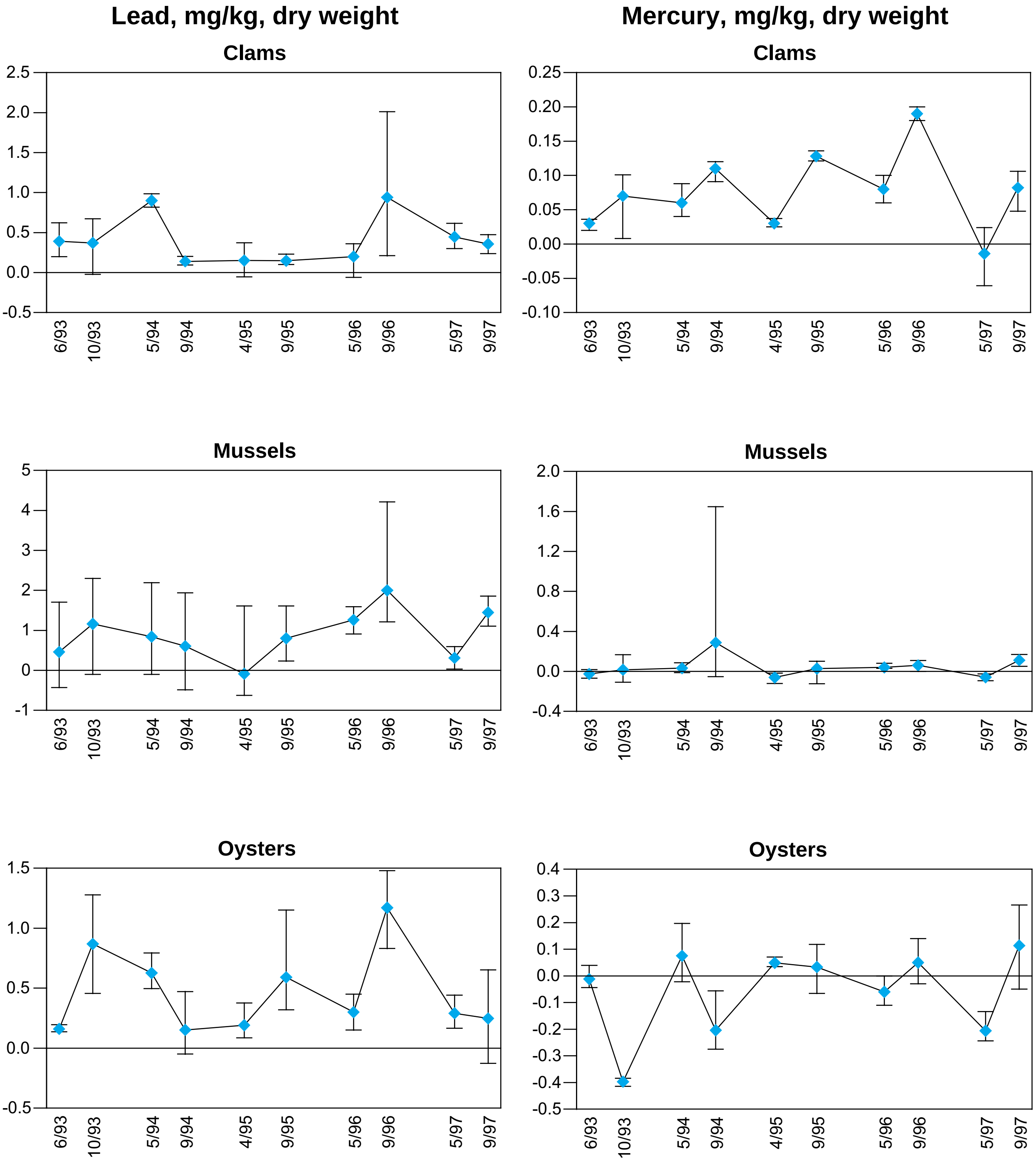
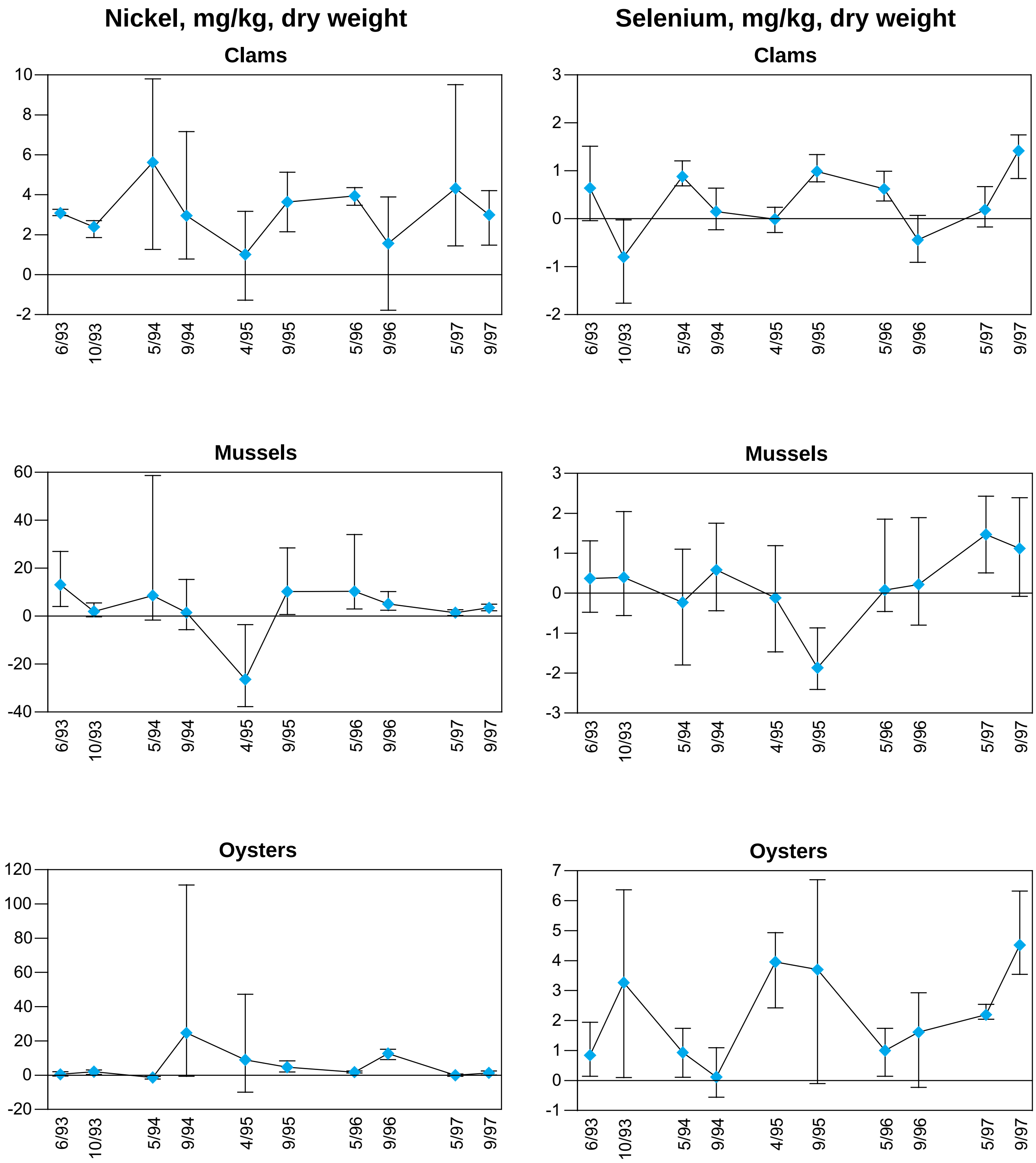


Figure 5.19 (continued). Trace element accumulation or depuration in parts per million dry weight (ppm) in three transplanted bivalve species for ten sampling periods from 1993–1997. Note different y-axis scales.



Nickel, mg/kg, dry weight

Selenium, mg/kg, dry weight

Clams

Mussels

Oysters

Figure 5.19 (continued). Trace element accumulation or depuration in parts per million dry weight (ppm) in three transplanted bivalve species for ten sampling periods from 1993–1997. Note different y-axis scales.

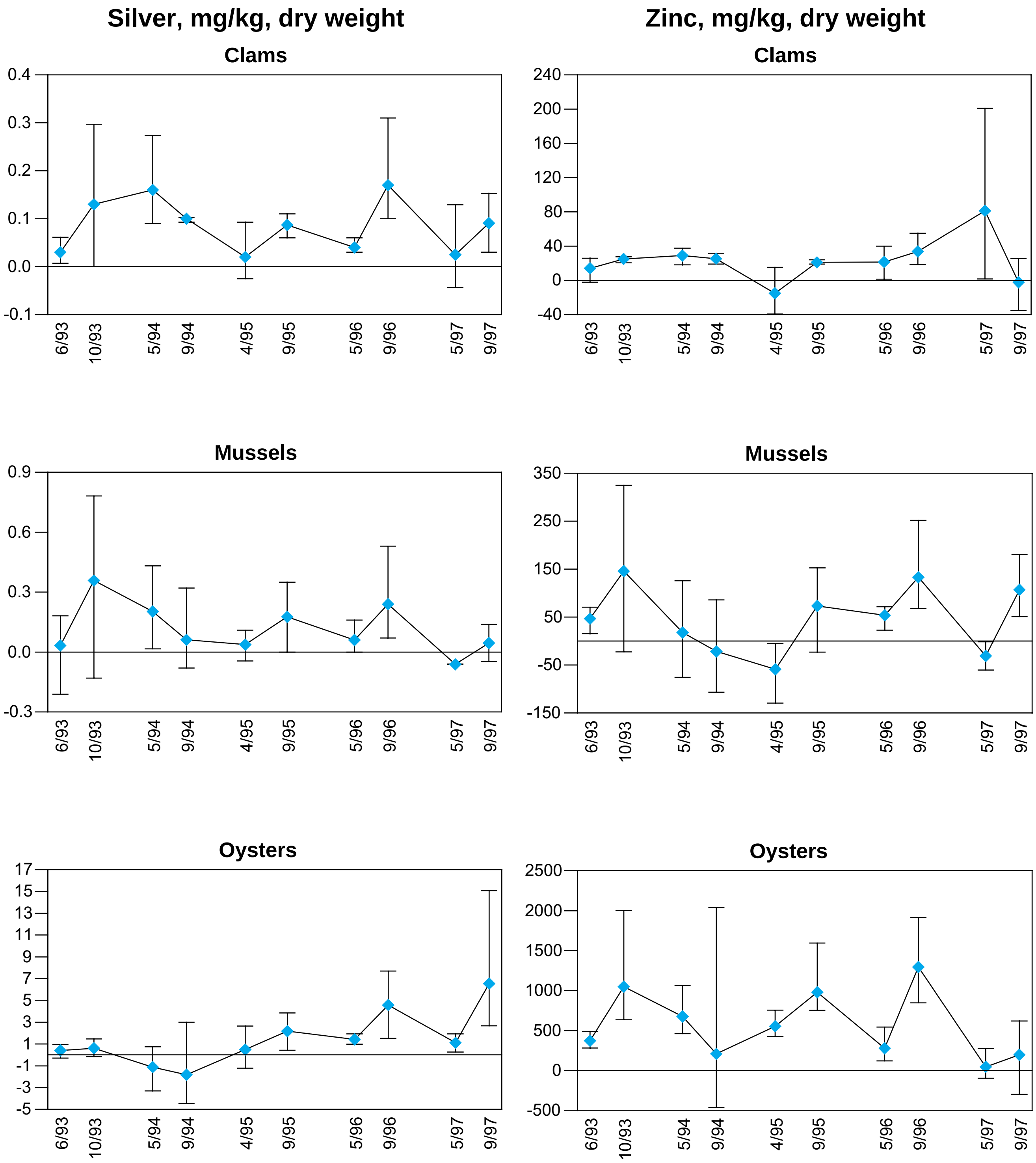


Figure 5.19 (continued). Trace element accumulation or depuration in parts per million dry weight (ppm) in three transplanted bivalve species for ten sampling periods from 1993–1997. Note different y-axis scales.

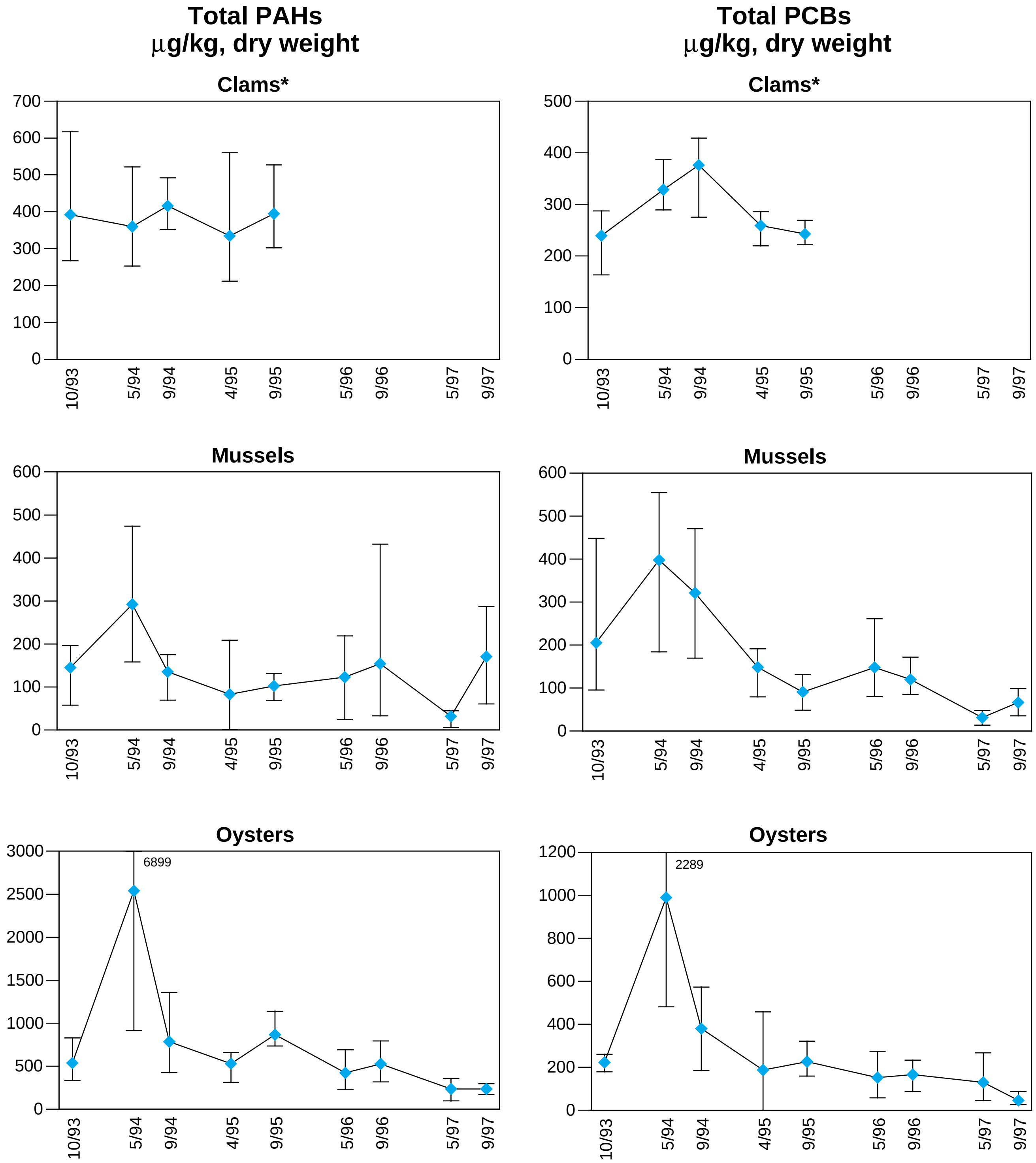


Figure 5.20. Trace organic accumulation or depuration in parts per billion dry weight (ppb) in three species of transplanted bivalves for nine sampling periods from 1993–1997 (mean of all stations). Accumulation or depuration was calculated by subtracting initial tissue (T-0) concentrations from concentrations after deployment. Bars indicate range of values within a sampling period. * In 1996, the reference population of "clean" *Corbicula fluminea* at Lake Isabella crashed and disappeared. Despite exploring several other potential reference sites, field staff was unable to find sufficiently large populations suitable for transplantation into the Estuary. Beginning with the 1996 data, *C. fluminea* bioaccumulation could no longer be compared with previous years due to the initial high concentrations of some contaminants, particularly trace organics, which biases bioaccumulation estimates toward the low end. Note different y-axis scales.

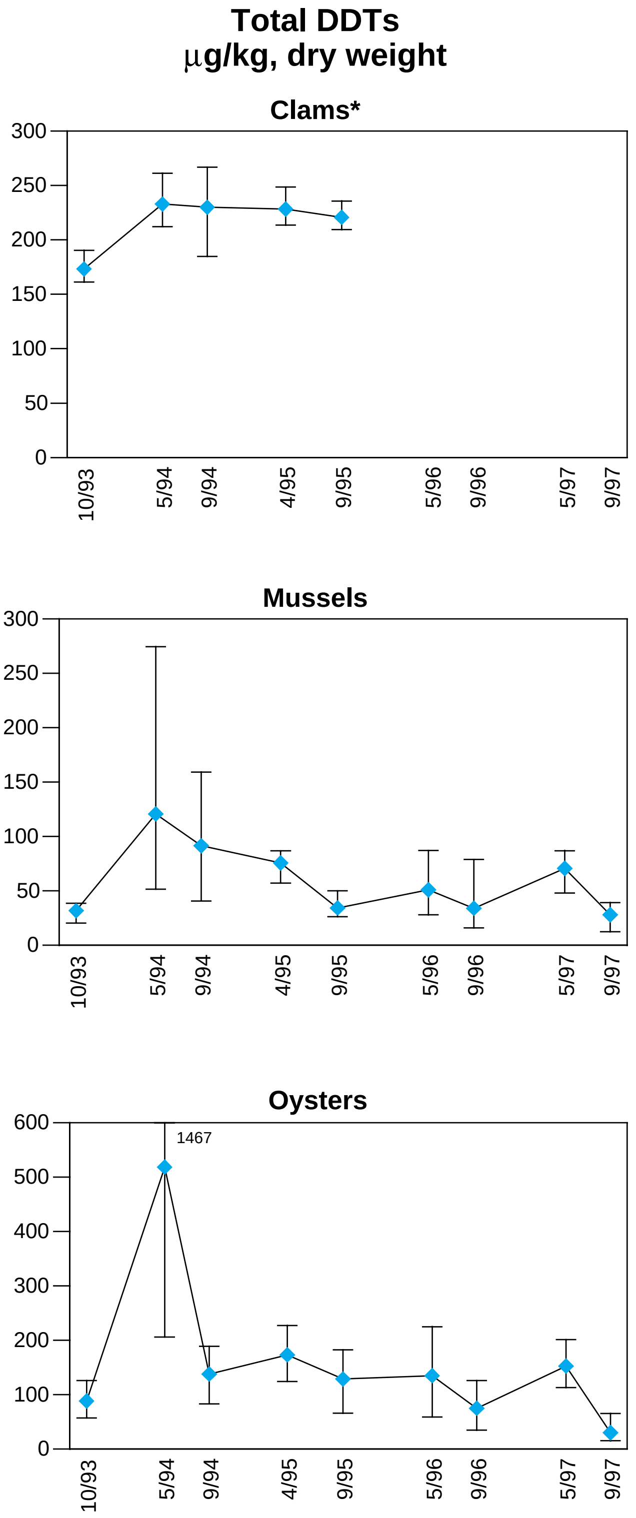


Figure 5.20 (continued). Trace organic accumulation or depuration in parts per billion dry weight (ppb) in three species of transplanted bivalves for nine sampling periods from 1993–1997 (mean of all stations). Note different y-axis scales.

A Review of Monitoring with Bivalves: Charting a Course for the Future

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Introduction

Following five years of RMP bioaccumulation monitoring, we determined that a more in-depth analysis of the database might enable us to assess how well this monitoring component met its original goals, and how it might evolve in the next few years to meet the new RMP objectives and help answer relevant management questions (see *Chapter 2: Review Implementation*). The purpose of this article is to continue synthesis of the growing bioaccumulation database in order to stimulate discussion for design improvements, including those related to monitoring contaminant effects (a new RMP objective). In 1998, the Steering Committee decided to modify the monitoring objectives to include a description of general sources and loadings of contamination to the Estuary and measurements of contaminant effects on selected parts of the Estuary ecosystem.

The initial goals of the RMP bivalve monitoring component were to:

1. Measure the bioavailable portion of contaminants in the water column.
2. Evaluate which contaminants may be transferred to higher trophic levels of the food web, and thus to what extent certain contaminants may pose health risks to wildlife and humans.

These general goals implicitly address the overall original RMP objectives of determining seasonal and long-term trends in chemical and biological water quality. Unlike the "snapshot" in time of contamination obtained from water sampling three times each year, the bioaccumulation component provides an integrative measure of water contamination, since exposure to varying concentrations during the three-month deployment is reflected in their tissues. Also, measuring dissolved and total/near-total contaminant concentrations in water and sediment alone does not reveal how likely it is for various contaminants to enter the food web and pose risks to higher-order consumers. Bivalves are very good trend indicators for many contaminants, particularly lipophilic compounds such as chlorinated hydrocarbons and PAHs, because their contaminant body burdens equilibrate with corresponding contaminants in the surrounding environment relatively quickly (Russell and Gobas, 1989; Stephenson, 1992). However, not all contaminants are bioaccumulated in the same way by bivalves, and bivalve species differ in their bioaccumulation characteristics. Overall, oysters accumulate trace metals to a greater degree than mussels and clams, while mussels accumulate PCBs to higher concentrations than oysters and clams. We have also learned that bivalves are unsuitable indicators for mercury bioaccumulation, although we know that methylmercury is highly accumulative in other species and is rapidly magnified in the food web, as evidenced in fish tissue levels that are of human health concern (see *Chapter 6: Pilot and Special Studies*). Similarly, bivalves do not appear to bioaccumulate arsenic and are likely of limited use in determining bioavailability of this contaminant, for trend monitoring, or as a diagnostic tool for identifying potential problem areas.

Time series of raw trace substance concentrations in bivalves (not normalized for tissue lipid content) for the last ten sampling events starting in 1993 (with the exception of *Corbicula fluminea*) are depicted in Figures 5.19 and 5.20 in *Bivalve Monitoring Trends*. As with water and sediment concentration *trends*, numerous environmental variables influence bivalve concentrations. In most cases, the raw data essentially show no trends, and the *noise* surrounding the *signal* of interest (tissue concentrations over time) is so large that any changes over time or spatial patterns require many years of measurements before any definitive conclusions can be drawn.

Gunther *et al*. (in press) and Gunther and Davis (1997) analyzed bivalve data by combining the databases of the RMP and the State Mussel Watch Program, thus increasing the size of the data set. They found statistically significant declines in silver in both Central and South Bay reaches, and less pronounced declines in mercury and lead concentrations. They also demonstrated that lipid normalization of chlorinated hydrocarbon concentrations in bivalves reveals patterns that otherwise may not be apparent. The combined databases normalized to tissue lipid content show dramatic initial declines in concentrations of chlorinated hydrocarbons, such as PCBs and DDTs after use restrictions were implemented. When 1997 data are added to the trend lines at Coyote Creek (BA10), Yerba Buena Island (BC10), and San Pablo Bay (BD20), unnormalized bivalve PCB concentrations show consistent declines at all stations between 1994 and 1997, but lipid-normalized PCB concentrations indicate a decline only at Yerba Buena Island (Figure 5.21). We have expanded this type of analysis to explore how water quality parameters, such as temperature, salinity, dissolved oxygen, suspended sediment, and chlorophyll *a* concentrations, might affect tissue concentrations and bivalve condition.

Bivalves as Tools for Meeting New RMP Objectives

As part of designing the RMP so it can answer the management questions formulated in 1998 (see *Chapter 2: Review Implementation*), we examined the possible role of biomonitoring with bivalves in meeting the new RMP objectives and answering some of the management questions. Bivalve measurements can serve more purposes than this RMP element was originally designed for. They have the potential or have been shown to contribute to the following assessments:

1. Bivalve tissue concentrations are probably the most suitable indicator *for long-term trends* of many contaminants in the Estuary.
2. Bivalves are suitable as a *diagnostic tool* for problem identification and prioritization of follow-up action, and for the identification of most bioaccumulative substances.
3. Studies by the U.S. Geological Survey and others (Luoma and Linville, 1996; Salazar and Salazar, 1995, 1998) have shown the potential of bivalves as *indicators of pollutant effects*.
4. Bivalve tissue concentrations can represent a “substitute” or *enhancement of water measurements*, since they integrate water concentrations over long periods of time.
5. They represent a tool to *estimate contaminant transfer to higher trophic levels* to be used by others for ecosystem risk assessments.
6. Bivalves can serve as a tool for prioritizing problem watersheds or sites that may contribute contaminants of concern to the Estuary (*pollutant source/pathway indicator*).

If the potential of bivalves in meeting these goals is to be recognized and evaluated for incorporation into the new RMP design, the kinds of analyses summarized in this article are a necessary first step.

Data Analysis

The analyses described in this article proceeded in three phases. First, we determined what quantitative relationships exist between bivalve data (i.e., trace substance concentrations and indicators of bivalve health) and key environmental factors. These quantitative relationships were then used to statistically adjust the bivalve data to remove the suggested effects of these environmental factors. This enabled us to determine the magnitude of the noise surrounding the signal that the environmental factors are likely to contribute. Second, we examined in more detail whether there were statistically significant spatial and temporal

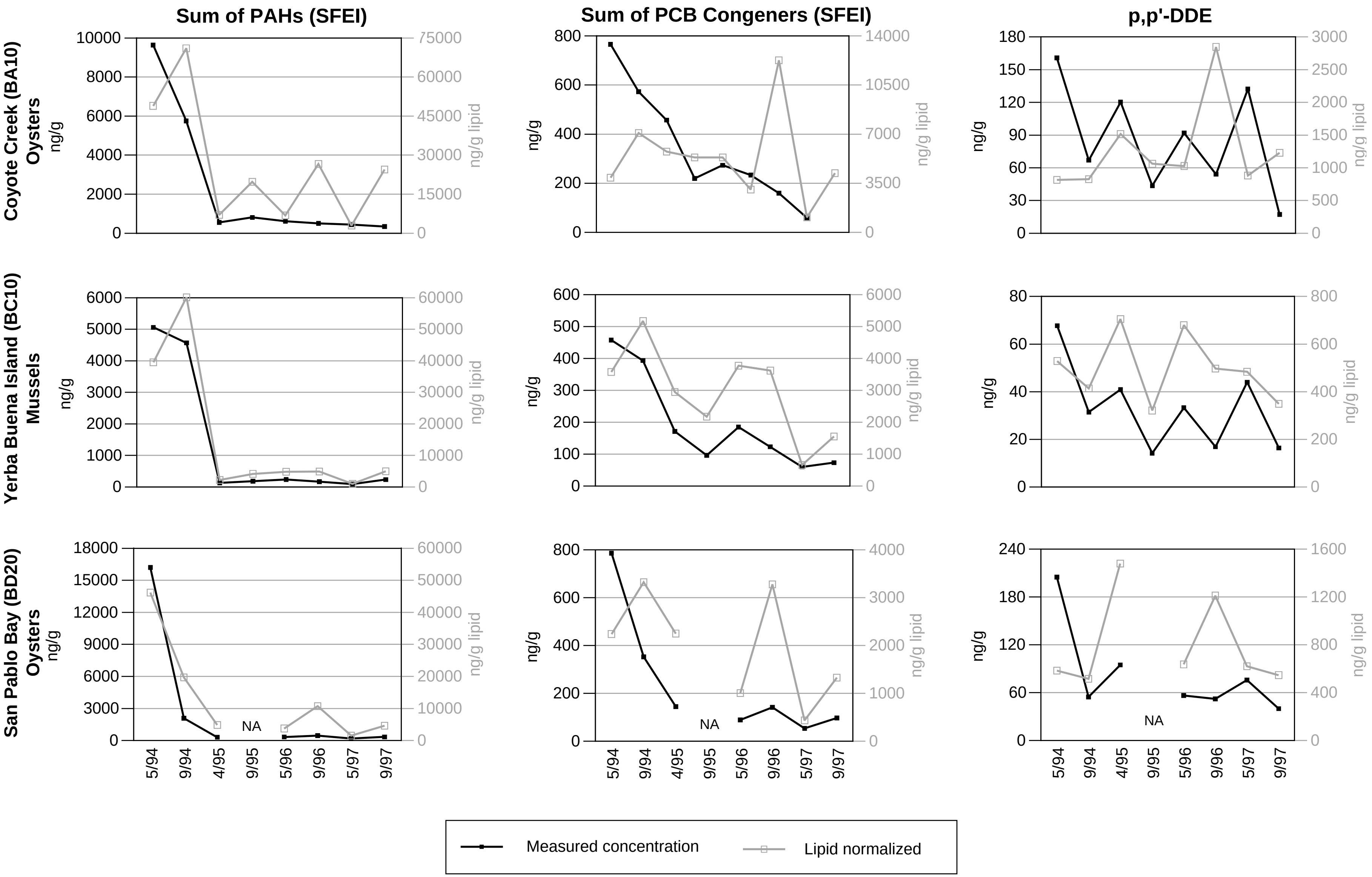

Figure 5.21. Trace organic trends at three RMP Base Program stations. Please note differences in y-axes within graphs. NA = not analyzed.

trends where the same species was deployed and whether these trends were affected by adjusting the bivalve data for the suggested effects of the environmental factors. This analysis was performed to determine whether there were significant trends and whether the trends were more or less apparent after the data had been adjusted. Third, we compared bivalve concentrations of trace substances, with and without adjustment for the suggested effects of environmental factors, with water concentrations in the particulate and dissolved fractions. The purpose of this analysis was to demonstrate the value that bivalve measurements add to the RMP, and to determine whether adjustment of bivalve data improved this value.

The initial step was to determine whether bivalve measurements may be affected by natural water quality parameters in ways that confound our ability to describe spatial and temporal trends in bioavailable contaminants. The influence of various water quality parameters on invertebrate bioaccumulation has been demonstrated in numerous studies (Absil *et al*., 1994; Hutchins *et al*., 1996; Luoma and Bryan, 1982; Magni, 1993; Wang *et al*., 1995; Wright and Zamuda, 1987). Although the bivalve bioaccumulation method has been used worldwide to determine spatial and temporal variation in contaminants, RMP data and other studies have shown that the San Francisco Estuary provides unique challenges because of the very high spatial and temporal variation in natural water quality parameters.

Statistical analyses were performed to determine whether chlorophyll, dissolved oxygen, salinity, temperature, and total suspended solids might be affecting the bivalves and their accumulation of trace substances. U.S. Geological Survey (USGS) water quality data, collected as part of the RMP base program and supported by both RMP and Department of Interior funds, are recorded on approximately monthly intervals (http://sfbay.wr.usgs.gov/access/wqdata/archive). We obtained these data for stations near seven RMP bivalve sites (Figure 5.22). The USGS data from the three 1-m intervals that bracketed our bivalve deployment depths were averaged across all the USGS cruises that occurred during each bivalve deployment period to estimate the conditions experienced by the bivalves for that site and deployment.

The potential effects of water quality parameters on bivalves were examined for four indicators of bivalve health (condition, tissue growth, percent tissue lipid, and survival) and the tissue concentrations of trace metals and selected organic contaminants (totals for PAHs, PCBs, DDTs, chlordanes, and HCHs). It should be noted that, based on initial analysis by Gunther and Davis (1997), all trace organic contaminants were normalized to lipid concentrations prior to these analyses. Oysters (*Crassostrea gigas*) were examined at Coyote Creek and Davis Point; mussels (*Mytilus californianus*) were examined at Redwood Creek, Alameda, Red Rock, and Pinole Point; and clams (*Corbicula fluminea*) were examined at Sacramento River (Figure 5.22).

The statistical procedures involved backward stepwise regressions using the water quality parameters as independent variables and the bivalve parameters as dependent variables. These procedures enable determination of which independent variables account for most of the variation in each dependent variable. The backward stepwise procedure initially begins with all of the independent variables included in the analysis, and the variables that account for the least variation are successively removed at each step until the remaining independent variable(s) account for most of the remaining variation in the dependent variable. The resulting regression coefficient approximates the percentage of the variation in the dependent variable that is due to the independent variables. The probability (P) indicates whether the resulting regression line for the relationship between the independent and dependent variables is statistically significantly different from zero (i.e., $P < 0.05$ is significantly different from zero). Because data were occasionally missing for some water quality parameters, whenever the stepwise procedures found a slope significantly different from zero, multiple regression was performed using only the important independent variables. The residuals from the multiple regressions (i.e., the distance of each data

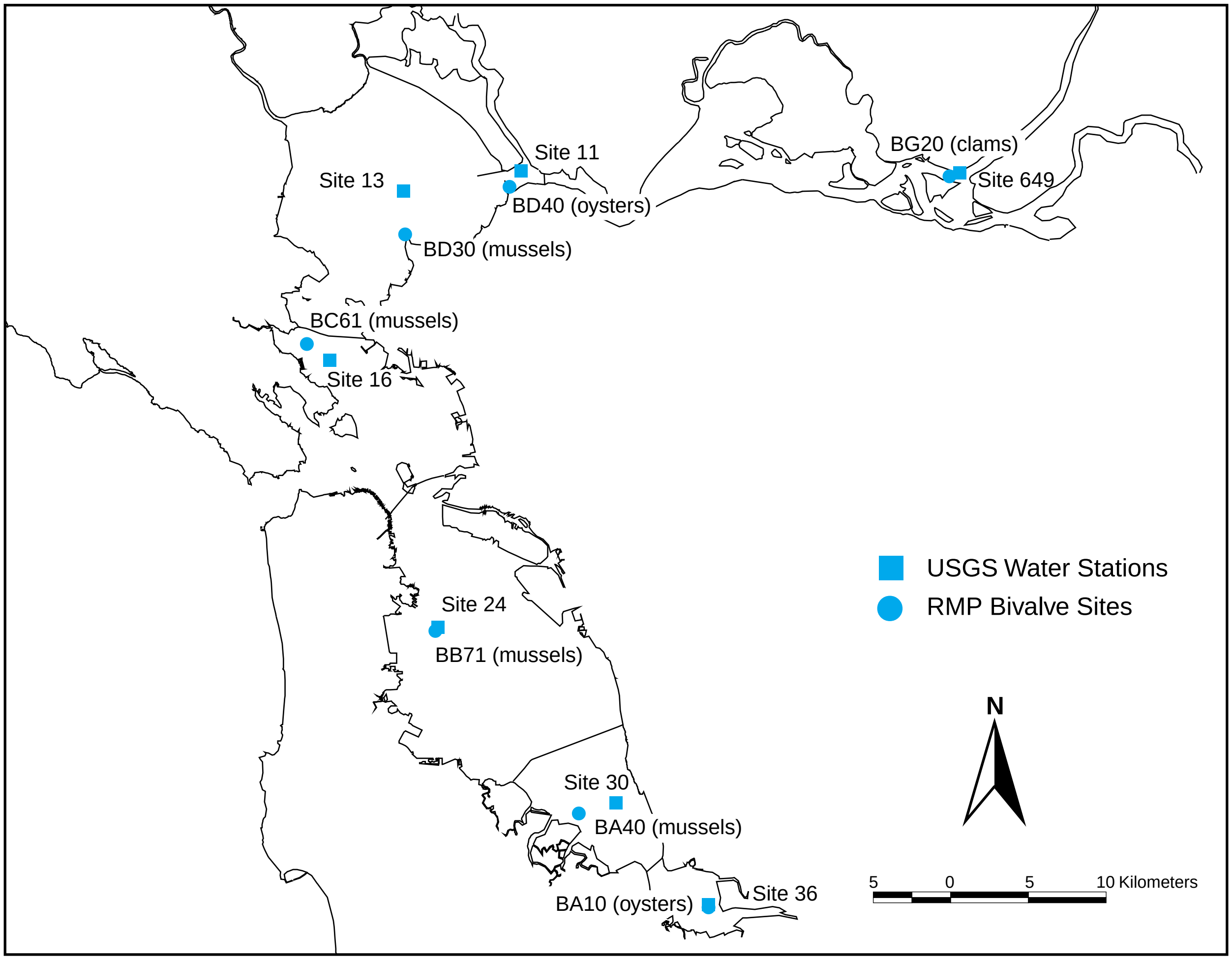

Figure 5.22. Site map of water quality and tissue monitoring sites.

point from the regression line) were used to correct the dependent variables (i.e., bivalve data) for the effects of the water quality parameters using the method of Hebert and Keenleyside (1995).

Following the application of any appropriate corrections to the bivalve measurements, we examined in more detail bivalve concentrations of copper, mercury, PAHs, and determined whether spatial and temporal trends were statistically significant. These four trace substances were selected because of their regulatory importance. Regressions of bivalve contaminant concentrations against time were tested to determine whether temporal trends were significant and whether trends differed among sites. Analyses of variance (ANOVA) were performed for the aggregate of all sites within each bivalve species to determine whether overall differences among years were significant. ANOVA was also performed to determine whether sites with the same species differed.

Caution must be used when interpreting the results of the regression analyses. Regression analyses assume the independent variables (i.e., chlorophyll, dissolved oxygen, salinity, temperature, total suspended solids, and time) affect the dependent variables (i.e., bivalve health and trace substance concentrations). While we have used the regression analyses to establish whether there are systematic relationships or correlations between the independent and dependent variables, true cause and effect relationships can only be confirmed through experimentation. Regression analyses were more advantageous for our purposes than calculations of simple correlations because the resulting regression equations provide the means to adjust the bivalve data for the suggested effects of environmental factors.

Effects of Water Quality Parameters on Bioaccumulation

Numerous bivalve measurements are significantly related to chlorophyll, dissolved oxygen, salinity, temperature, and total suspended solids (Tables 1, 2, and 3 in *Appendix E*). Thirteen out of 18 bivalve measurements were significantly related to these water quality parameters for *Mytilus californianus* (Table 1 in *Appendix E*), 11 out of 18 were significantly related for *Crassostrea gigas* (Table 2 in *Appendix E*), and five out of 18 were significantly related for *Corbicula fluminea* (Table 3 in *Appendix E*). This finding in and of itself is not surprising and was expected.

Mussels

Health and Survival

Condition, tissue growth, percent lipid, and survival of *M. californianus* were all significantly positively related to various combinations of chlorophyll, dissolved oxygen, and salinity. The suggested effects of dissolved oxygen on condition, tissue growth, and percent lipid are consistent with the super-saturated dissolved oxygen concentrations prevalent in the surf zone where these bivalves naturally live. The sharp decline in survival below salinities of 18–20 parts per thousand (Figure 5.23) was fit best with a second-order polynomial regression. This relationship between survival and salinity is also consistent with the open coast habitat of this species.

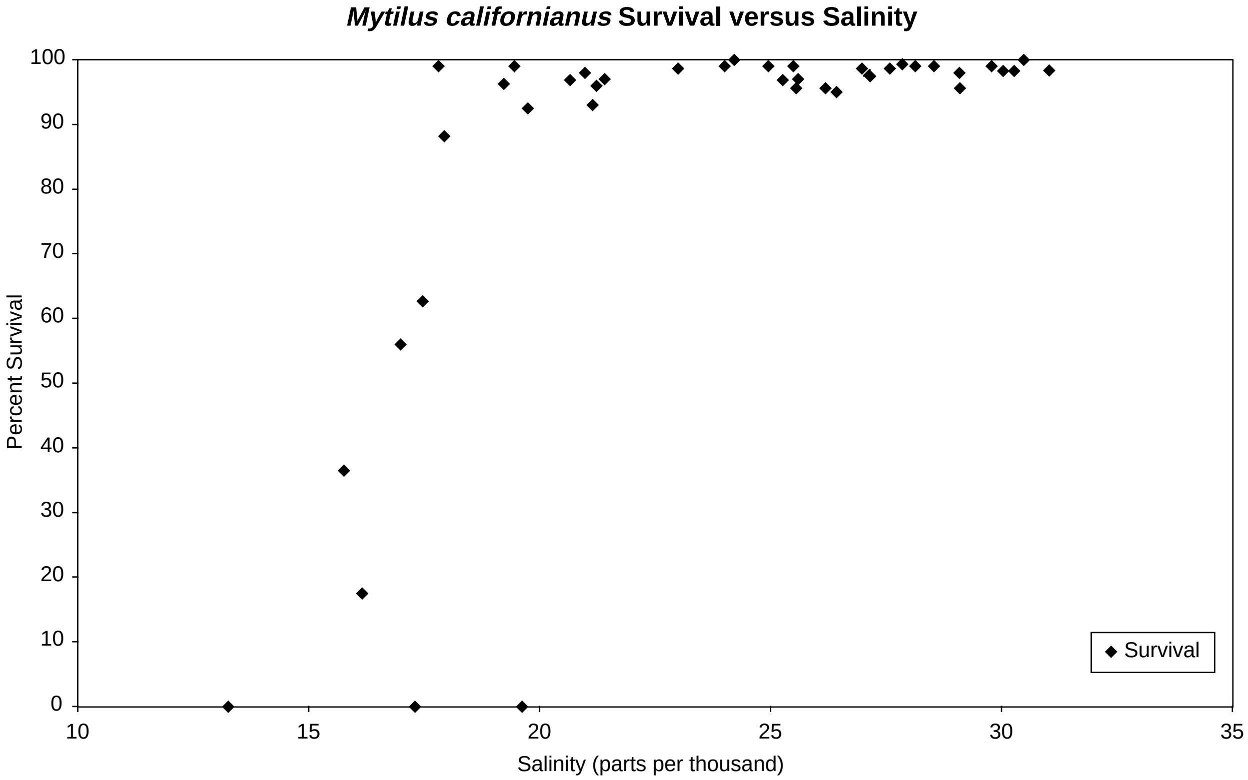

Figure 5.23. Survival in mussels versus salinity. Data are from 1993 to 1997.

Bioaccumulation

All the water quality parameters, either singly or in combination, were significantly related to bioaccumulation of silver, cadmium, lead, nickel, zinc, PAHs, PCBs, chlordanes, and HCHs. Only chlorophyll and temperature were consistent regarding the direction of their effects, with bioaccumulation of cadmium and zinc being negatively related to chlorophyll, and bioaccumulation of silver, lead, and zinc being positively related to temperature.

Oysters

Health and Survival

Condition and tissue growth were negatively related to temperature, with the negative relationship between survival and temperature also being nearly significant. Percent lipid was positively related to dissolved oxygen, salinity, and total suspended solids.

Bioaccumulation

All the water quality parameters, either singly or in combination, also were significantly related to bioaccumulation in oysters. Only dissolved oxygen and temperature were consistent in the direction of their suggested effects, with bioaccumulation of cadmium, PAHs, and PCBs being negatively related to dissolved oxygen, and bioaccumulation of chromium and lead being positively related to temperature.

Clams

Health and Survival

Condition and survival were negatively related to temperature and chlorophyll, respectively, while condition was positively related to salinity.

Bioaccumulation

Only three contaminants, silver, PCBs, and HCHs, were significantly related to water quality parameters, probably because of the low sample size related to using data from a single site. All three contaminants were negatively related to chlorophyll. Silver and HCHs were also negatively related to total suspended solids and temperature, respectively.

These findings confirm the common wisdom that water quality variables influence bivalve parameters, although this is the first time that RMP data were subjected to this kind of analysis. It is now possible to determine whether the adjustments to bivalve data for the suggested effects of water quality variables reveal spatial or temporal trends that are not apparent using unadjusted data. These analyses also reveal that some water quality parameters in the Estuary are outside optimum levels for the bivalves and may thus affect bioaccumulation. For example, dissolved oxygen concentrations in the Estuary seem to affect the “health” (as defined by tissue growth, condition, and percent lipid) of *Mytilus californianus*. This species also survived poorly where salinities averaged less than 20‰. Summer temperatures in the Estuary also may exceed those that are optimal for *Crassostrea gigas*. This is not to say that these bivalves are inappropriate for bioaccumulation monitoring in the Estuary, but that the ultimate data users need to be clear regarding the limitations of these indicators and the uncertainties surrounding the data. Although these transplanted bivalves experience environmental stress in the Estuary, resident bivalves may also experience stress at certain times of the year. Nevertheless, drawing conclusions about the absolute biomagnification potential of a trace substance based solely on transplanted bivalves may not be appropriate, and other bivalve species that are better adapted to Estuary conditions may be more suitable for contaminant transfer estimates.

Spatial and Temporal Trends and the Effects of Analyzing Adjusted Bivalve Data

Numerous spatial and temporal trends occurred for copper, mercury, PAHs, and PCBs in the three species of bivalves. If significant regressions were not found between tissue contaminant concentrations and the natural variables (Tables 1, 2, and 3 in *Appendix E*), trends are described for unadjusted data (i.e., measured concentrations of metals and lipid-normalized concentrations of organic contaminants). But, whenever possible, data are used that have been adjusted for the suggested effects of the natural variables.

Mussels

ANOVA results indicated relatively little spatial variation in the bioaccumulation of copper, mercury, PAHs, and PCBs (Table 5.1). Only PCBs indicated a significant difference (Table 5.1), with mussels deployed at Redwood Creek bioaccumulating greater amounts of PCBs than did mussels deployed at Pinole Point or Red Rock. This is in agreement with previous conclusions drawn from sediment and water data comparing Estuary reaches, with the South Bay exhibiting higher PCB concentrations than the Central Bay reach.

ANOVA results also indicated relatively little temporal variation in the bioaccumulation of copper, mercury, PAHs, and PCBs (Table 5.1). Tissue concentrations of copper were significantly greater in 1996 and 1997 than in 1993 and 1994, suggesting increases through time. Unadjusted PCBs were significantly lower in 1995 and 1997 than in 1994. There were no significant differences among years for mercury or PAHs.

Regression analyses using unadjusted data revealed that significant temporal trends were site-specific (Figures 5.24–5.27). The increase of copper through time was significant at Pinole Point and nearly significant at Redwood Creek, but not at Alameda or Red Rock. The very slight decline in mercury through time was nearly significant at Alameda, but not at any other site. Increases in PAH concentrations were nearly significant at Red Rock and Redwood Creek, but not at Alameda or Pinole Point. Decreases in PCB concentrations were nearly significant at Alameda and Redwood Creek, but the decreases at Red Rock and Pinole Point were much less pronounced and insignificant.

Adjustment of tissue concentrations of PAHs and PCBs for suggested effects of environmental variables provided contrasting results (Figures 5.28 and 5.29). In the case of PAHs, adjustment of

Table 5.1. ANOVAs for differences among sites and years in concentrations of four contaminants in mussels.

Contaminant	P	*a posteriori* results[a]
Among Sites		
Copper[b]	.8983	Red Rock Pinole Point Alameda Redwood Creek
Mercury[b]	.6059	Pinole Point Redwood Creek Red Rock Alameda
PAH[b]	.8769	Red Rock Alameda Redwood Creek Pinole Point
PAH[c]	.7814	Pinole Point Alameda Red Rock Redwood Creek
PCB[b]	.0531	Redwood Creek Alameda Red Rock Pinole Point
PCB[c]	.0348	Redwood Creek Alameda Pinole Point Red Rock
Among Years		
Copper[b]	.0011	1996 1997 1995 1994 1993
Mercury[b]	.1262	1994 1995 1993 1997 1996
PAH[b]	.0725	1997 1996 1995 1994
PAH[c]	.0693	1997 1996 1994 1995
PCB[b]	.0295	1994 1996 1995 1997
PCB[c]	.0213	1994 1995 1996 1997

[a] Sites and years are arranged with the highest mean on the left and the lowest mean on the right. Sites or years that are connected by a common line are not significantly different.

[b] Unadjusted data were tested.

[c] Adjusted data were tested.

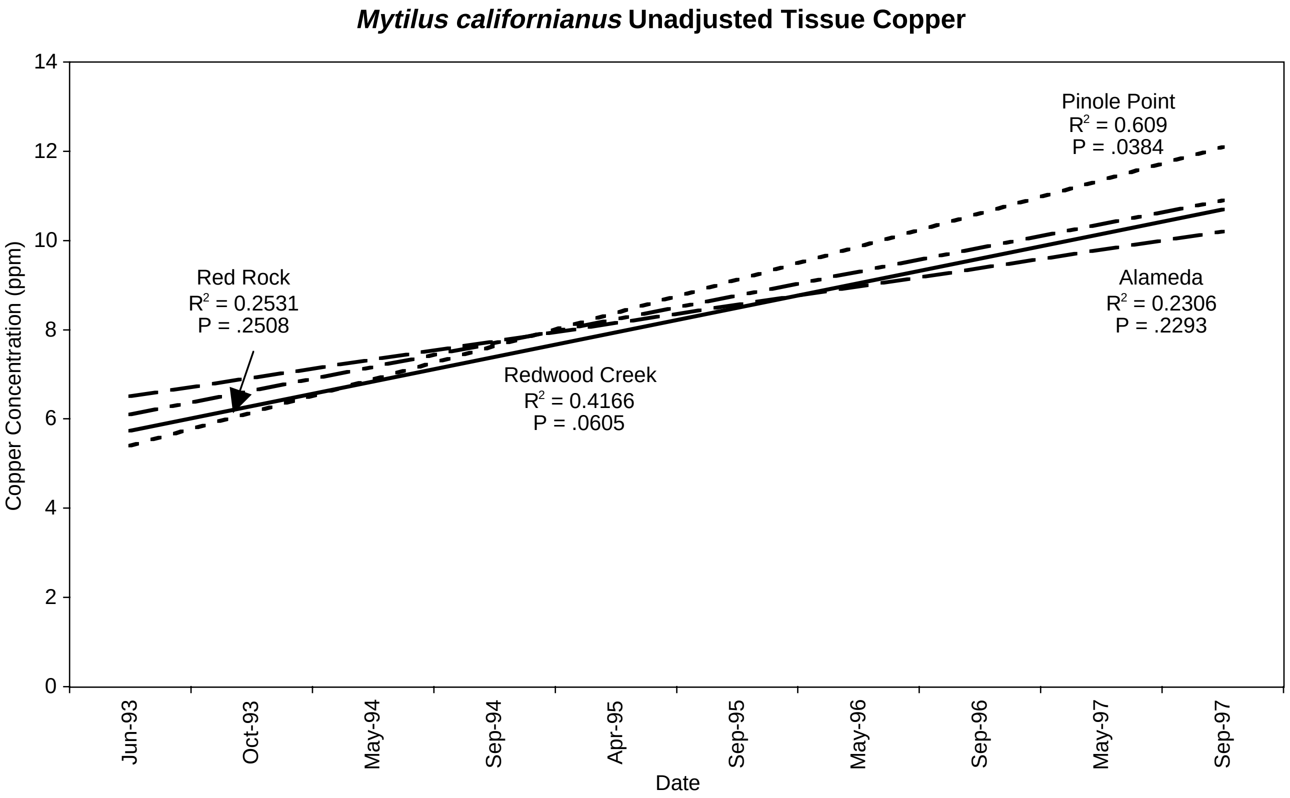

Figure 5.24. Trendlines for unadjusted copper in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

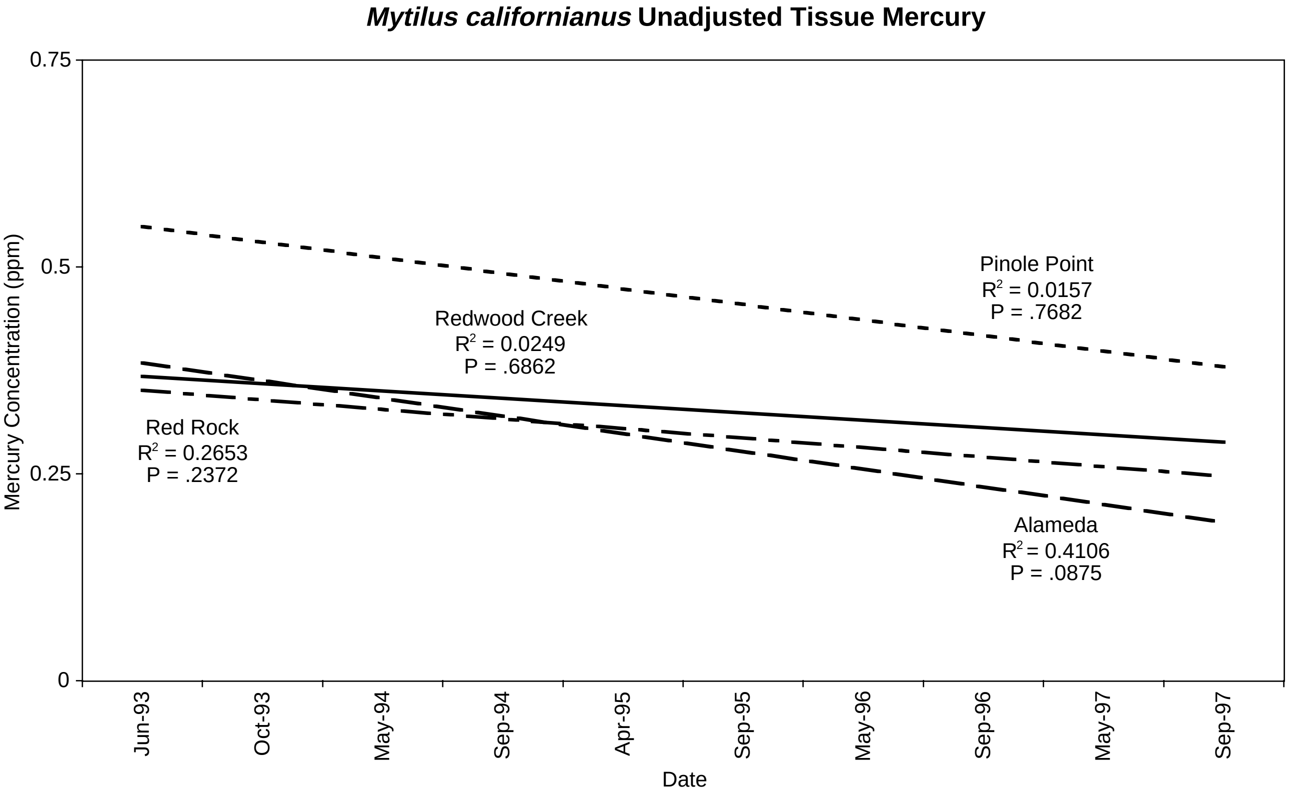

Figure 5.25. Trendlines for unadjusted mercury in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

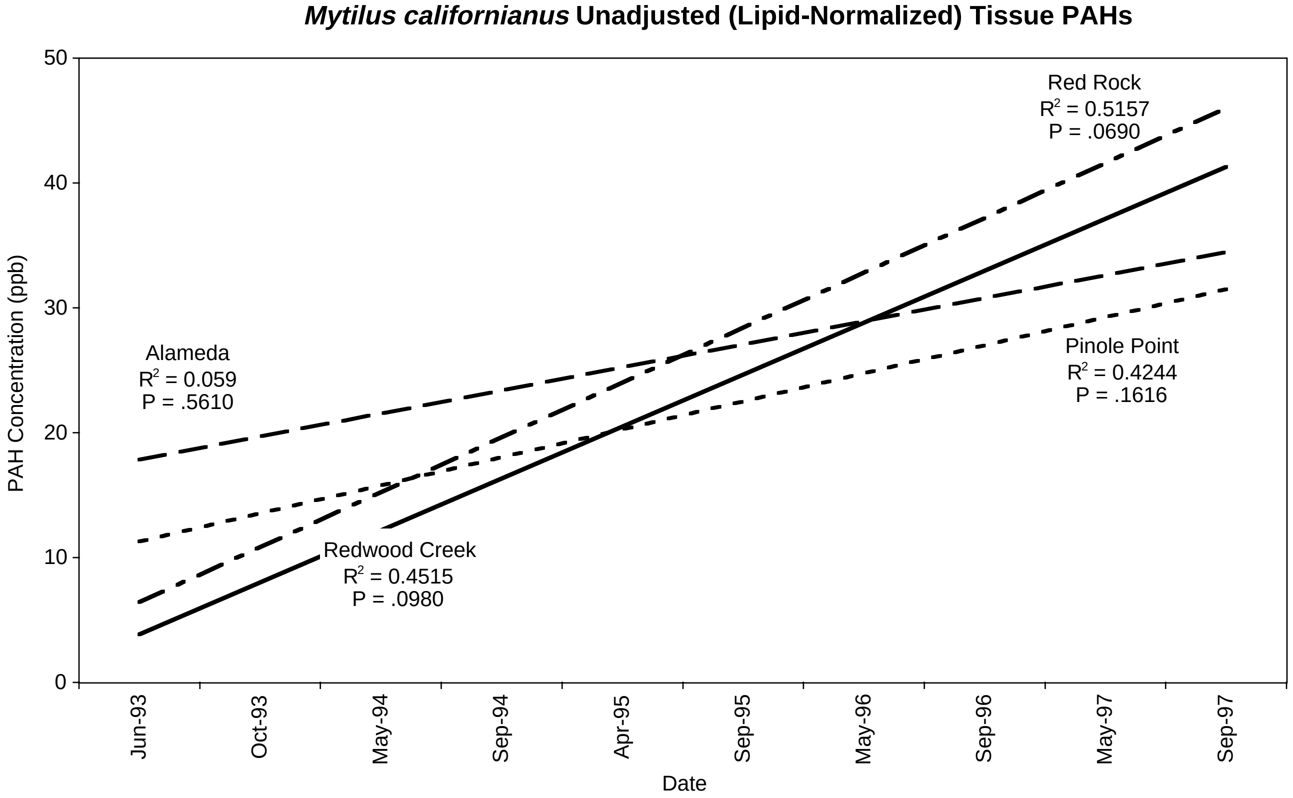

Figure 5.26. Trendlines for unadjusted (lipid-normalized) PAHs in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

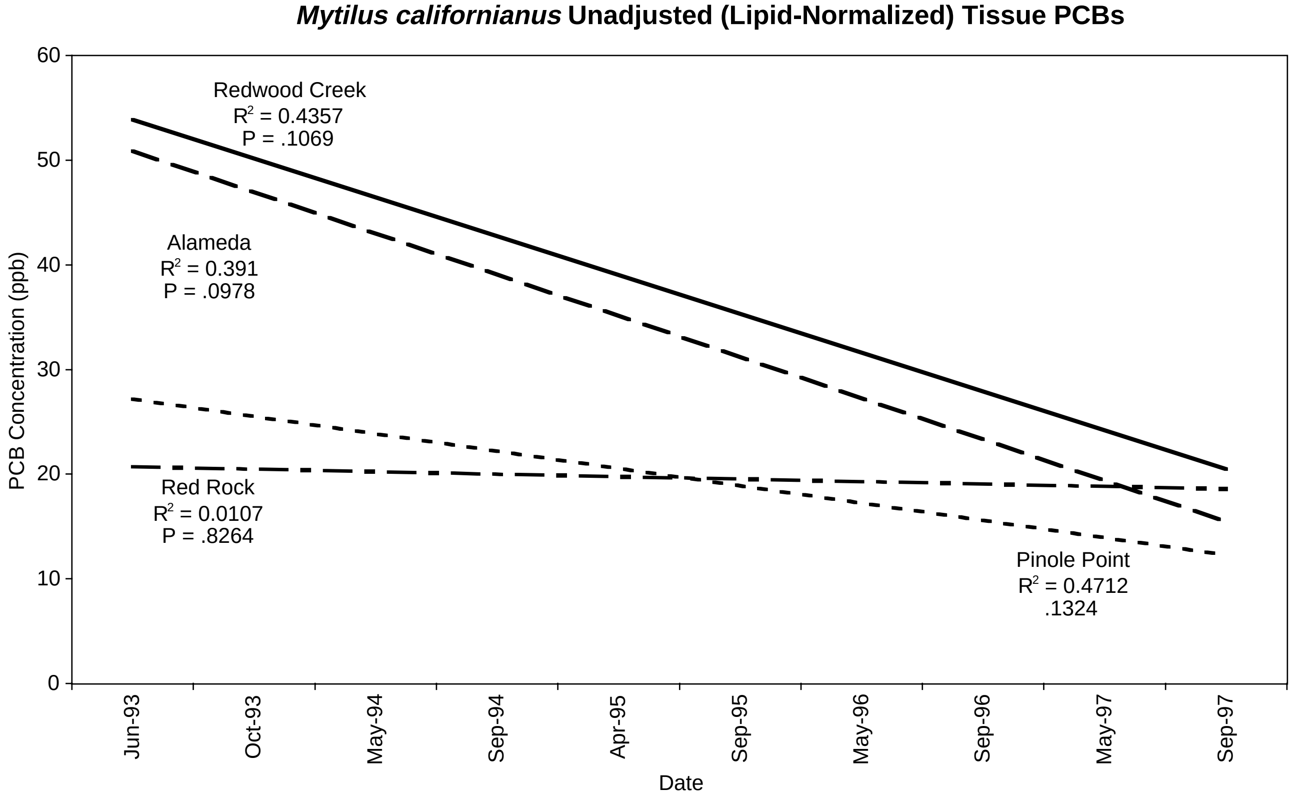

Figure 5.27. Trendlines for unadjusted (lipid-normalized) PCBs in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

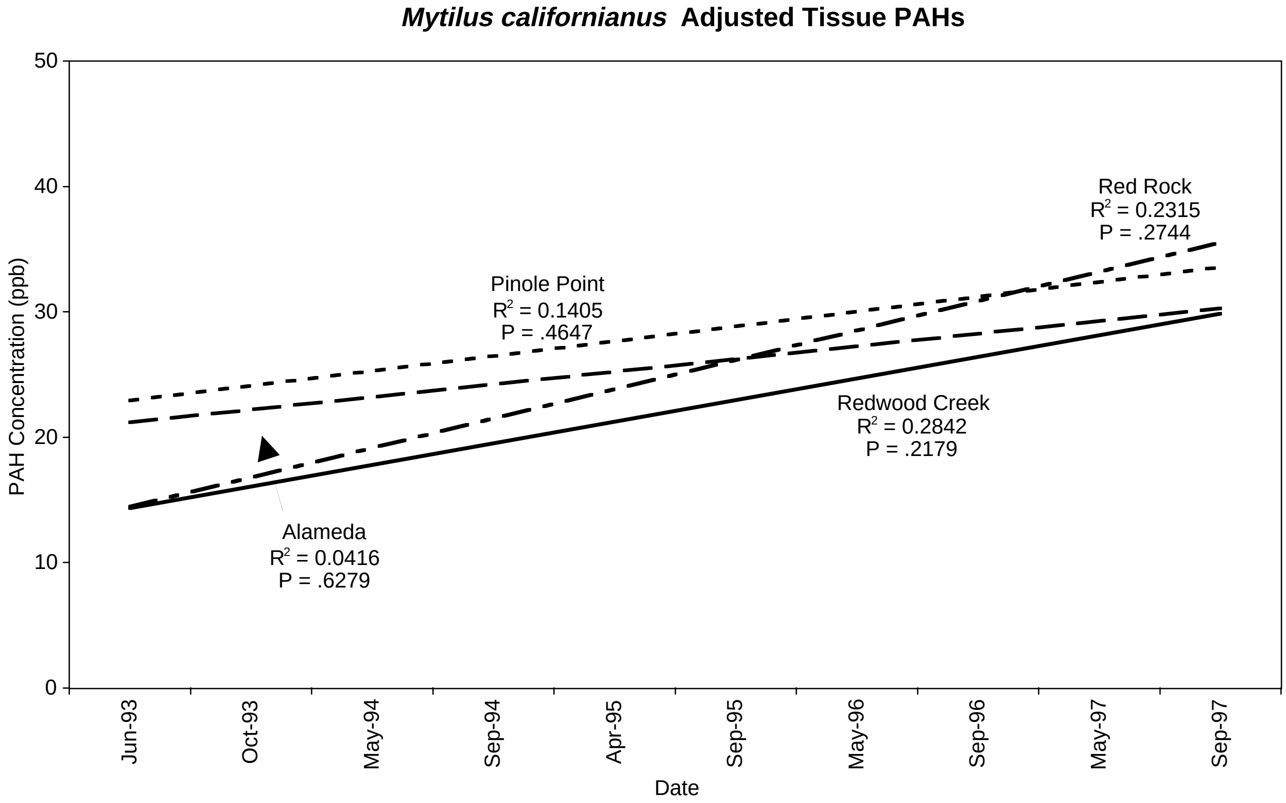

Figure 5.28. Trendlines for adjusted PAHs in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

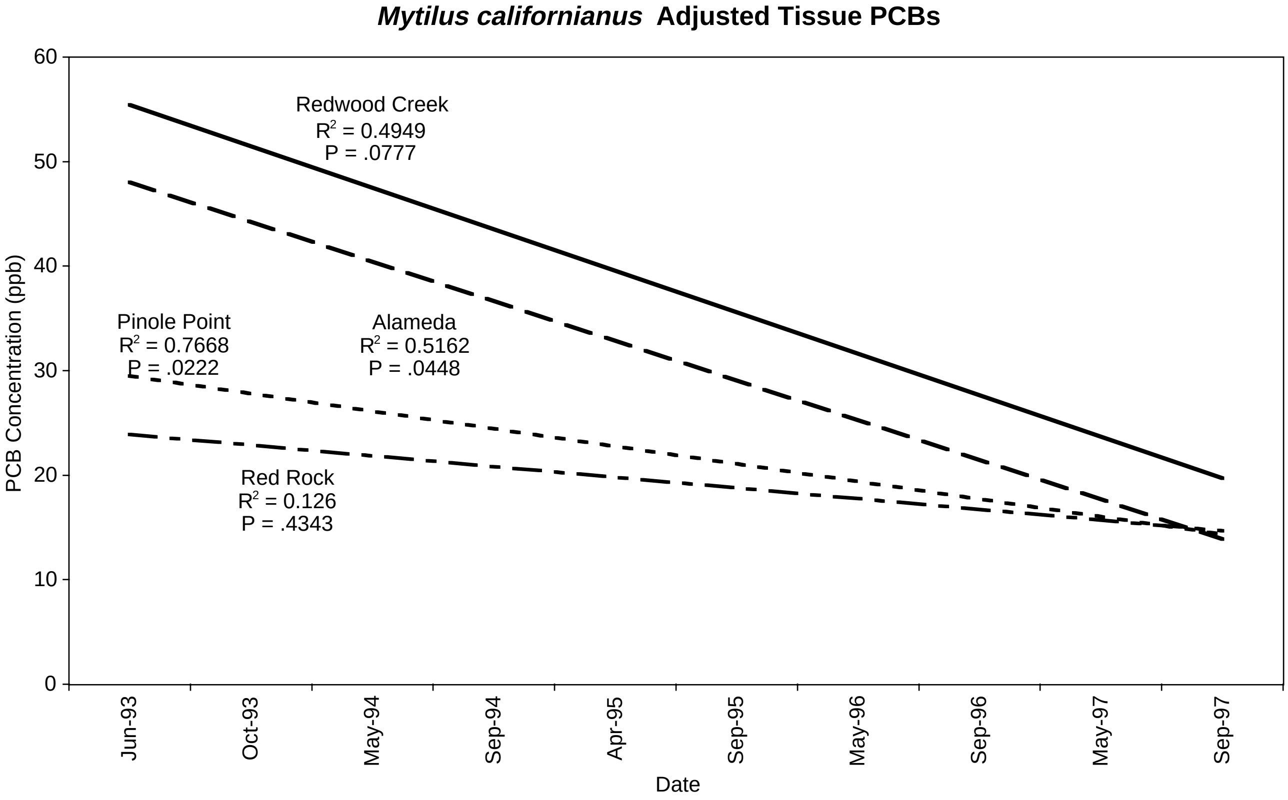

Figure 5.29. Trendlines for adjusted PCBs in mussels at four sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

tissue data made no difference in the ANOVA results, except that with unadjusted data, 1994 had the lowest mean, and with adjusted data, 1995 had the lowest mean (Table 5.1). Probabilities were also lower with adjusted data indicating reduced variation within sites and years. Use of adjusted data in the analysis of temporal trends indicated much less dramatic increases through time at each site than were seen with the unadjusted data (Figure 5.26), suggesting that the increases seen in the unadjusted data may be related to differences in dissolved oxygen and total suspended solids. P values for trend lines based on adjusted data were substantially greater, indicating that by adjusting PAH tissue concentrations, any hint of increases through time was even less pronounced than for unadjusted data (Figures 5.26 and 5.28; Table 5.2). In the case of PCBs, adjustment of tissue data made no difference in the ANOVA test for differences among sites, although the probabilities were lower (Table 5.1). The ANOVA test for differences among years gave different results for adjusted and unadjusted data, with adjusted data suggesting more consistent decreases from year to year. Use of adjusted PCB data in the analysis of temporal trends suggested decreases through time that were more significant than for unadjusted data (Figures 5.27 and 5.29; Table 5.2).

Oysters

Unlike for mussels, ANOVAs for oysters revealed no significant differences among sites or years for any of the four contaminants (Table 5.3). Unadjusted tissue data also revealed no significant trends through time (Figures 5.30–5.33).

Adjustment of oyster tissue data changed the slope of some trend lines, but all remained insignificantly different from zero (Figures 5.34–5.37). For instance, the insignificant decrease in copper at Coyote Creek for unadjusted data became an insignificant increase with adjusted data (Figures 5.30 and 5.34; Table 5.2) and the insignificant

Table 5.2. Comparison of temporal trends using adjusted and unadjusted bivalve data. Direction of arrow indicates increases or decreases from 1993 to 1997. * = probability that slope of trendline was different from zero was < 0.2. ** = probability that slope of trendline was different from zero was < 0.1. *** = probability that slope of trendline was different from zero was < 0.05. NA = not analyzed.

Trace Substance					
Site/Species	**Treatment**	**Copper**	**Mercury**	**PAH**	**PCB**
Coyote Creek/Oysters	Adjusted	↓	↑	↑ *	↓
	Unadjusted	↑	↑	↑	↓
Redwood Creek/Mussels	Adjusted	NA	NA	↑	↓ **
	Unadjusted	↑ **	↓	↑ **	↓ *
Alameda/Mussels	Adjusted	NA	NA	↑	↓***
	Unadjusted	↑	↓ **	↑	↓ **
Red Rock/Mussels	Adjusted	NA	NA	↑	↓
	Unadjusted	↑	↓	↑ **	↓
Pinole Point/Mussels	Adjusted	NA	NA	↑	↓***
	Unadjusted	↑ ***	↓	↑ *	↓ *
Davis Point/Oysters	Adjusted	↓	↓	↓	↓ **
	Unadjusted	↓	↓	↑	↓ *
Sacramento River/Clams	Adjusted	NA	NA	NA	↓
	Unadjusted	↑ ***	↑ **	↑	↓***

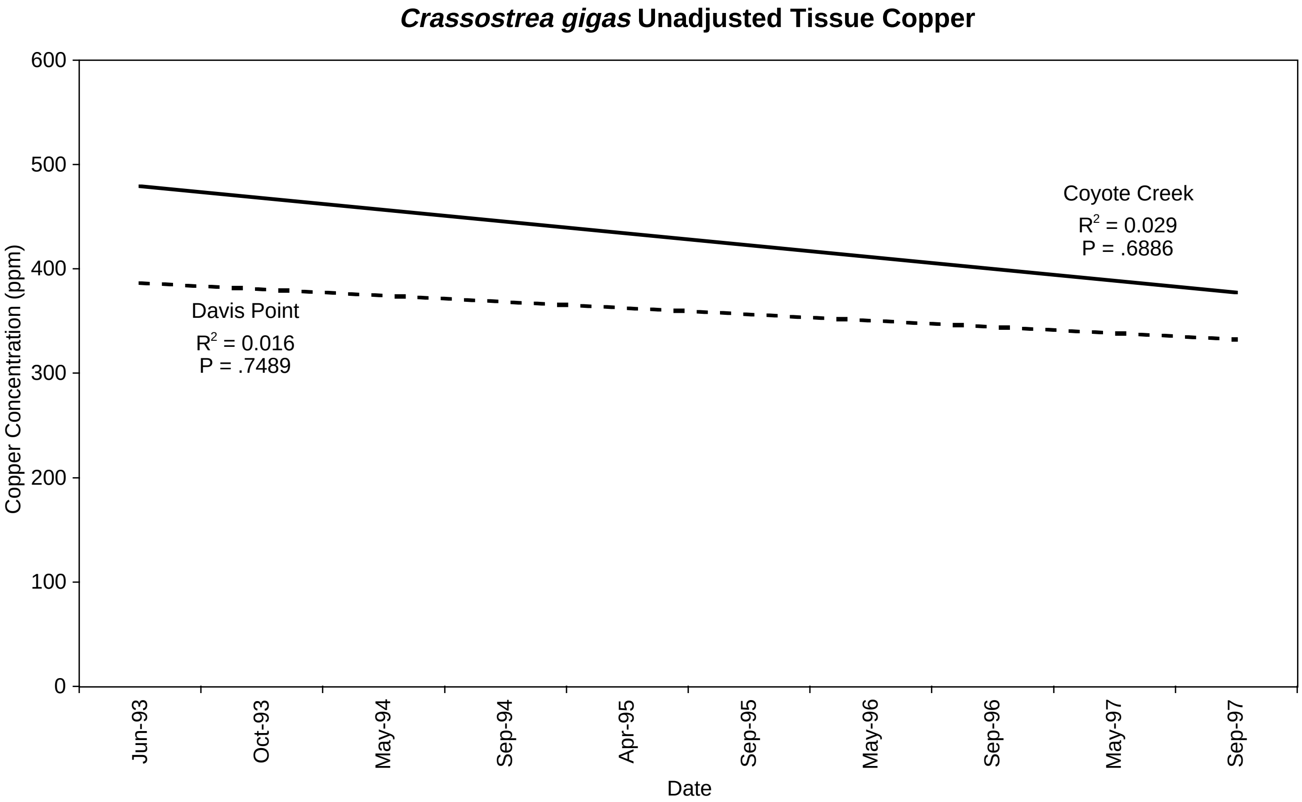

Figure 5.30. Trendlines for unadjusted copper in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

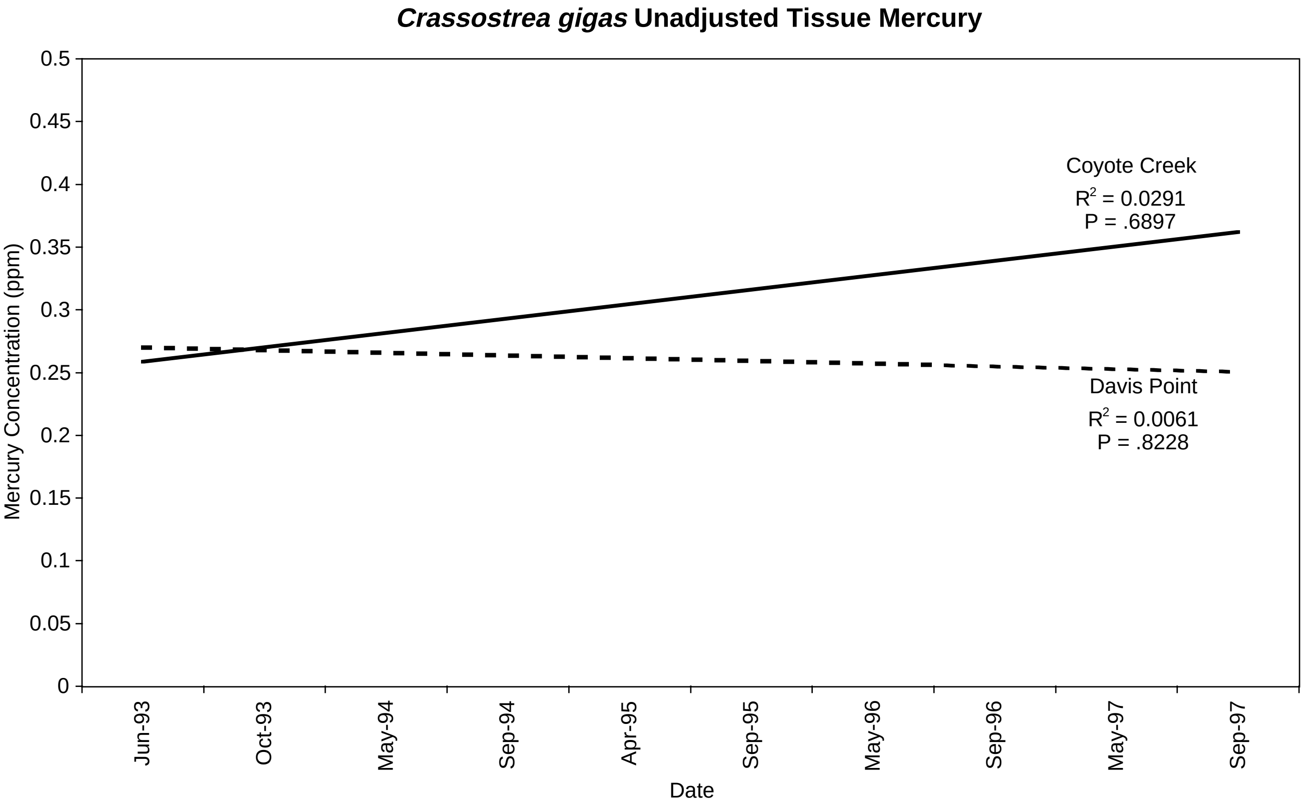

Figure 5.31. Trendlines for unadjusted mercury in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

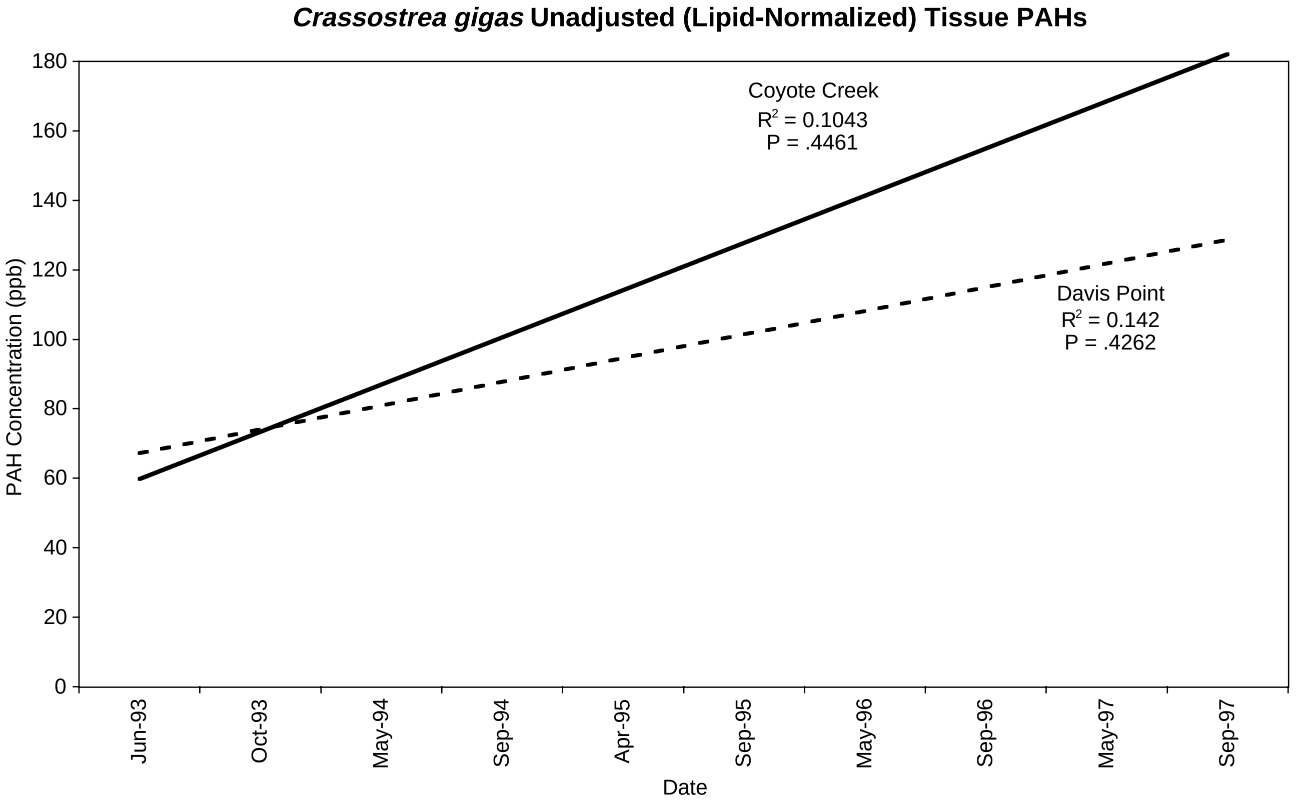

Figure 5.32. Trendlines for unadjusted (lipid-normalized) PAHs in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

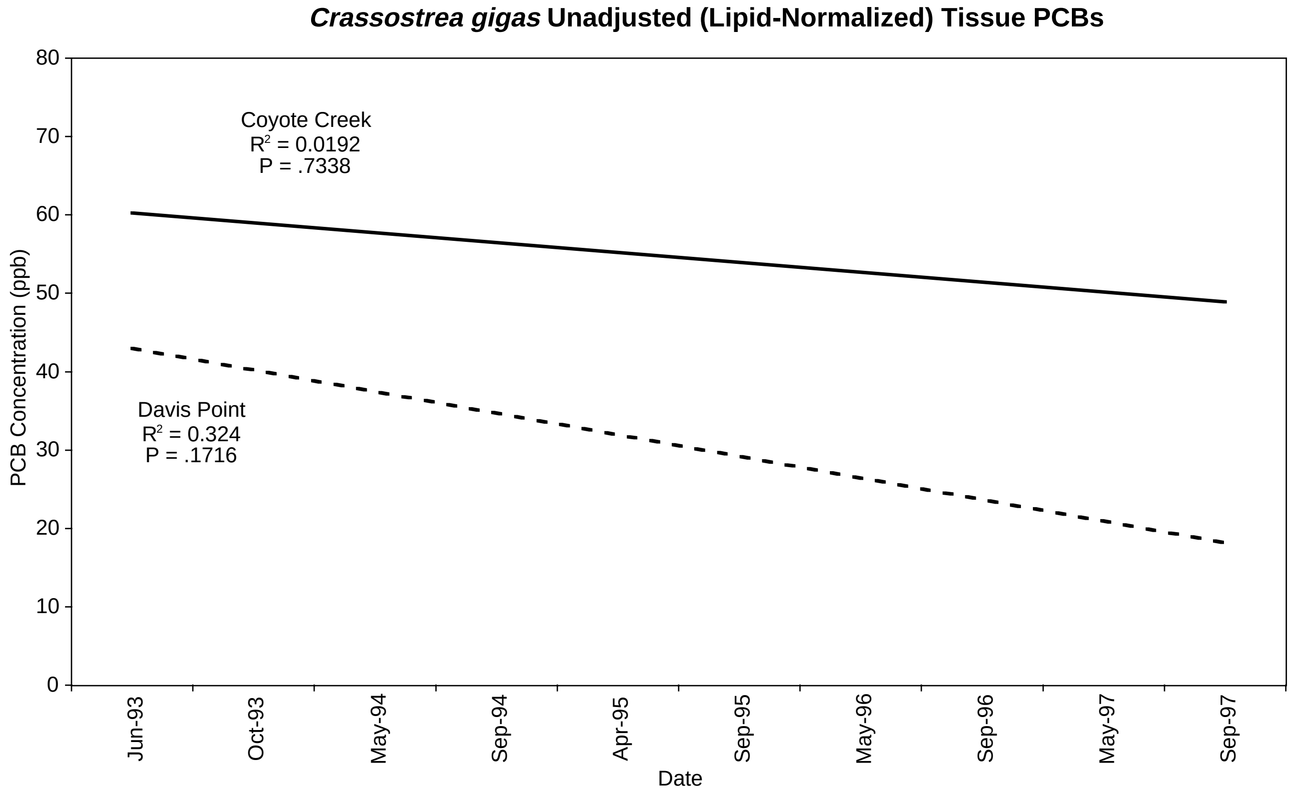

Figure 5.33. Trendlines for unadjusted (lipid-normalized) PCBs in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

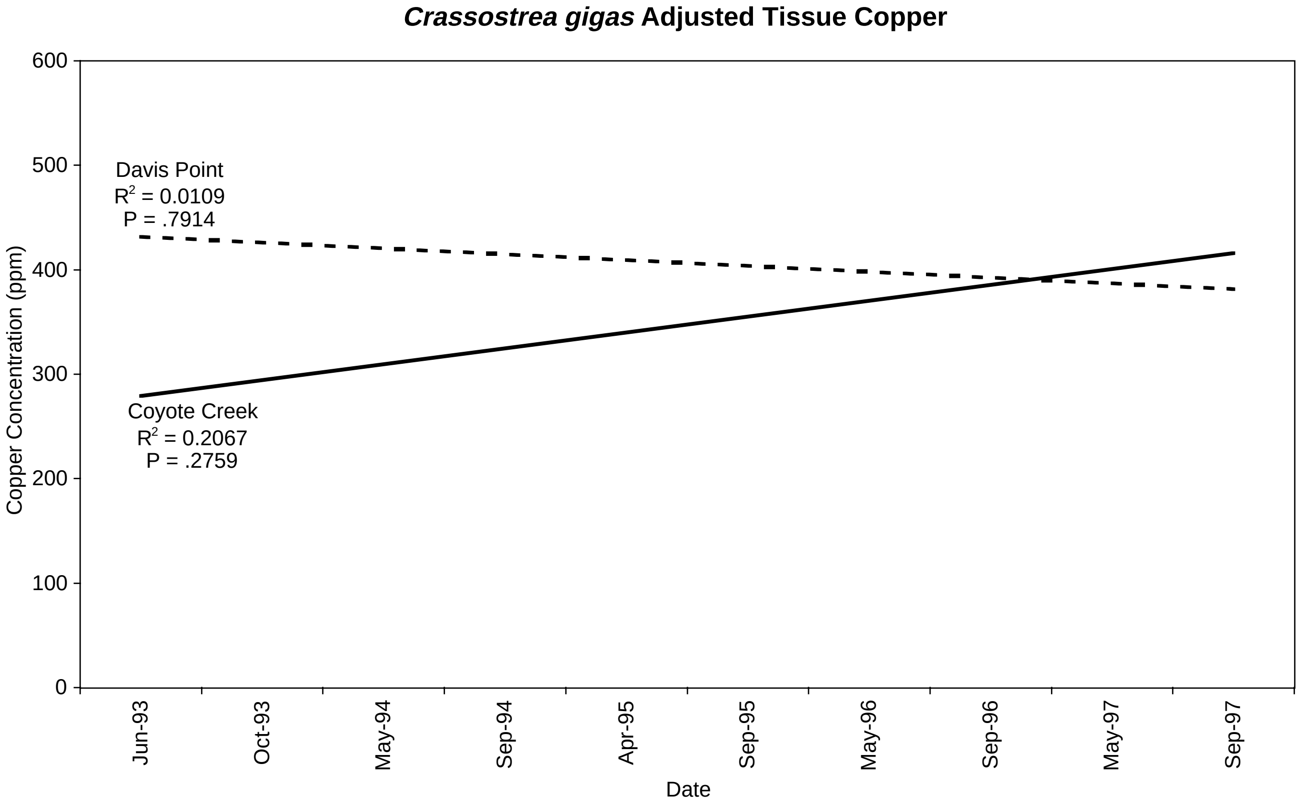

Figure 5.34. Trendlines for adjusted copper in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

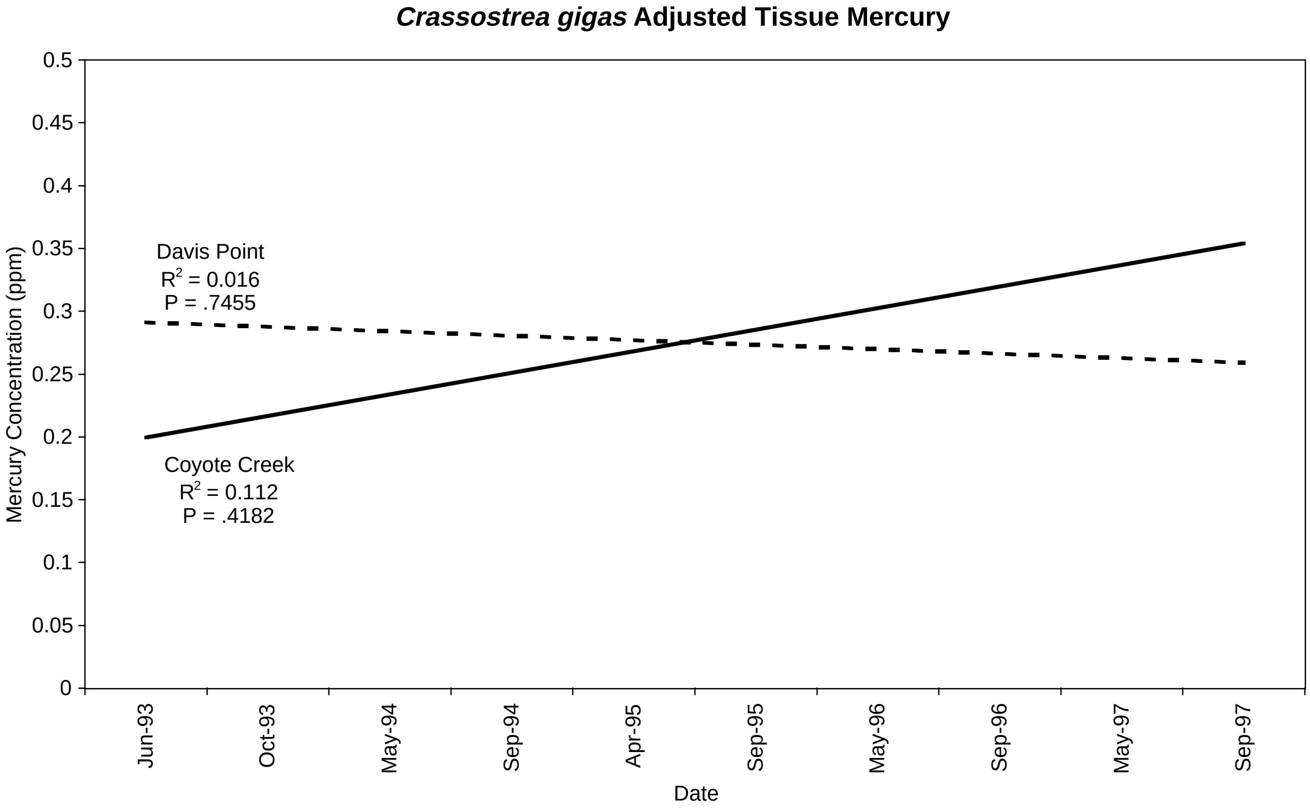

Figure 5.35. Trendlines for adjusted mercury in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

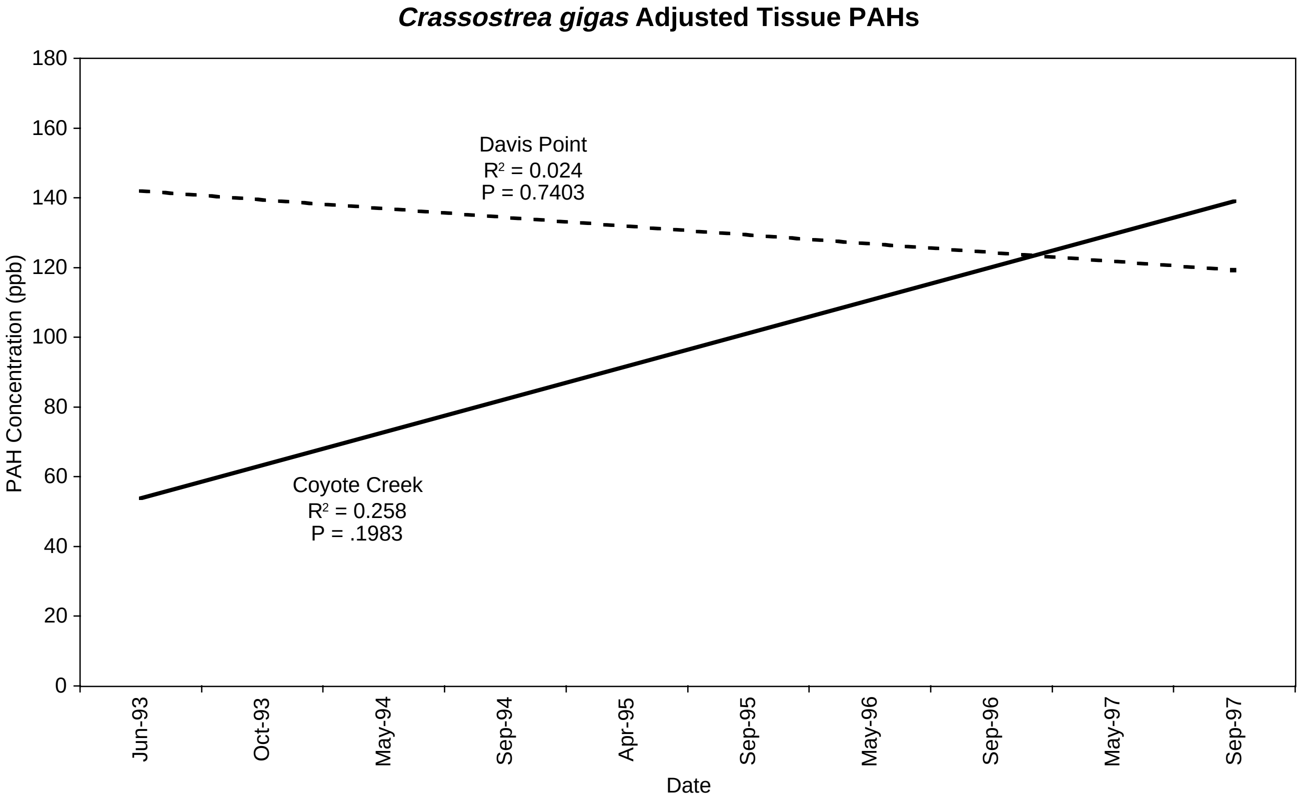

Figure 5.36. Trendlines for adjusted PAHs in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

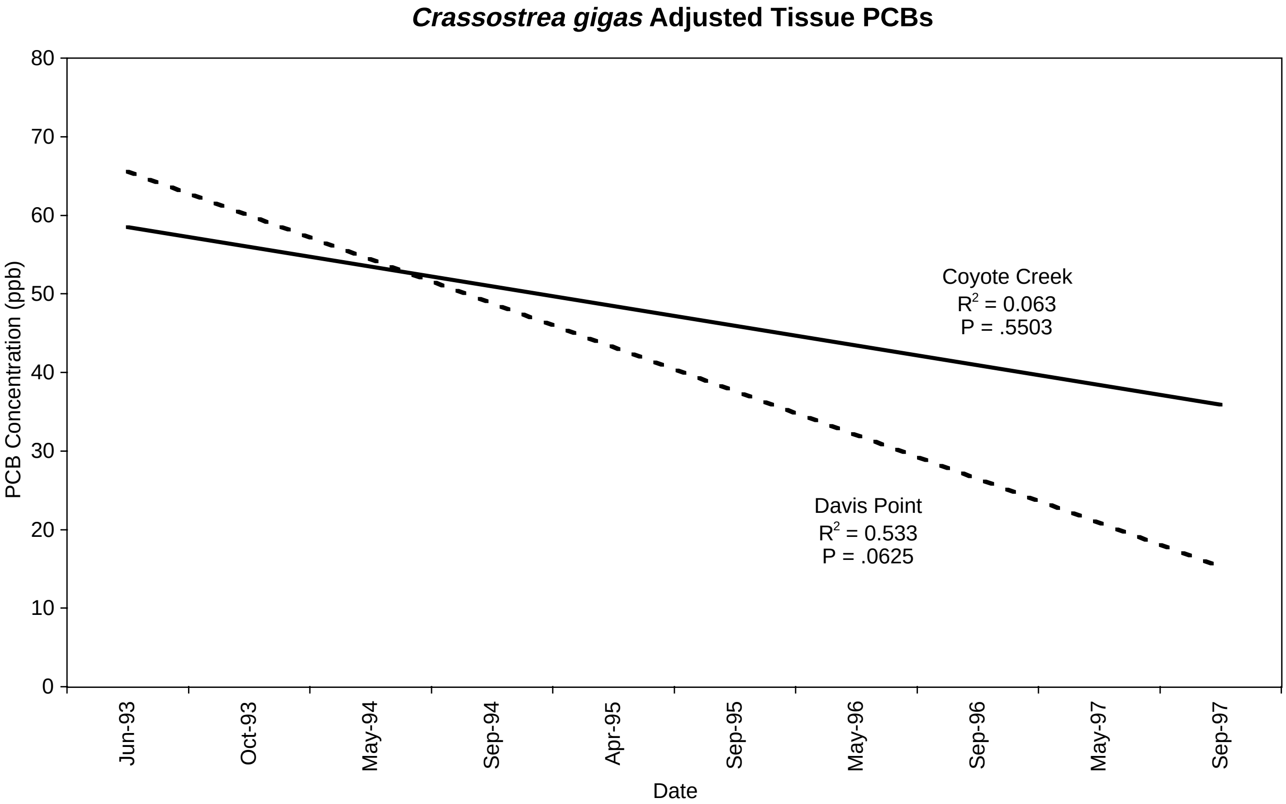

Figure 5.37. Trendlines for adjusted PCBs in oysters at two sites between June 1993 and September 1997. Regression coefficients and probabilities for trendlines are indicated.

increase in PAHs at Davis Point for unadjusted data became an insignificant decrease with adjusted data (Figures 5.32 and 5.36; Table 5.2). Use of adjusted data caused the increase and decrease in mercury at Coyote Creek and Davis Point, respectively, to become less insignificant in each case. The use of adjusted data for PCBs caused temporal trend lines to be slightly less insignificant.

Clams

Because only the Sacramento River site was used in the statistical tests for clams, it is not possible to evaluate spatial variation, although there were indications of temporal variation. Although ANOVA results revealed no significant differences among years (Table 5.4), trendlines based on unadjusted data indicated significant increases in copper, nearly significant increases in mercury, insignificant increases in PAHs, and significant decreases in PCBs (Figures 5.38–5.41). Adjustment of PCB data for the suggested effects of environmental variables made the decrease in PCBs insignificant (Figure 5.42 and Table 5.2).

We can conclude from the ANOVAs and trendlines that there are spatial and temporal differences in trace substance accumulation by bivalves in the Estuary. For example, there were higher concentrations of PCBs in mussels from South Bay sites, which are consistent with RMP water and sediment data. The decreases in PCBs at most sites, although generally not significant in unadjusted data, are also consistent with previous findings (Gunther *et al.*, in press). The increases in copper also appear to be regional because they were evident at every mussel site and the clam site. The absence of significant spatial and temporal differences in the oysters indicates that either there is a high degree of spatial variation between the oyster sites and nearby mussel sites, or the bioaccumulation trends are species-specific.

Adjustment of bivalve data for suggested effects of environmental variables often reduces variation in the data and improves our ability to detect spatial and temporal trends. In eight of the 13 cases in which ANOVAs were performed on both adjusted and unadjusted data, the adjusted

Table 5.3. ANOVAs for differences among sites and years in concentrations of four contaminants in oysters.

Contaminant	P	*a posteriori* results[a]
Among Sites		
Copper[b]	.6682	Coyote Creek Davis Point
Copper[c]	.4502	Coyote Creek Davis Point
Mercury[b]	.3633	Coyote Creek Davis Point
Mercury[c]	.7919	Coyote Creek Davis Point
PAH[b]	.3958	Coyote Creek Davis Point
PAH[c]	.2861	Davis Point Coyote Creek
PCB[b]	.0904	Coyote Creek Davis Point
PCB[c]	.5194	Coyote Creek Davis Point
Among Years		
Copper[b]	.7304	1995 1994 1996 1997
Copper[c]	.9632	1995 1994 1997 1996
Mercury[b]	.8104	1996 1997 1995 1994
Mercury[c]	.9572	1997 1994 1996 1995
PAH[b]	.7890	1996 1997 1995 1994
PAH[c]	.7053	1996 1997 1995 1994
PCB[b]	.6431	1996 1994 1995 1997
PCB[c]	.2381	1994 1996 1995 1997

[a] Sites and years are arranged with the highest mean on the left and the lowest mean on the right. Sites or years that are connected by a common line are not significantly different.

[b] Unadjusted data were tested.

[c] Adjusted data were tested.

Table 5.4. ANOVAs for differences among years in concentrations of four contaminants in clams.

Contaminant	P	a posteriori results[a]
Among Years		
Copper[b]	.2769	1997 1996 1994 1995 1993
Mercury[b]	.0881	1993 1994 1997 1995 1996
PAH[b]	.5774	1997 1994 1995
PCB[b]	.0238	1994 1996 1995 1997
PCB[c]	.5918	1996 1994 1995 1997

[a] Sites and years are arranged with the highest mean on the left and the lowest mean on the right. Sites or years that are connected by a common line are not significantly different.

[b] Unadjusted data were tested.

[c] Adjusted data were tested.

data had lower probabilities (i.e., the results were either more significant or less insignificant; Table 5.1, 5.3, and 5.4).

Analysis of bivalve data that have been adjusted for the suggested effects of environmental variables may also lead to different conclusions than would be drawn from analyzing raw, unadjusted data. For example, the slopes for copper and PAH trendlines in oysters at Coyote Creek and Davis Point, respectively, differed between adjusted and unadjusted data. Also, the greater significance of decreases in mussel PCBs and the disappearance of significance in decreases in clam PCBs after adjusting the tissue data could lead to different conclusions regarding temporal trends in trace substances in the Estuary. Such conclusions have important ramifications in the assessment of the health of the Estuary and the evaluation of regulatory requirements. Nevertheless, only in the cases of copper and PAHs at Coyote Creek and Davis Point, respectively, would conclusions about the direction of trends be affected.

Comparisons of Bivalve Bioaccumulation and Water Contaminant Concentrations

Backward stepwise regressions were performed to determine how well the concentrations of contaminants in bivalves tracked concentrations of dissolved and particulate water contaminants. More specifically, the data were analyzed to shed light on the following questions:

1. Do the data from one or two water measurements during a bivalve deployment account for significant variation in the bivalve data? In other words, are high or low water concentrations reflected by corresponding bivalve tissue concentrations?

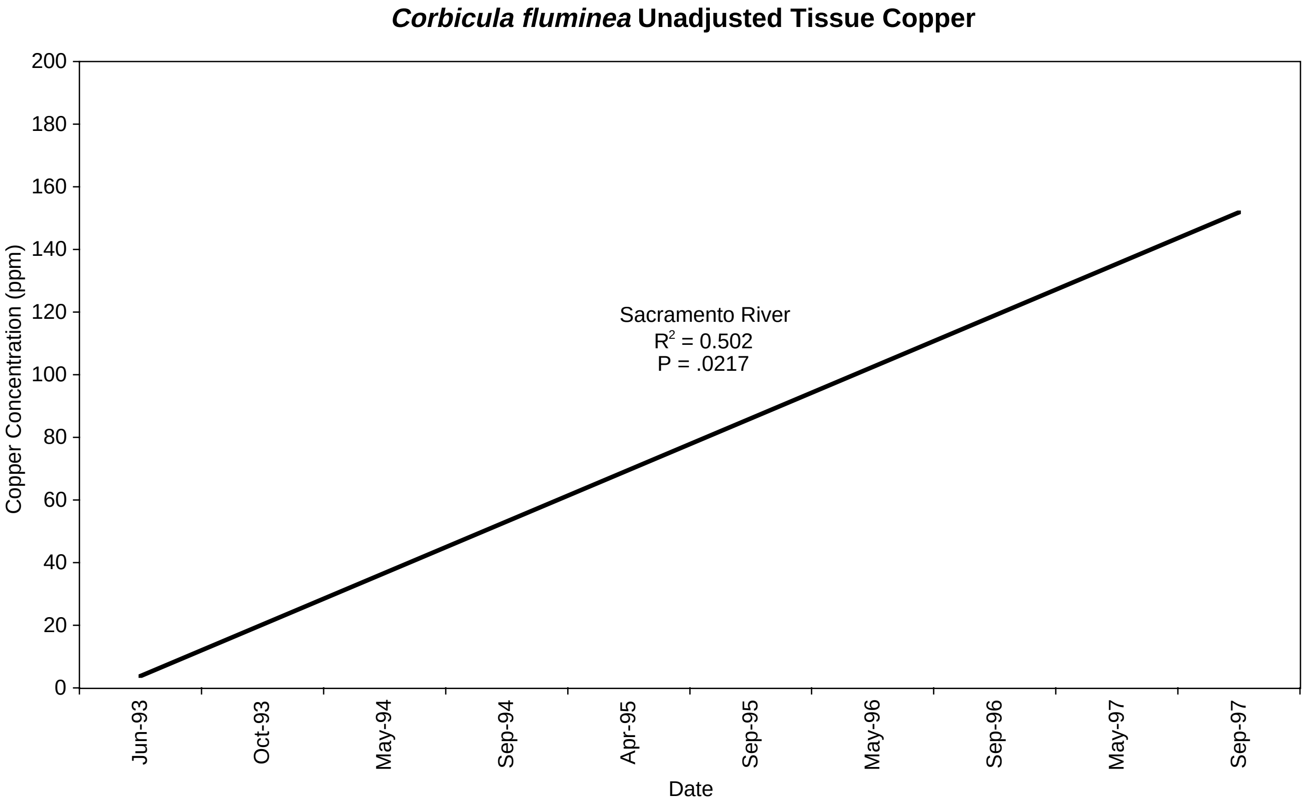

Figure 5.38. Trendlines for unadjusted copper in clams at one site between June 1993 and September 1997. The regression coefficient and probability for the trendline is indicated.

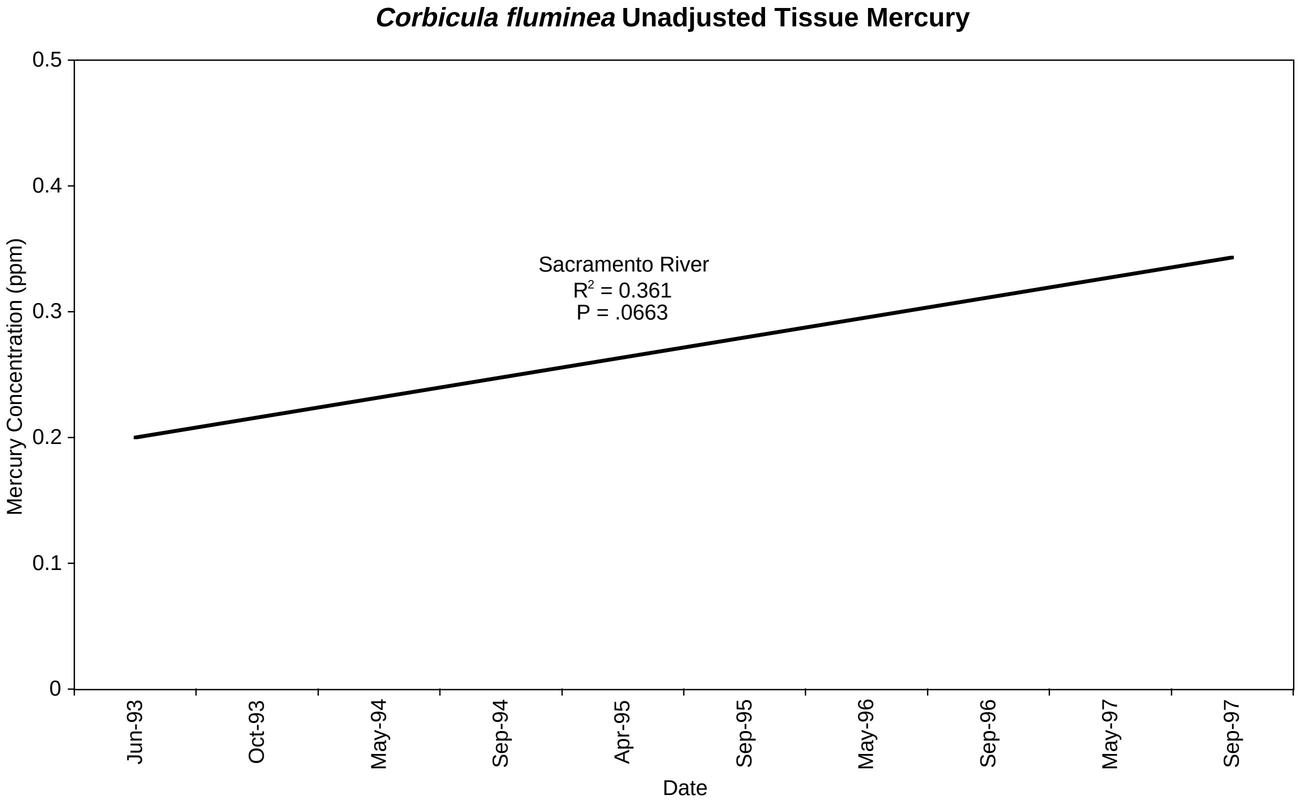

Figure 5.39. Trendlines for unadjusted mercury in clams at one site between June 1993 and September 1997. The regression coefficient and probability for the trendline is indicated.

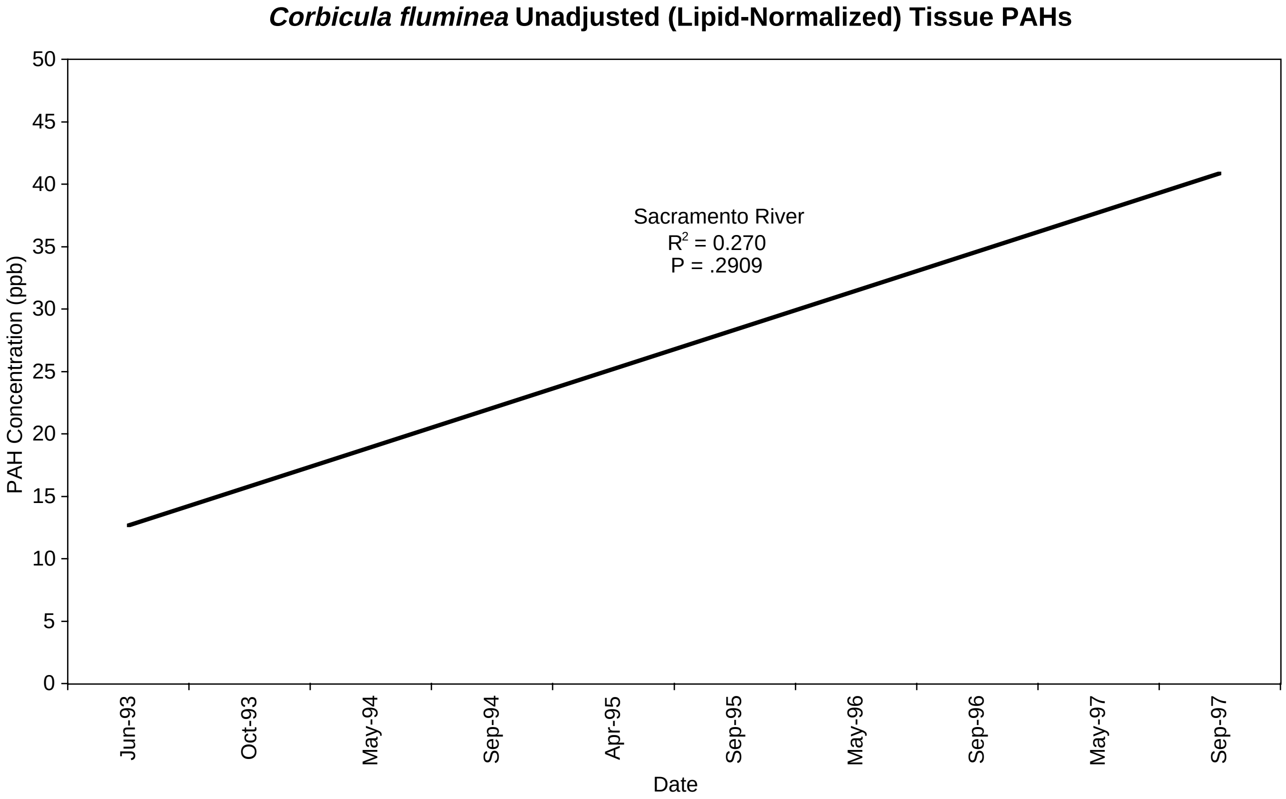

Figure 5.40. Trendlines for unadjusted (lipid-normalized) PAHs in clams at one site between June 1993 and September 1997. The regression coefficient and probability for the trendline is indicated.

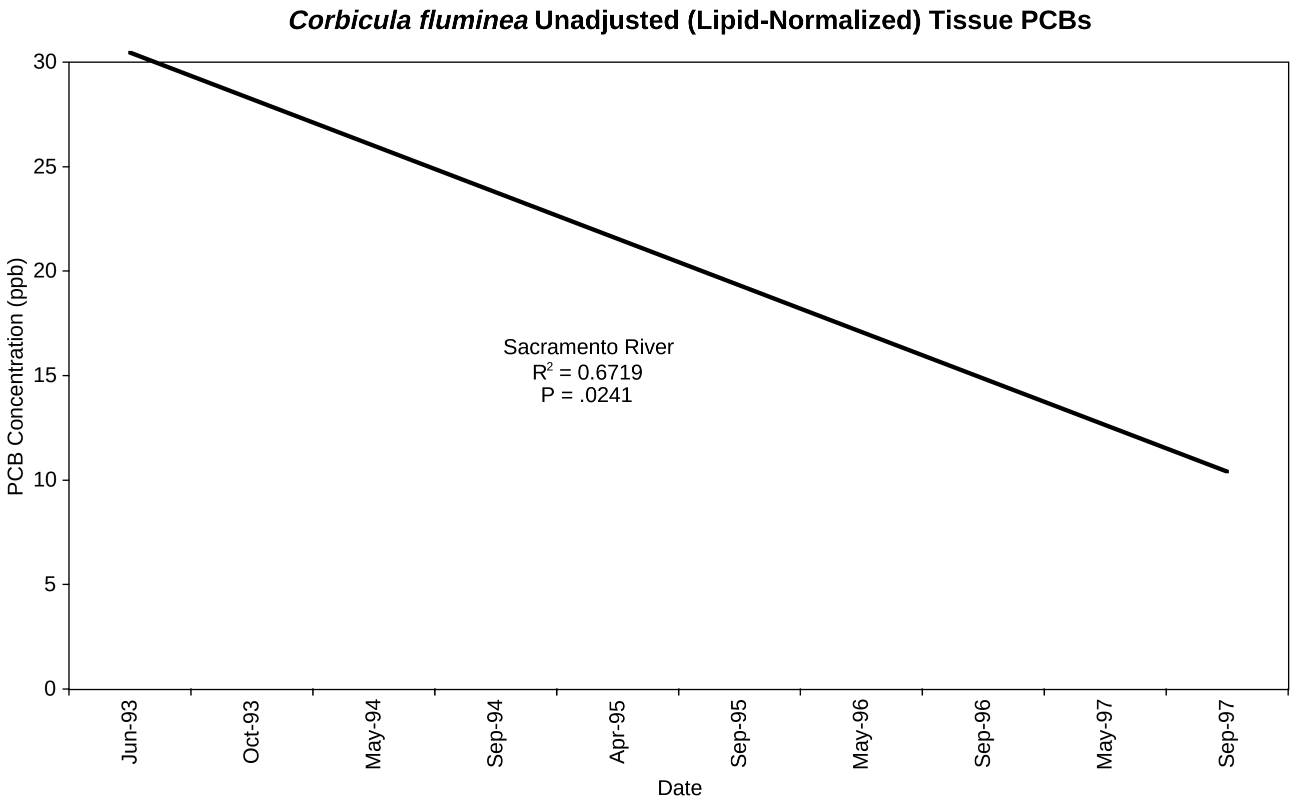

Figure 5.41. Trendlines for unadjusted (lipid-normalized) PCBs in clams at one site between June 1993 and September 1997. The regression coefficient and probability for the trendline is indicated.

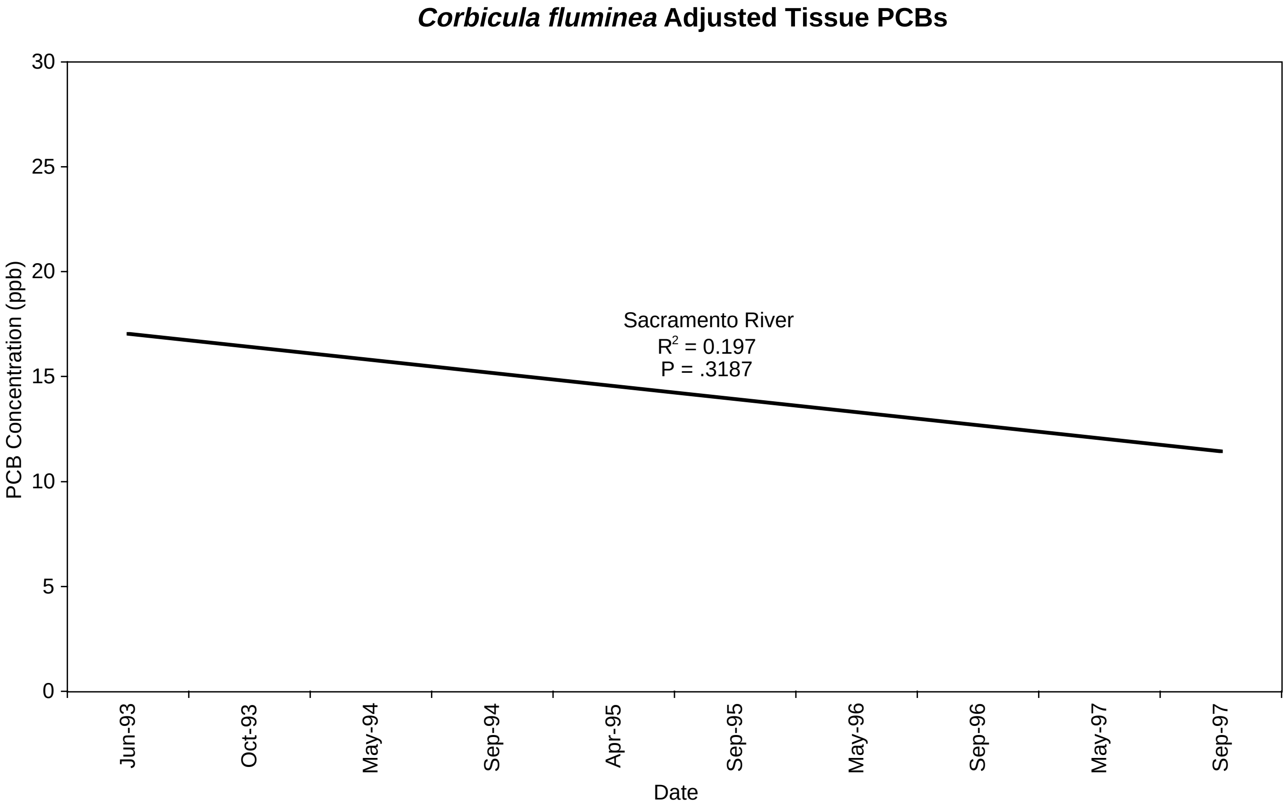

Figure 5.42. Trendlines for adjusted PCBs in clams at one site between June 1993 and September 1997. The regression coefficient and probability for the trendline is indicated.

2. Do the adjustments to tissue concentrations for suggested effects of water quality parameters improve the correspondence between tissue measurements and water measurements?
3. Do the bivalves consistently bioaccumulate certain contaminants from either the dissolved or particulate fractions?

Mussels

The tissue concentrations of very few contaminants were significantly related to either dissolved or particulate water fractions (Table 4 in *Appendix E*). The measured tissue concentrations of copper, mercury, and zinc were negatively related to particulate or dissolved fractions and five of the remaining 20 possible regressions indicated non-significant negative regressions, suggesting no effect of water measurements on the tissue measurements. Adjustment of tissue data for the effects of water quality parameters actually reduced the correspondence between water measurements and tissue measurements for silver and chlordane, although adjustment did provide a significant regression between tissue and the dissolved water fraction for chlordane. Adjusted tissue concentrations improved the correspondence between tissue and water PCBs, with a significant regression for the dissolved fraction.

No consistent relationship existed between either the adjusted or unadjusted tissue trace substances and the dissolved or particulate water fractions, although the dissolved fraction appeared more important. Eleven out of 23 possible regressions indicated either significant or non-significant positive correlations with the dissolved fraction, and four indicated significant or non-significant positive correlations with the particulate fraction. The remaining regressions indicated negative relationships with either dissolved or particulate fractions.

Oysters

Oysters were similar to mussels in the paucity of significant regressions between tissue concentrations and either water fraction (Table 5 in *Appendix E*). Only four contaminants had significant regressions for either adjusted or unadjusted tissue contaminants. The tissue concentrations of both copper and mercury exhibited negative correlations with the particulate fraction. Six of the remaining tissue trace substances indicated non-significant negative correlations with either dissolved or particulate fractions. Adjustment of tissue data for suggested effects of environmental variables decreased the correspondence to water measurements for PCBs, although both adjusted and unadjusted tissue data indicated positive correlations with dissolved water concentrations. None of the four cases of significant regressions indicated improved correspondence between water measurements and adjusted tissue concentrations.

Neither the dissolved nor the particulate fractions were predominant in their suggested effects on tissue concentrations. Three tissue trace substances indicated significant or non-significant positive correlations with the dissolved fraction and two indicated significant or non-significant positive correlations with the particulate fraction.

Clams

There were only four trace substances in clam tissues (mercury, selenium, PAH, PCB) that were significantly correlated with either dissolved or particulate water fractions on tissue concentrations (Table 6 in *Appendix E*), and one of them (selenium) was negatively correlated with the dissolved. Four tissue trace substances indicated non-significant negative correlations with either dissolved or particulate fractions. Adjustment of tissue data for suggested effects of environmental variables improved the correspondence to water measurements for mercury and PCB, although the significant regression for adjusted PCB included positive effects of the particulate fraction and negative effects of the dissolved fraction.

Unlike with the mussels and oysters, tissue trace substances were more often positively correlated with the particulate fraction than with the dissolved fraction. Seven tissue trace substances had either significantly or non-significantly positive correlations with the particulate fraction and only two had significantly or non-significantly positive correlations with the dissolved fraction.

Findings and Conclusions

1. Bivalves are effective tools for monitoring long-term trends, especially for bioaccumulative trace organics.
2. Bivalves are of limited use in monitoring trends for those trace elements that do not accumulate in tissues, as integrators of water contamination for mercury and arsenic, or for estimating mercury transfer to higher levels of the food web.
3. The comparisons of tissue and corresponding water concentrations reveal that time-integrated bioaccumulation of contaminants by bivalves generally does not correspond well to water measurements of contaminants made on one or two occasions during bivalve deployments. Although this conclusion is not necessarily surprising, it indicates that bivalves are important sampling devices and add information that water or sediment data alone would not supply.
4. Bivalves are but one of many tools to determine the transfer and potential magnification of contaminants to higher trophic levels. The current use of non-resident species appears suboptimal in this regard.
5. The bivalve data indicate spatial and temporal trends in contaminants that have important implications for management of the Estuary. Although PCB tissue concentrations seem to be decreasing at some stations, overall Estuary trends are not yet clear. For PCBs, the removal of natural environmental variables that may influence tissue trace substance data may reveal different patterns from the unadjusted data (e.g., temporal trends for mussels and clams). Other trace substances, when the suggested effects of environmental variables are statistically removed from tissue concentrations, may exhibit clearer trends than PCBs and will be investigated in the future. Tissue concentrations of PCBs are higher in the South Bay reach than in other reaches, thus mirroring the findings in water and sediment. Both mussels and clams indicate increases in copper in the Estuary. Whether this increase is due to increased copper loading to the Estuary from runoff or other causes is not immediately apparent. Perhaps most interestingly, the spatial and temporal trends evident with the mussels were not apparent in the oyster data. This emphasizes the importance of species selection in view of the management issues important for the Estuary. Bivalves serve as useful biomonitors for site comparisons (provided the same species can be deployed) in efforts to determine general pollutant sources or pathways.
6. The bivalve monitoring component includes measurements that theoretically lend themselves to evaluate contaminant effects on these indicators, such as growth, condition, and survival. While we are currently using bivalves merely as contaminant integrators and surrogates for pollutant measurements in the water column, they might also serve as response indicators to pollutants. Whether or not bivalves are an effective tool for evaluating pollutant effects remains to be assessed and will likely be introduced in the RMP re-design discussion.

Recommendations for Consideration in Re-design

1. Maintain the approach of using transplanted bivalves for long-term trend monitoring and as a relatively simple diagnostic tool of emerging pollutant problems, provided that the current analyte list is expanded to include bioaccumulative substances and other

contaminants that are currently not quantified but which are suspected to cause environmental problems.

2. Determine the potential application of a variety of bivalve species in pollutant source and pathway identifications.
3. Determine if bivalves are useful in the determination of pollutant effects.
4. Continue to explore the effects of environmental variables on bivalve health and bioaccumulation by collecting water data near bivalve deployment sites at the same depths as the bivalves.
5. Evaluate which indicator species should be used to assess contaminant transfer to higher trophic levels.

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CHAPTER 6

Pilot and Special Studies

Estuary Interface Pilot Study

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Introduction

After the first three years of pollutant characterization throughout the Estuary, it became evident that sampling stations at the Estuary margins generally exhibited higher concentrations of trace elements and trace organic pollutants in water and sediment than those in the deeper parts of the Bay. It was not clear which factors were primarily responsible for this phenomenon, and in order to determine what role pollutant inputs from adjacent watersheds are playing, sampling at the interface between the Bay and upland had to be conducted. Initially, one station at the upper end of the tidal prism of Coyote Creek was selected, and in 1997 the sampling was expanded to the mouth of the Guadalupe River, also known as Alviso Slough.

Objectives

The overall goals of the Estuary Interface Pilot Study (EIP) have remained the same as in 1996:

- Link pollutant patterns found in the Estuary with those in adjacent watersheds to test if runoff and sediment taken at the lower end of Coyote Creek and the Guadalupe River differ from each other and from water and sediment in the South Bay, including the Local Effects Monitoring stations maintained by the San Jose-Santa Clara Wastewater Treatment Plant and the Sunnyvale Treatment Plant.
- Explore what kinds of ancillary water quality parameters and watershed characteristics should be measured or described to explain some of the patterns found, improve sampling design, and fine-tune testing methodology.

Specific questions for the second year of sampling included:

1. Is the concentration gradient for certain pollutants that was observed in 1996 for Coyote Creek also applicable for the Guadalupe River?
2. Are there pronounced differences in the pollutant profiles between the two interface stations?
3. Are there pronounced differences between high- and low-flow periods between the interface stations and those in the Estuary?
4. Which factors may influence the findings?

This article describes a two-year data set which should not be interpreted as a definitive assessment of Coyote Creek or Guadalupe River watershed contributions to the Estuary. However, the data will be used in designing a new monitoring component of the RMP that is scheduled to take effect some time in 2001, and that meets the new objective of determining loading pathways of contaminants to the Estuary.

Sampling Plan

In 1997, a second sampling station was selected in the lower reach of the Guadalupe River known as Alviso Slough (BW15). The South Bay Yacht Club graciously provided access to their dock for sampling purposes, and their assistance is gratefully acknowledged. The Coyote Creek sampling station at Standish Dam (BW10) was also occupied in 1997. That station is located very close to Dixon Landing Road and Highway 880 where the city boundaries of Fremont, Milpitas, and San Jose converge (Figure 6.1). Both locations are within the tidal prisms. During the wet season, runoff amounts are large enough to dominate the

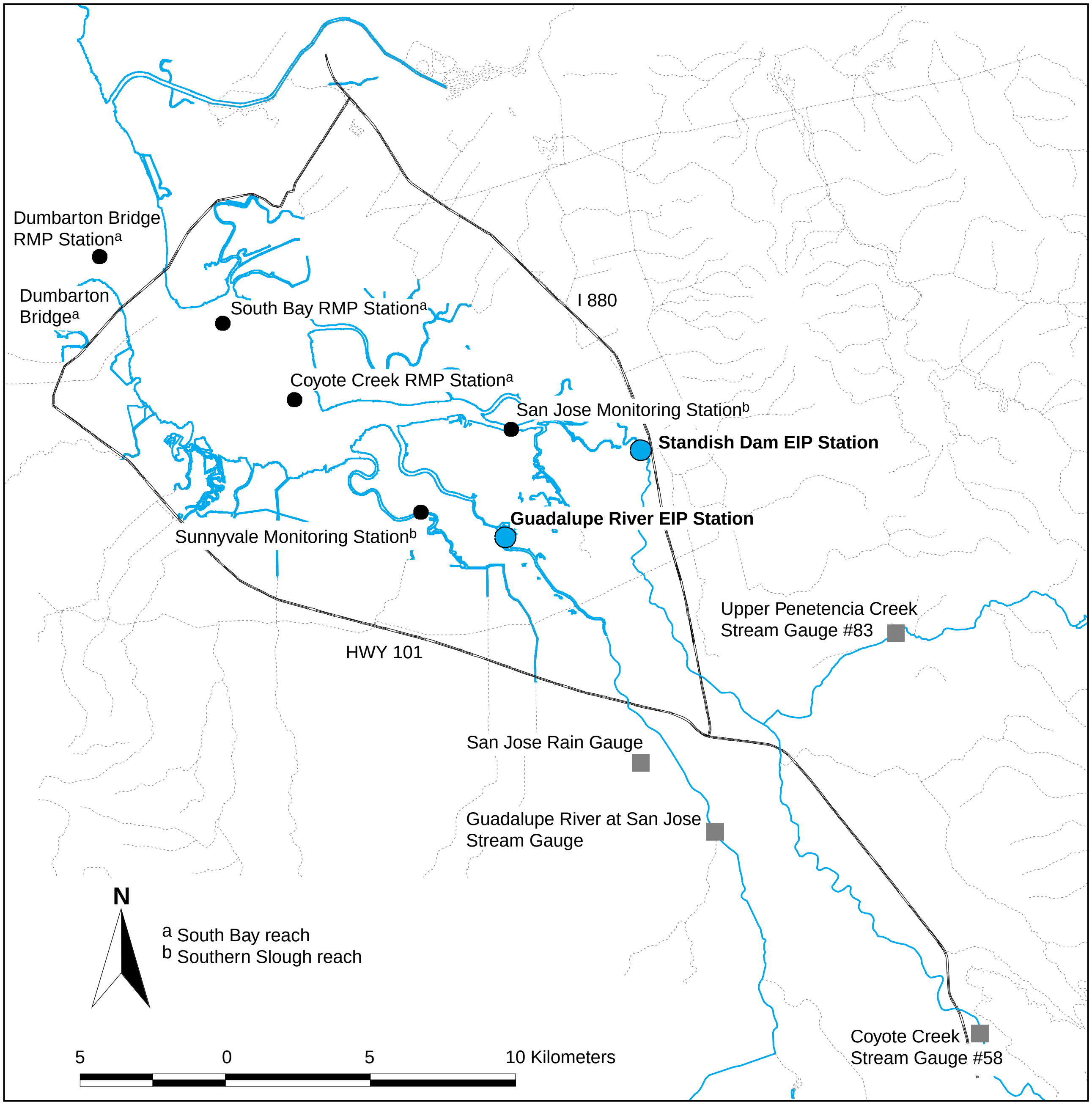

Figure 6.1. Map of Estuary Interface Pilot Study stations.

pollutant signal, while during the dry season, water sampled at both stations was a brackish mix of both freshwater runoff and Bay water. Both sites were selected for their accessibility, location in the brackish transitional zone, and the fact that sediment deposition and accumulation was likely to occur. The winter of 1996/97 was very unusual in that rains produced extremely high runoff during December and January, while very little precipitation occurred during subsequent months.

The same parameters in water and sediment were measured here as in the Estuary at approximately the same times (late February/early March, late April, and early August). The sampling methodology for water was similar to that employed by the RMP. Sediment was sampled from the creek bank at low tide using a Dykon®-coated scoop (see *Appendix A: Methods*). Any surface diatom layer was removed before collecting the top five centimeters of an area approximately the same size as the van Veen grab used at the Estuary stations. Each sample was then homogenized. The homogenate was divided into aliquots for analysis of trace elements, trace organics, conventional sediment parameters such as grain size, total nitrogen, and total organic carbon (TOC), and for archiving. Parameters analyzed in water included trace elements and trace organic contaminants, ammonia, chlorophyll *a*, dissolved organic carbon, hardness, nitrates, nitrites, pH, phaeophytin, phosphate, silicates, and total suspended solids (TSS). Parameters analyzed at the bottom as well as the top of the water column included conductivity, dissolved oxygen (DO), salinity, and temperature.

Flows

Because there are no currently operating stream gauges near the mouth of Coyote Creek, its flow was calculated by combining flow data from the U.S. Gegological Survey (USGS) Stream Gauge Station 58 on Coyote Creek at Edenvale and Station 83 on Upper Penetencia Creek, a major tributary to Coyote Creek. This combined value is the best available estimate for Coyote Creek discharge into the South Bay in lieu of a stream gauge closer to the mouth of the creek. A USGS stream gauge currently operates on the Guadalupe River at San Jose approximately 11 km from the Guadalupe River Station, with no major tributaries between it and the station. Values from this stream gauge station were used for stream flow calculations. Rainfall data for both Standish Dam (BW10) and Guadalupe River (BW15) were taken from the San Jose rain gauge, which is the rainfall data source used in the Santa Clara Valley Non-Point Source Pollution Program (SCVNSS, 1991).

Stream and rain gauge locations are found in Figure 6.1. Flows peaked at an estimated 3,500 cubic feet per second (cfs) at Guadalupe River during January floods. The estimated flow on Coyote Creek during the January flood was approximately 5,300 cfs. Because of the high runoffs, Anderson Reservoir filled to capacity by January 23, began discharging over its spillway to Coyote Creek, and continued to do so throughout the remainder of the month. By February 1 flows had receded to where the reservoir was again below the spillway. Flows during the 1997 sampling were higher than those of 1996 (see Table 6.1). There are four reservoirs which empty directly or indirectly to the Guadalupe River: Calero, Almaden, Guadalupe, and Lexington. Calero Reservoir did not discharge over its spillway during the 1996/97 wet season. Almaden Reservoir spillway discharge occurred from January 1 through February 16, and from May 12 through May 30. Guadalupe Reservoir spillway discharge occurred from January 1 through January 8, and again from January 22 through January 27. Lexington Reservoir spillway discharge occurred from January 3 through January 8, from January 10 through January 31, and from April 1 through April 9. Stream and rain gauge hydrographs for Coyote/Penetencia creeks and Guadalupe River are shown in Figure 6.2.

Results and Analyses

All available data from this Pilot Study have been included in the data tables (see *Appendix C: Data Tables*). Total silver concentrations are not available. Total lead and dissolved silver concentrations are available for the wet season sampling period only. Dissolved lead concentrations are not available for the dry season. No values for silver

Table 6.1. Flows at the gauging stations on the EIP streams and tributaries.

Date	Station #58, Coyote Creek at Edenvale cfs	Station #83, Upper Penetencia Creek at Dorel Dr. cfs	Guadalupe River at San Jose cfs	Sample Type
3/4/96	725.00	64.00	567.00	water
3/8/96	813.00	33.00	461.00	sed
4/16/96	44.00	7.50	42.00	water
8/12/96	1.70	0.51	13.00	sed
8/16/96	2.20	0.47	15.00	water
2/7/97	487.00	22.00	253.00	water,sed
4/9/97	11.00	7.00	23.00	water
8/1/97	9.60	0.08	12.00	water
8/6/97	3.20	0.07	13.00	sed

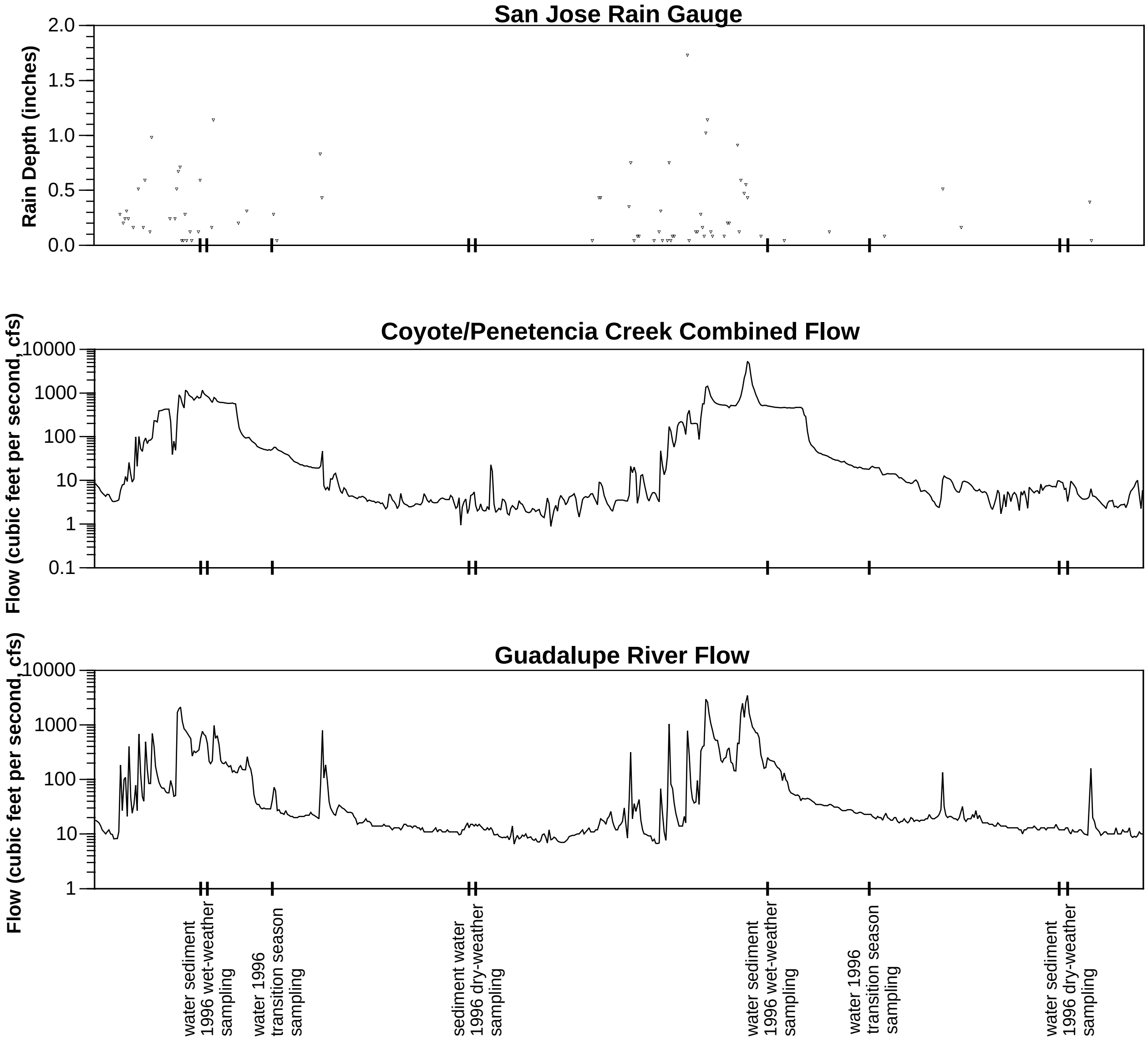

Figure 6.2. Estuary Interface Pilot Study hydrographs.

concentrations in sediment for the sampling event in late summer are reported due to blank contamination. Statistical analyses were performed using SAS (SAS Institute, 1990).

With a second year of data available for the Standish Dam sampling station, as well as a year's worth of data from the Guadalupe River station, additional analyses were performed. Potential seasonal differences between the EIP stations were examined, as were comparisons between years for the Standish Dam station. The mean values of the combined EIP stations (1996-97 Standish Dam and 1997 Guadalupe River) were pooled and compared with those of the other San Francisco Bay reaches during the same time period. Bay reaches are defined in the *Sediment Introduction*. They are, in addition to the EIP stations, the Southern Sloughs, South Bay, Central Bay, Northern Estuary, and Rivers. Significant difference of means was determined using one-way ANOVA and Tukey-Kramer Honestly Significant Difference (HSD; p = 0.05). Stream flow and rainfall data were examined in relation to contaminant concentrations measured in the EIP. Normalizing factors for contaminant concentrations in sediment were determined and used to account for possible variations in concentrations. It should be noted that the observed sediment concentrations are heavily influenced by flow conditions prior to sampling. During low-flow periods, sediment accumulates in the flat, low-energy reaches of the two creeks and is dominated by small particles in the clay-sized fraction. With the advent of the rainy season, flow velocities increase, thereby scouring the creek beds and banks and carrying smaller-sized particles into the Bay. At the time of the wet-season sampling events in mid-winter, the sediment accumulated during the low-flow periods had likely already been mobilized (see Figure 6.2) for EIP sampling in relation to rainfall and stream flow hydrographs.

Water Metals

Figure 6.3 shows the concentrations of dissolved trace metals in water. The wet season transitional sampling period (April, Cruise 14), showed the highest concentrations of most dissolved metals in the EIP stations, with the exception of mercury from the wet-season sampling (January, Cruise 13). Selenium was consistently higher at the Guadalupe River station for all samples; zinc was higher, and nickel slightly higher, at Standish Dam in the spring sampling. Concentrations of all dissolved trace metals except selenium were higher at Standish Dam in the 1997 sampling year than in 1996. The mean of the pooled reaches was significantly higher for the EIP stations than at any of the other Estuary reaches for selenium and zinc (one-way ANOVA, $p = < 0.0001$).

Figure 6.4 shows the concentrations of total trace metals in water. A similar seasonal pattern was found in the total trace metal concentrations as was found in the dissolved fraction. The wet-season transitional sampling period showed the highest concentrations in both EIP stations with the exception of selenium in both stations, and chromium, copper, and nickel at the Standish Dam station. The Guadalupe River station showed consistently higher concentrations of all total trace metals in the wet season transitional sampling period. Concentrations of all total trace metals were higher at Standish Dam in the 1997 sampling year than in 1996. The pooled mean was significantly higher for the EIP stations for selenium (one-way ANOVA, $p = < 0.0001$) than at any of the other Estuary reaches. The pooled mean values at the EIP stations for arsenic, mercury, nickel, and zinc were not significantly different from those for the Southern Sloughs, but were significantly higher than those of the other Estuary reaches (one-way ANOVA, $p = < 0.0001$).

Water Organics

Figure 6.5 shows the concentrations of dissolved trace organics in water. Dissolved PAHs and chlorpyrifos were higher in the spring samples at both EIP stations, and for chlordanes the Guadalupe River station concentrations were higher. DDT and dieldrin were higher at the Standish Dam station in the summer. Concentrations of dissolved PCBs, diazinon, and chlordanes were higher in the 1996 sampling year, while dieldrin, chlorpyrifos, and PAHs were higher in the 1997 sampling year at the EIP stations. The mean values of the pooled reaches were significantly higher for the EIP stations than the Estuary reaches for DDTs and chlordanes (one-way ANOVA, $p = < 0.0001$). The pooled mean value at the EIP stations for dieldrin was not statistically different from that of the River reach, but was significantly higher than those of the other Estuary reaches (one-way ANOVA, $p = < 0.0002$). The pooled mean values at the EIP stations for chlorpyrifos and PAHs were not significantly different from those for the Southern Sloughs, but were significantly higher than those of the other Estuary reaches (one-way ANOVA, $p = < 0.0001$).

Figure 6.6 shows the concentrations of total trace organics in water. DDTs, chlordanes, and dieldrin dominated in one or both of the EIP stations. Concentrations of dieldrin and PAHs were higher in the 1996 sampling year at the EIP stations. The mean values of the pooled reaches were significantly higher for the EIP stations than the Estuary reaches for DDTs and chlordanes (one-way ANOVA, $p = < 0.0001$). The pooled mean value for PAHs was not significantly different between the EIP stations and the Southern Sloughs, but was significantly higher than mean values at the other Estuary reaches (one-way ANOVA, $p = < 0.0001$).

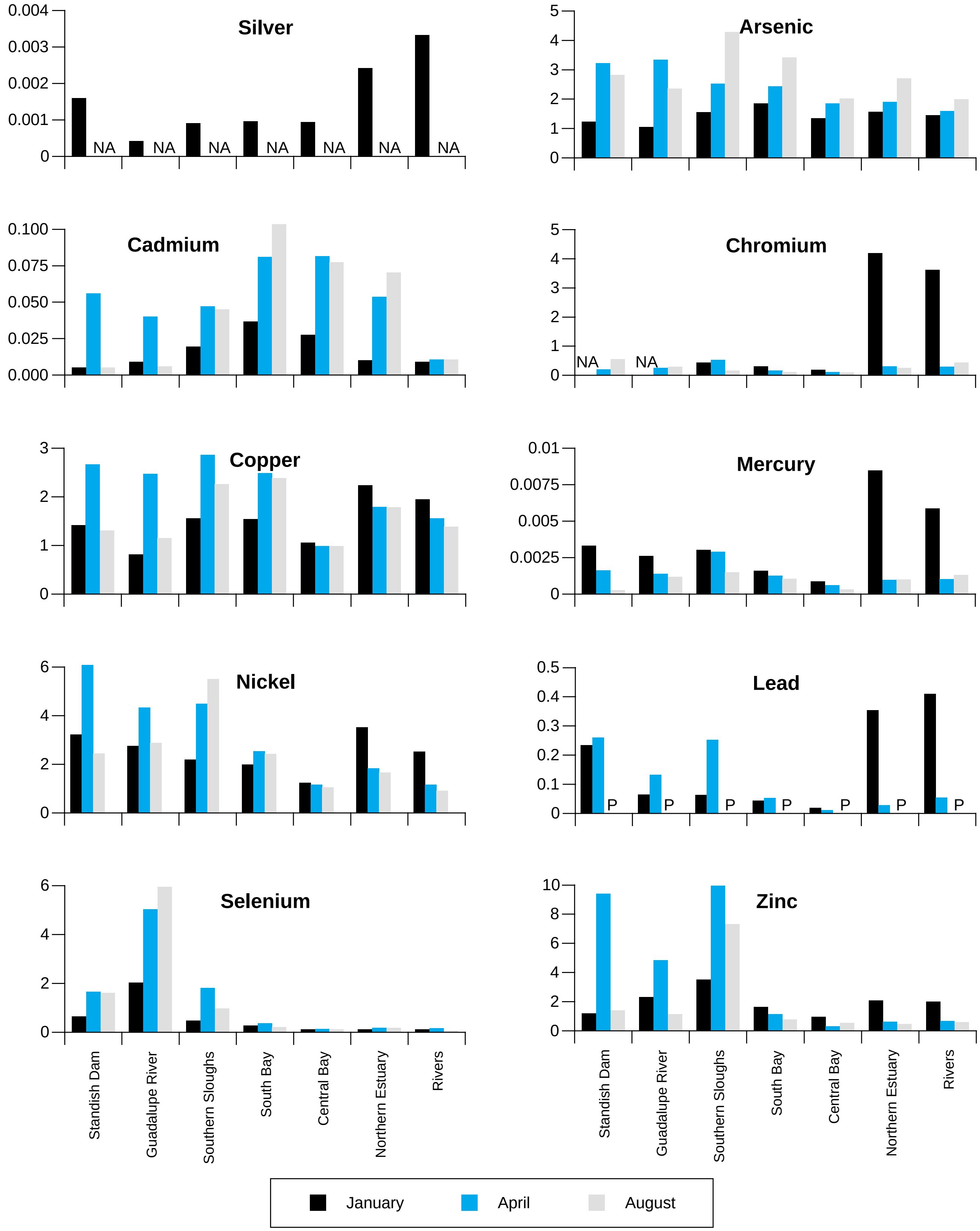

Figure 6.3. Concentrations of dissolved trace elements in water at the EIP sites compared with RMP stations averaged by Bay reach, 1997. NA = not analyzed. P = data pending. All concentrations are in parts per million (ppm).

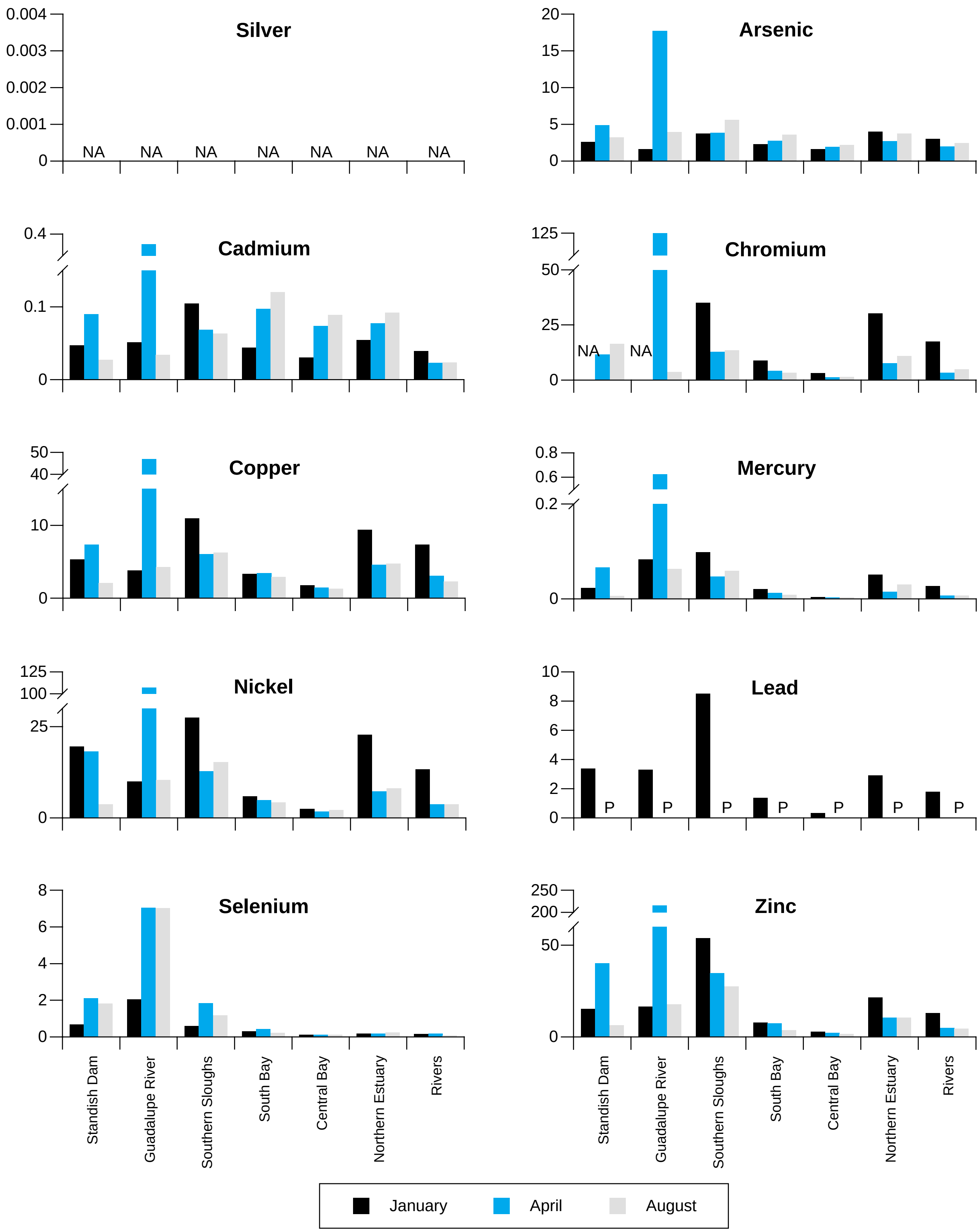

Figure 6.4. Concentrations of total trace elements in water at the EIP sites compared with RMP stations averaged by Bay reach, 1997. NA = not analyzed. P = data pending. All concentrations are in parts per million (ppm).

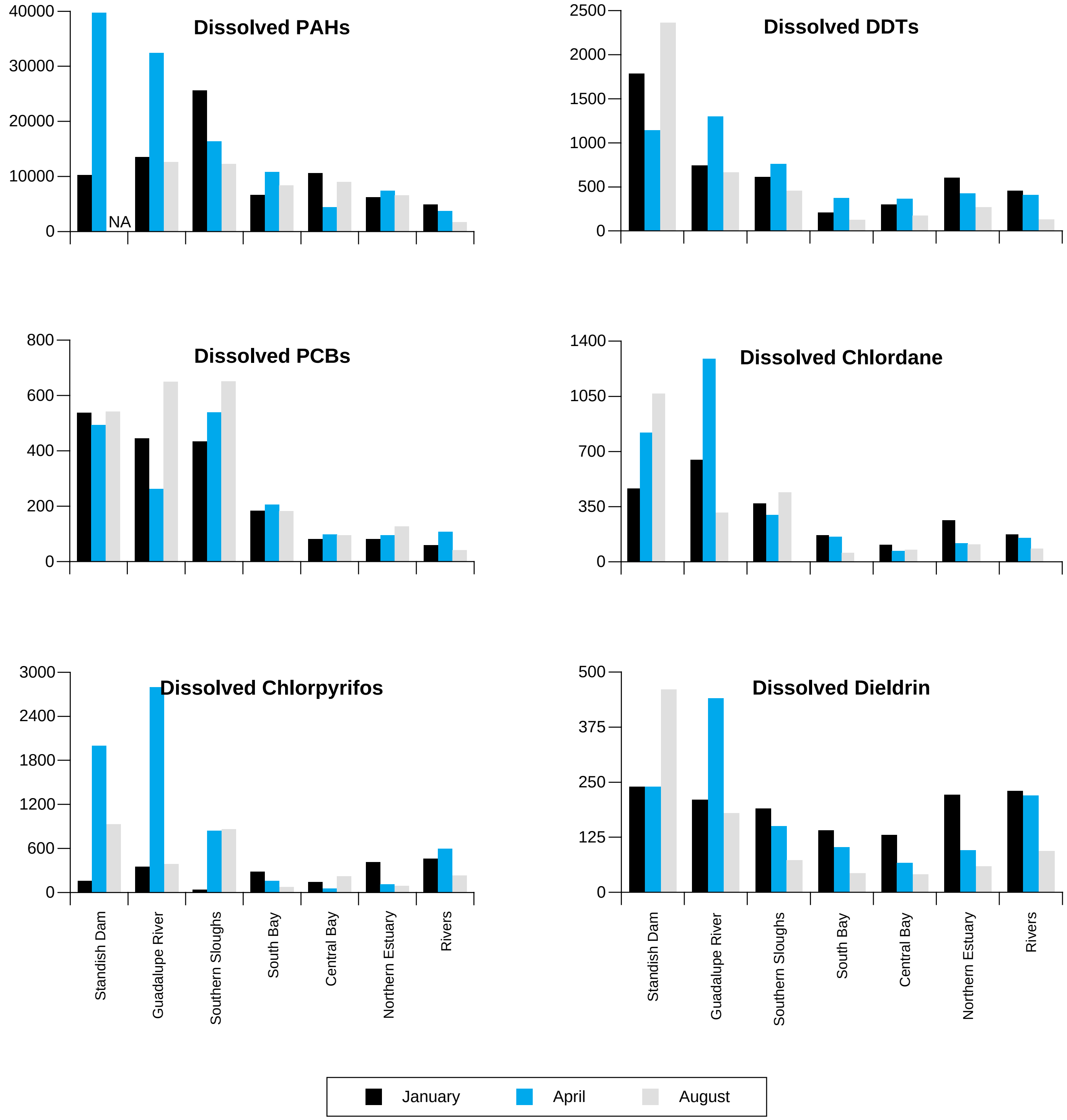

Figure 6.5. Concentrations of dissolved trace organics in water at the EIP sites compared with RMP stations averaged by Bay reach, 1997. NA = not analyzed. All concentrations are in parts per quadrillion (ppq). Concentrations of diazinon were below detections in the dissolved fraction of water at most stations, and therefore not represented.

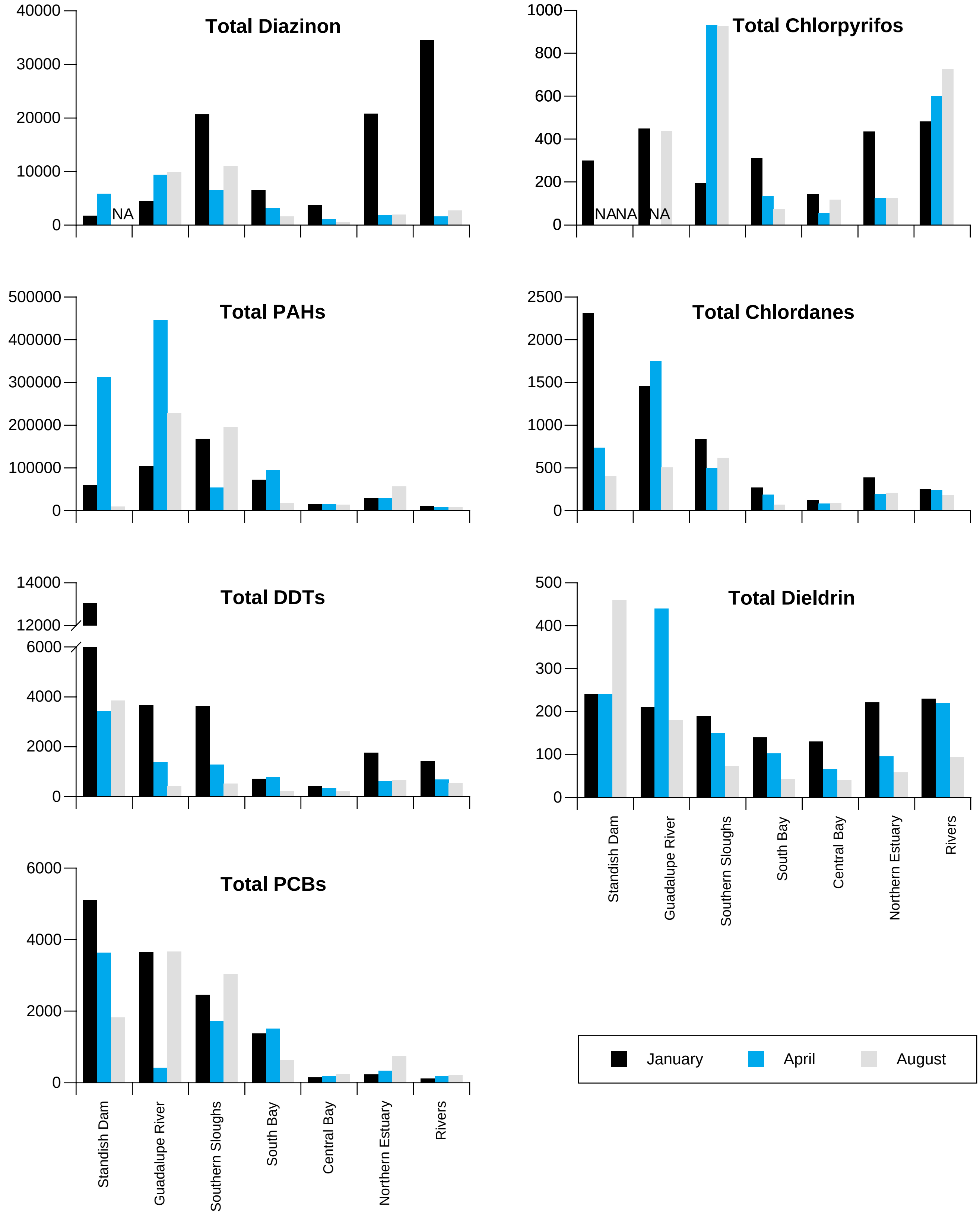

Figure 6.6. Concentrations of total trace organics in water at the EIP sites compared with RMP stations averaged by Bay reach, 1997. NA = not analyzed. All concentrations are in parts per quadrillion (ppq).

Sediment Metals

All raw trace metal concentrations at the EIP stations, except selenium, were higher in the 1997 sampling year compared to 1996. The mean raw concentrations of trace metals at the EIP stations were not significantly different than those of the other reaches, with the exception of cadmium. The mean raw concentrations of cadmium at EIP and Southern Slough stations were not significantly different from each other but as a group these were significantly higher than concentrations at the other reaches (one-way ANOVA, p = < 0.0001). The EIP, Southern Sloughs, and South Bay stations were not significantly different from each other, but as a group exhibited significantly higher metals concentrations than the other Bay reaches (one-way ANOVA, p = < 0.0002).

Sediment Contaminant Normalization

A common practice used to improve the sensitivity of comparing trace element and organic contaminant concentrations in sediments is to normalize them to some sediment constituent which is unaffected by human activities such as contaminant input (Luoma, 1990; Hanson, 1993; Daskalakis and O'Connor, 1995). Some of the constituents commonly used include aluminum, iron, TOC, and grain size (Daskalakis and O'Connor, 1995). Statistically speaking, these are *independent variables*, i.e. their concentrations are independent of the variable being examined, the *dependent variable*. The dependent variable in this case is defined as the organic or trace element contaminant whose concentration is dependent on the concentrations of the independent variable(s) found in the sediment.

Since all four of the independent variables mentioned above were analyzed in this pilot study, the first step in the normalization process was to determine how they were correlated with each other. If there was a high correlation between the four independent variables, it would then be possible to reduce the group to a single representative normalizing analyte. This was indeed the case. A Pearson product-moment pair-wise correlation was used to determine if there was a significant linear relationship between the variables. Aluminum was significantly correlated with iron (r = 0.89; p = 0.0001), with clay (r = 0.74; p = 0.0001; a surrogate for grain size), and with TOC (r = 0.66; p = 0.0001). It was, therefore, chosen as the normalizing variable.

The next step was to calculate correlation coefficients for aluminum and the trace elements and organic contaminants. This was done using the Pearson product-moment pair-wise correlation. Chromium, copper, nickel, lead, selenium, and zinc had a correlation value r of at least 0.60 (p = 0.0001). Mercury was more closely correlated with TOC than with aluminum (r = 0.57; p = 0.0001). Silver, cadmium, and total chlordanes, PAHs, PCBs, and DDTs had lower correlations (r < 0.50) with both aluminum and TOC. Interestingly, TOC was not significantly correlated with any of the organic contaminants in the data set, which is contrary to what would be expected. All available 1997 RMP observations (n = 50 ≤ 102, depending on the analyte) were used in the above correlation calculations. The r values are found in Table 6.2.

Table 6.2. Pearson correlation coefficients r.

Pearson correlation coefficient (r) of aluminum and

	r	n	p
Cu	0.7983	52	0.0001
Cr	0.7598	52	0.0001
Se	0.7391	52	0.0001
Ni	0.6166	52	0.0001
Zn	0.6085	52	0.0001
Pb	0.5927	51	0.0001
Hg	0.5059	52	0.0001
Cd	0.3885	52	0.0044
PAHs	0.2896	51	0.0393
DDTs	0.1212	49	0.4068
PCBs	0.0456	45	0.7662
Ag	-0.0419	50	0.7728
Chlordanes	0.0121	50	0.037

Pearson correlation coefficient (r) of TOC and

	r	n	p
Cu	0.6977	51	0.0001
Se	0.6935	51	0.0001
Al	0.6645	51	0.0001
Pb	0.6000	50	0.0001
Hg	0.5719	51	0.0001
Ni	0.5451	51	0.0001
Cr	0.5258	51	0.0001
DDTs	0.4373	48	0.0019
Zn	0.3974	51	0.0039
Cd	0.3330	51	0.0169
Ag	0.3166	49	0.0267
PAHs	0.2685	50	0.0593
Chlordanes	0.1954	20	0.4091
PCBs	0.1780	44	0.2476

Now it is possible to calculate an adjusted (i.e., normalized) value which takes into account these independent variables. This value is commonly expressed as a ratio of the contaminant concentration for which there was a significant correlation divided by the concentration of Al (or in the case of Hg with TOC) at each site. Figure 6.7 shows normalized values for the 1997 data compared with the corresponding raw values.

Figure 6.8 shows the concentrations of all available trace metals in sediment. Raw value concentrations at the Standish Dam station were higher in the summer than in the winter for all trace metals. However, when normalized for aluminum, all trace metals at this station except chromium were higher in the winter in relation to summer. Looking at raw value concentrations, there were no predominant seasonal differences at the Guadalupe River station except for mercury, which was higher in the winter. However, when normalized for aluminum, trace metals were higher in the winter sampling period for chromium, copper, nickel, lead, selenium, and zinc. These results are not surprising, since high flows prior to wet-season sampling had removed the finer particle sizes that generally contain greater contaminant mass per unit weight than larger sediment particles. Therefore, the relative concentrations of these contaminants, after normalizing for aluminum, were greater in the winter sampling period with its greater hydrographic activity.

Sediment Organics

Figure 6.9 shows the concentrations of trace organics in sediment. Concentrations of PCBs, DDTs, and chlordanes were higher in wet-season samples compared to those collected during the dry season, but total PAHs were higher in the dry-season samples. Because dieldrin was below the detection limit at most of the stations, it was not included in these analyses. As in 1996, the 1997 sampling year showed that EIP stations had the highest concentrations of DDTs and chlordanes. There was no significant difference in concentrations of PAHs or PCBs at Standish Dam in the 1996 sampling season compared with 1997. Chlordanes were higher, and DDTs slightly higher in 1997. There was no difference in the mean concentration of PAHs at the Estuary interface stations compared with the other Bay reaches. The mean concentrations of total chlordanes was significantly higher at the EIP stations than the other Bay reaches (one-way ANOVA, $p = < 0.0001$). The mean concentrations of total DDTs at the EIP stations were significantly higher than concentrations at the other reaches (one-way ANOVA, $p = < 0.0001$).

PCB Fingerprinting

Analysis of the congener spectrum of PCBs to discern source, fate, and transport patterns has been undertaken in a number of studies (van Bavel, 1997; Johnson *et. al.*, 1998). A congener spectrum of this sort is often called a “fingerprint”. PCB fingerprints were generated from samples collected at the EIP stations and representative stations in all reaches of the Bay, for the dissolved and particulate fractions of water and for sediments, for all cruises.

Similar patterns of higher molecular weight congeners dominated in the EIP and South Bay in both the water fractions and the sediments. These patterns were distinctly different from those measured in the rest of the Bay, which consisted of higher percentages of the lower weight congeners, and lower overall concentrations. A concentration gradient can even be seen between the EIP stations, which are higher, and San Jose (C-3-0), the representative South Bay station. This suggests a possible ongoing source load near the EIP stations, and a mixing of the PCB congener signal away from the watersheds. An example of a PCB fingerprint is shown in Figure 6.10.

The concentration gradients found in the water fractions between the EIP stations and South Bay representative station San Jose (C-3-0) were not seen in the sediment samples. On the contrary, the concentrations of PCB congeners at San Jose (C-3-0) were at least as high if not higher, which suggests that this area could be a PCB sink for sediments transported away from the EIP stations. There was, however, a discernible sediment concentration gradient between Coyote Creek (BA10) and the rest of the South

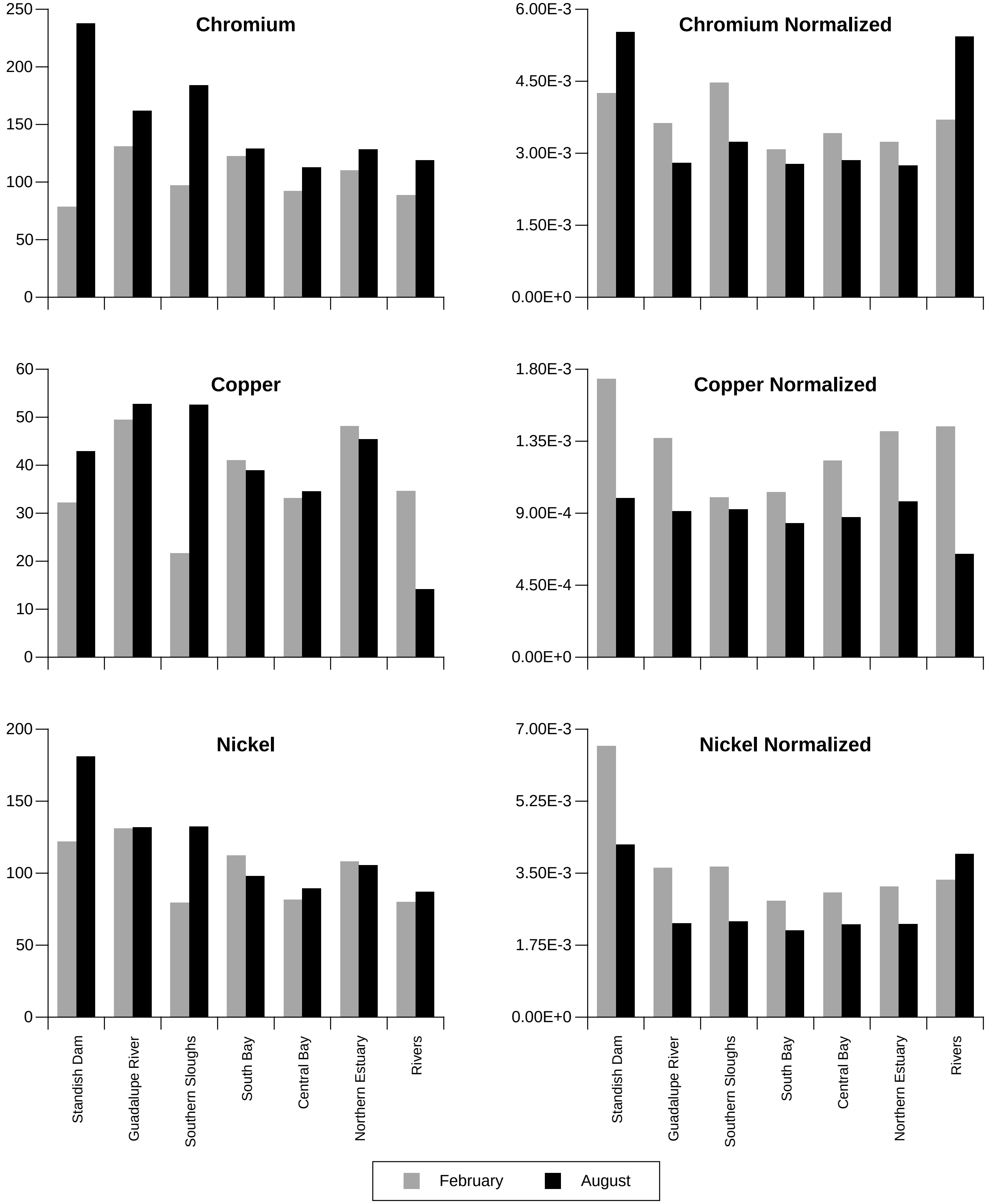

Figure 6.7. Normalized versus non-normalized values. Concentrations of trace elements in sediments for the Standish Dam and Guadalupe River sites compared with RMP stations averaged by Bay reach, 1997. Non-normalized concentrations in parts per million (ppm). Normalize values ratio of trace element concentration/concentration of aluminum.

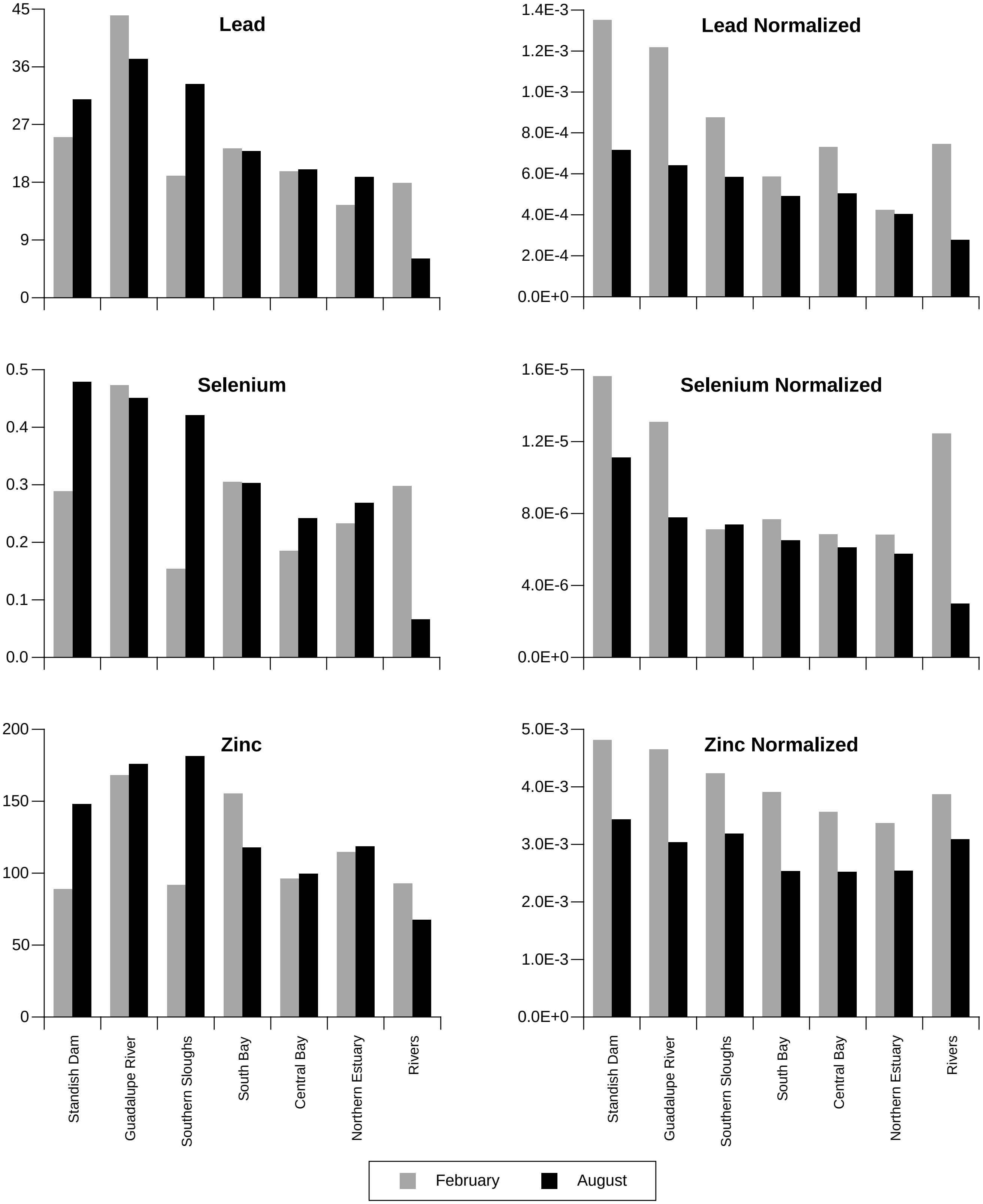

Figure 6.7 (continued). Normalized versus non-normalized values. Concentrations of trace elements in sediments for the Standish Dam and Guadalupe River sites compared with RMP stations averaged by Bay reach, 1997. Non-normalized concentrations in parts per million (ppm). Normalize values ratio of trace element concentration/concentration of aluminum.

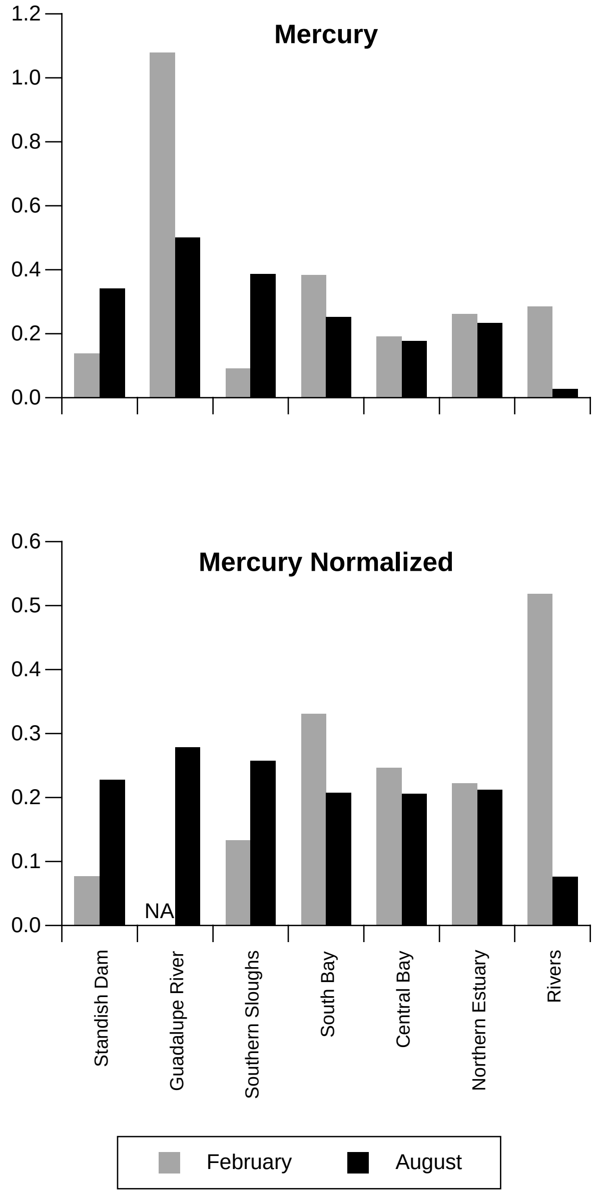

Figure 6.7 (continued). Normalized versus non-normalized values. Concentrations of trace elements in sediments for the Standish Dam and Guadalupe River sites compared with RMP stations averaged by Bay reach, 1997. NA = not analyzed. Non-normalized concentrations in parts per million (ppm). Normalize values ratio of trace element concentration/percent total organic carbon.

Bay stations. Furthermore, the South Bay as a whole exhibits higher PCB concentrations in sediment than do the other Estuary reaches and the EIP stations. Similar gradient patterns are seen in other localized watershed sampling efforts in the Bay. Preliminary data from the San Leandro Bay Project (see Daum and Thompson, 1998) strongly suggest localized inputs of PCBs, as well as PAHs, and some trace metals.

Water Particulates and Sediments

In order to assess whether the Coyote Creek or Guadalupe River watersheds contribute significant sources of trace metal or organic contamination, the concentrations of these contaminants which are on the particulate fraction of the water coming into the Bay must be determined. This was done for three trace metal contaminants of concern: copper, mercury, and nickel. Particulate concentrations for each metal were calculated by subtracting the filtered (dissolved) concentration from the unfiltered (total), with the difference being the particulate fraction. Dividing this value by the total suspended solids (TSS) concentrations gave the normalized water particulate concentration. Each one of these measurements has an associated uncertainty, which can be calculated. The water particulate values from the EIP stations were then compared with the sediment and water particulate values in the Southern Sloughs and South Bay stations to determine if the EIP station concentrations were higher compared to those found in the other stations. Figure 6.11 shows these comparisons for the wet- and dry-season sampling events.

Sampling during the wet season showed roughly the same concentrations of water particulates and sediments for the EIP, Southern Sloughs, and South Bay stations for copper and nickel. The Guadalupe River station showed elevated levels of mercury. Results for the dry weather sampling were striking. Water particulate concentrations were much higher in all three metals and at both Standish Dam and Guadalupe River stations.

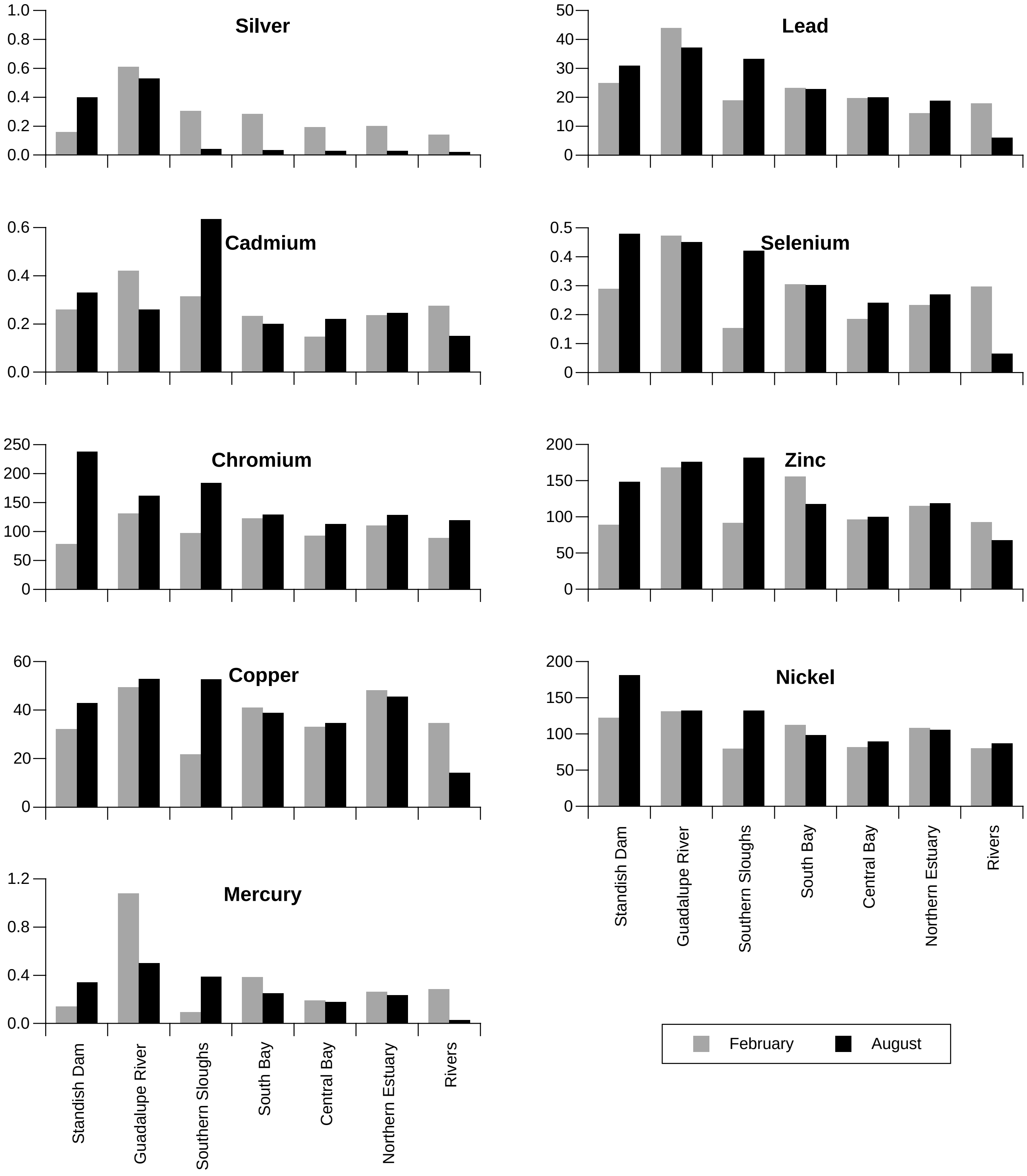

Figure 6.8. Concentrations of trace elements in sediments for the Standish Dam and Guadalupe River sites compared with RMP stations averaged by Bay reach, 1997. All concentrations in parts per million (ppm).

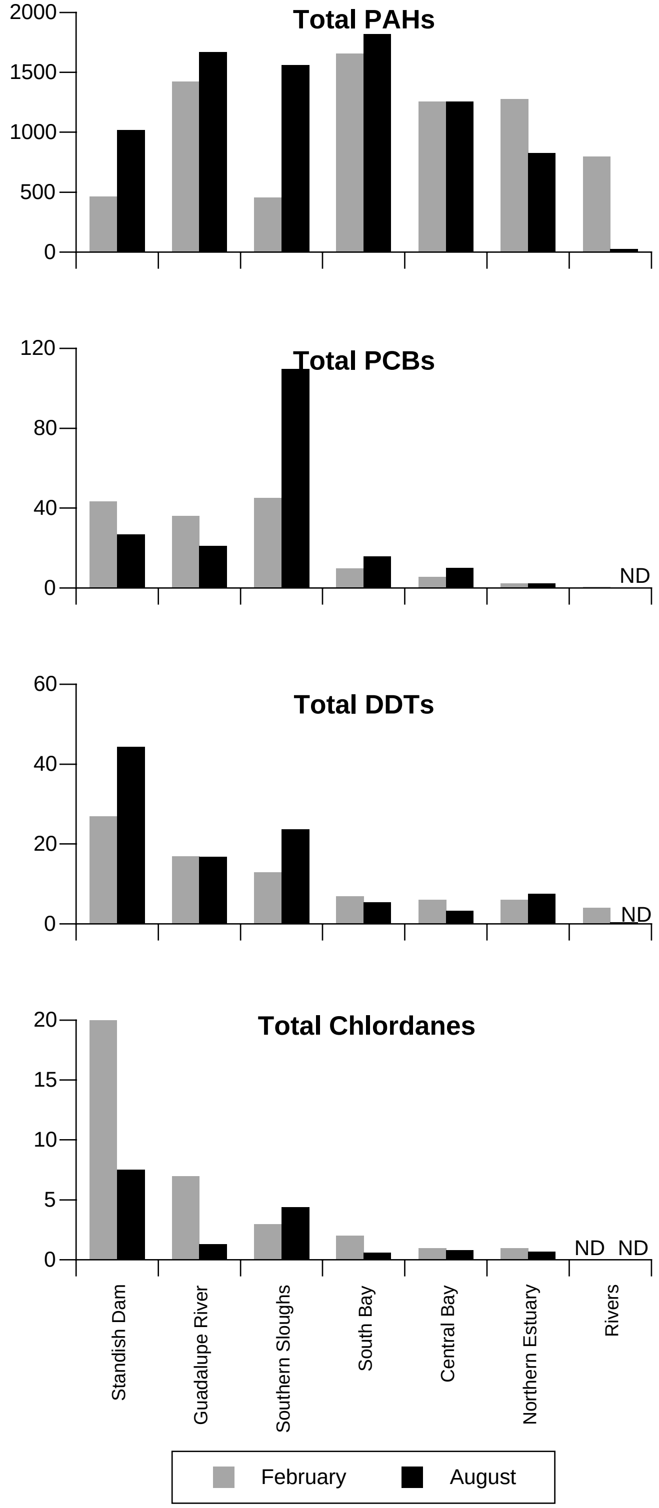

Figure 6.9. Concentrations of trace organics in sediments for the Standish Dam and Guadalupe River sites compared with RMP stations averaged by Bay reach, 1997. All concentrations in parts per billion (ppb). ND = below detection limit. Because dieldrin was below the detection limit at most stations, it was not included.

Conclusions

The second year of the Estuary Interface Pilot Study showed some definite patterns emerging. Although only two years of data have been analyzed, some conclusions can be made. There appear to be similarities in the concentration gradients in both of the EIP stations for many of the contaminants in both the water and sediment fractions. The particulate fraction of water entering the Estuary from the Guadalupe River in the dry season have concentrations of copper, mercury, and nickel which are greatly elevated compared to the respective sediment concentrations of these metals in the Southern Sloughs and South Bay. Hornberger *et al*. (1998) found background levels (i.e., not enriched by human activity) in Grizzly Bay and San Pablo Bay for mercury to be 0.06 ppb +/- 0.01; nickel 82–110 ppb; and copper 23–41 ppb. If the natural background levels in the Coyote Creek and Guadalupe River watersheds are comparable to Grizzly and San Pablo bays, then the incoming particulate metals' concentrations are indeed enriched. More study is needed to determine if this is the case.

It is also probable that copper, lead, and nickel are enriched over background levels in creek sediment, after normalizing for aluminum. The elevated mercury concentrations are probably due to the New Almaden Mine which is located in the Guadalupe River watershed. Results from the Santa Clara Valley Urban Runoff Pollution Prevention Program have indicated that suspended stream sediments are enriched compared to suspended sediments in the South Bay for copper, lead, and nickel among others, which might be contributors to the elevated sediment levels noted here. And formerly widespread use of pesticides, including chlordanes, occurred in both watersheds prior to use restrictions and have been found in urban runoff (BASMAA, 1996; SFEI, 1998).

Specific events such as tidal or storm-influenced shifting water masses, with the resulting pulses of TSS loading, can skew the calculated particulate concentrations for metals and organics. This may explain some of the observed concentration peaks as being artifacts of these events, which are especially acute at the EIP stations. The

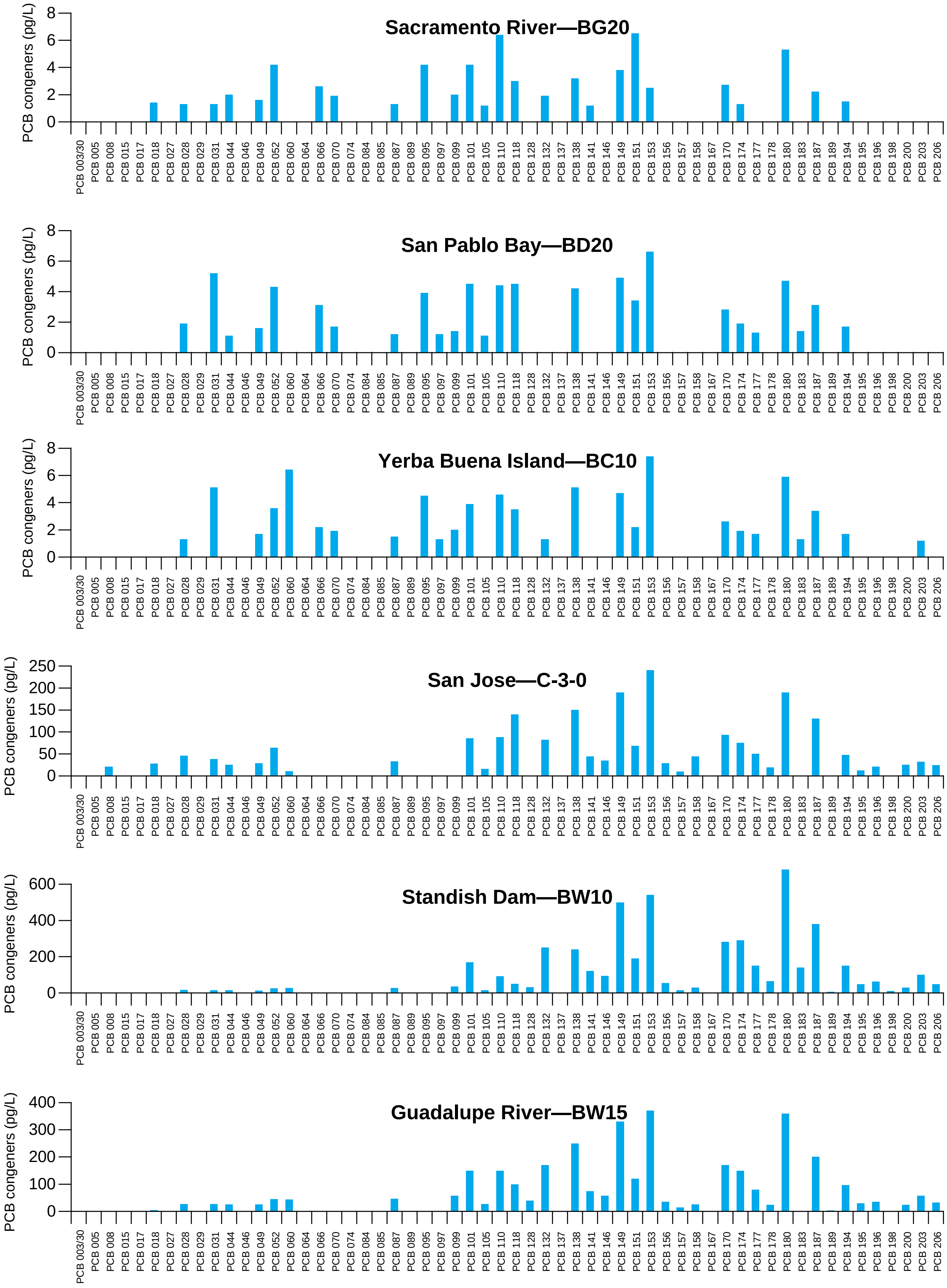

Figure 6.10. PCB fingerprint of the water particulate fraction from the wet season cruise for the Estuary Interface Pilot Program stations and a representative station from each of the reaches.

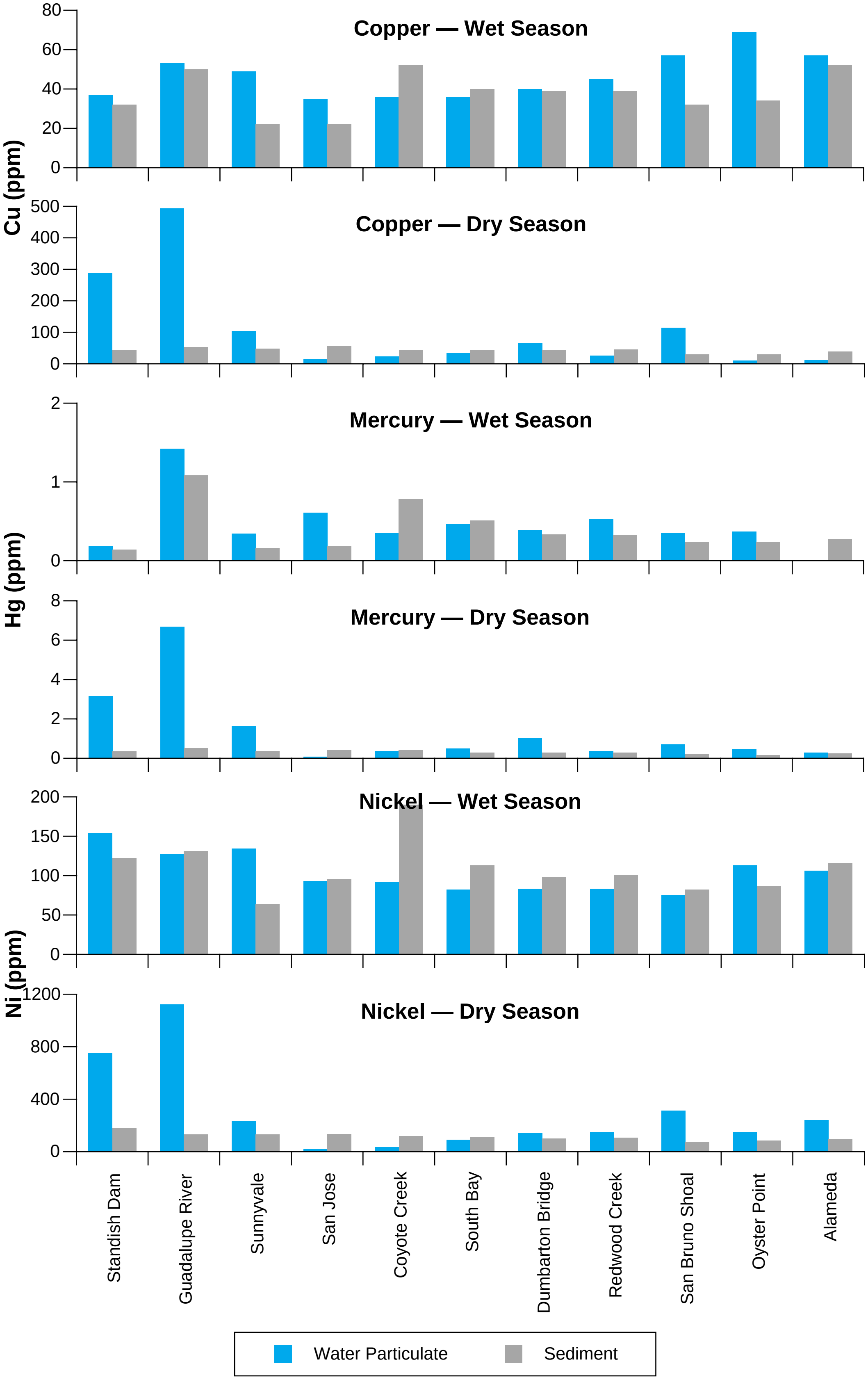

Figure 6.11. Concentrations of trace elements on water particulates and sediments at the Estuary Interface stations compared with the Southern Sloughs and South Bay stations.

RMP Base Program sampling effort is not frequent enough to incorporate these specific conditions, nor is it meant to be. Event-driven sampling, perhaps examining a limited suite of contaminants, could be undertaken to incorporate these conditions. Conversely, avoiding these conditions in the Base Program sampling may enable the collection of more truly representative ambient or background data.

Acknowledgments

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Contaminant Concentrations in Fish from San Francisco Bay, 1997: Summary[1]

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Introduction

In 1994 the Bay Protection and Toxic Cleanup Program (BPTCP) performed a pilot study to measure concentrations of contaminants in fish in San Francisco Bay (SFBRWQCB *et al*., 1995, Fairey *et al*., 1997). Screening values to identify chemicals of potential human health concern were calculated for the study based on U.S. EPA guidance (U.S. EPA, 1993). The study indicated that there were six chemicals or chemical groups that were of potential human health concern for people consuming Bay-caught fish: PCBs, mercury, DDT, dieldrin, chlordane, and dioxins.

As a result of this pilot study the Office of Environmental Health Hazard Assessment (OEHHA) issued an interim health advisory for people consuming fish from San Francisco Bay (OEHHA, 1994). The advisory states that:

1. Adults should limit consumption of Bay sport fish to, at most, two meals per month.
2. Adults should not eat any striped bass over 35 inches (89 cm).
3. Pregnant women or women that may become pregnant or are breast-feeding, and children under 6 should not eat more than one meal per month, and should not eat any meals of shark over 24 inches (61 cm) or striped bass over 27 inches (69 cm).

The advisory does not apply to salmon, anchovies, herring, and smelt caught in the Bay, other ocean-caught sport fish, or commercial fish. The advice was issued due to concern over human exposure to residues of methylmercury, PCBs, dioxins, and organochlorine pesticides in Bay-caught fish.

As a followup to the 1994 pilot study, an RMP Fish Contamination Committee, including representatives from government agencies, dischargers, and environmental groups, was set up to design a RMP component to measure fish contamination. The RMP Fish Contamination Committee developed two main objectives for the RMP fish contamination monitoring component:

1. To produce the information needed for updating human health advisories and conducting human health risk assessments.
2. To measure contaminant levels in fish species over time to track trends and to evaluate the effectiveness of management efforts.

A five-year workplan for the RMP fish contamination monitoring component was developed in 1997 and included: 1) a core monitoring program that is intended to be conducted every three years, 2) special studies, which are designed to answer questions that were brought up in the pilot study and will lead to a more scientifically sound and

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[1] This is a shortened version of a report “Contaminant Concentrations in Fish from San Francisco Bay, 1997”. The full report is available in hardcopy from SFEI, and on the internet at http://www.sfei.org.

cost-effective monitoring program in the future, and 3) development of a study design and survey instruments to measure the rates at which people consume fish caught in San Francisco Bay. This article describes results for the fish tissue core monitoring program and special studies conducted in 1997. The fish consumption study is currently in progress and results will be presented in a technical report in mid-1999.

The core monitoring program targeted seven species that are frequently caught and eaten by Bay fishers and seven popular fishing areas in the Bay (see methods for more details). Special studies included in the 1997 sampling were: 1) collecting and analyzing samples to determine variance among individual fish to assist in the future development of a more cost-effective study design; and 2) a study to determine the difference in contaminant concentrations of fillets of white croaker with and without skin. The second study was designed to determine whether removing the skin from muscle fillets could significantly reduce exposure to organic contaminants. This information should be valuable to public information efforts. Due to space limitations, results of analyses of variance among individual fish (#1 above) are not discussed in this article, but will be included in deliberations concerning design of the sampling to be performed in 2000.

Although the main focus of this study is on human health, it is important to note that the chemicals discussed in this article accumulate in the Bay food web and may also have an effect on other species at higher trophic levels. Studies of piscivorous birds and marine mammals in the Bay have found concentrations of persistent contaminants that appear to be high enough to impair the health of these species (Davis *et al*., 1997; Davis, 1997; Young *et al*., 1998).

Methods

The species and fishing locations in the Bay were selected for sampling based on available information on frequencies of catch and consumption by Bay fishers, continuity with the 1994 pilot study, and to provide a broad geographic coverage of the Bay. The locations sampled are shown in Figure 6.12. Sampling details are provided in Table 6.3.

Fish were collected between May 27, 1997 and July 25, 1997. Special efforts to collect sturgeon only occurred on several days in both March 1997 and October 1997. A complete description of the sampling methods and a detailed cruise report are available from the San Francisco Estuary Institute.

U.S. EPA (1995) defines screening values as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted. Screening values were calculated following U.S. EPA (1995a) guidance. Details about this approach are described in SFBRWQCB *et al.* (1995). A consumption rate of 30 g fish/day that applies to recreational fishers was used in calculating screening values. The only changes in screening values from the pilot study were for mercury and PCBs. A screening value of 0.233 µg/g wet for mercury was applied to the 1997 data based on an updated reference dose (U.S. EPA, 1995b). The mercury screening value applied to the 1994 data was 0.140 µg/g wet (SFBRWQCB *et al*., 1995). A screening value of 23 ng/g wet for PCBs was applied to the 1997 data based on an updated cancer slope factor (U.S. EPA, 1998). The PCB screening value applied to the 1994 data was 3 ng/g wet (SFBRWQCB *et al*., 1995).

Summary and Conclusions

Comparisons to Screening Values

As found in the 1994 pilot study (SFBRWQCB *et al*., 1995, Fairey *et al*., 1997), persistent toxic chemicals in Bay fish were found at concentrations of potential human health concern in 1997 RMP sampling (Tables 6.4 and 6.5).

Mercury exceeded the screening value in 44 of 84 samples. All collected samples of leopard shark and striped bass exceeded the mercury screening value. For some species, including leopard shark and striped bass, the older and larger fish accumulated higher mercury concentrations. Adjust-

Table 6.3. Fish contamination core monitoring program sampling design. Empty boxes were targeted but fish could not be collected.

Species	**White Croaker**	**Shiner Surfperch**	**Jacksmelt**	**Leopard Shark**	**Striped Bass**	**California Halibut**	**White Sturgeon**
Target # size classes	1	1	1	3	3	2	2
Target # fish per composite	5	20	5	3	3	3	3
Target size range (cm)	20–30	10–15	21–30	Small: 90-105 Medium: 106-140 Large: >140	Small: 45-59 Medium: 60-82 Large: >82		Small: 117-133 Medium: 134-183
# Size classes caught	1	1	1	2 (small and medium)	2 (small and medium)	1	2 (small and medium)
# Fish per composite	5	20	5	3*	3*	1	3*
Size range (cm)	20–30	10–15	20–30	Small: 91-102 Medium: 108-135	Small: 45-59 Medium: 60-82	55-92	Small: 117-128 Medium: 135-149
Tissue sampled	muscle with skin	muscle with skin	muscle with skin	muscle without skin	muscle without skin	muscle without skin	muscle without skin
South Bay Bridges		3 composites Hg+OCs X 3		2 small 1 medium Hg+OCs X 3	1 small 1 medium (2 fish) 8 individuals OCs X 2 Hg X 10	1 small Hg+OCs X 1	1 small 1 medium (2 fish) 1 individual Hg+OCs X 2 Se X 6
Oakland Harbor	4 composites Hg+OCs X 4 Dioxins X 1	3 composites Hg+OCs X 3	3 composites Hg+OCs X 3				
San Francisco Water Front	3 composites Hg+OCs X 3 Dioxins X 1	3 composites Hg+OCs X 3	3 composites Hg+OCs X 3				
Berkeley	4 composites Hg+OCs X 3 Dioxins X 1	3 composites Hg+OCs X 3	3 composites Hg+OCs X 3	2 small Hg+OCs X 2	1 small 1 medium (2 fish) Hg+OCs X 2	3 small 1 large Hg+OCs X 4	
San Pablo Bay	3 composites Hg+OCs X 3 Dioxins X 3	3 composites Hg+OCs X 3	3 composites Hg+OCs X 3	2 small 1 medium (1 fish) Hg+OCs X 3	2 small (one 12 fish megasample) 1 medium Hg+OCs X 3 Dioxins X 1	1 small 2 large Hg+OCs X 3	1 small 1 medium 1 individual Hg+OCs X 2 Se X 7
Davis Point**					2 small 1 medium 10 individuals OCs X 3 Hg X 13		
Suisun Bay					1 small Hg+OCs X 1		

* Except as noted

** Davis Point not included in original design

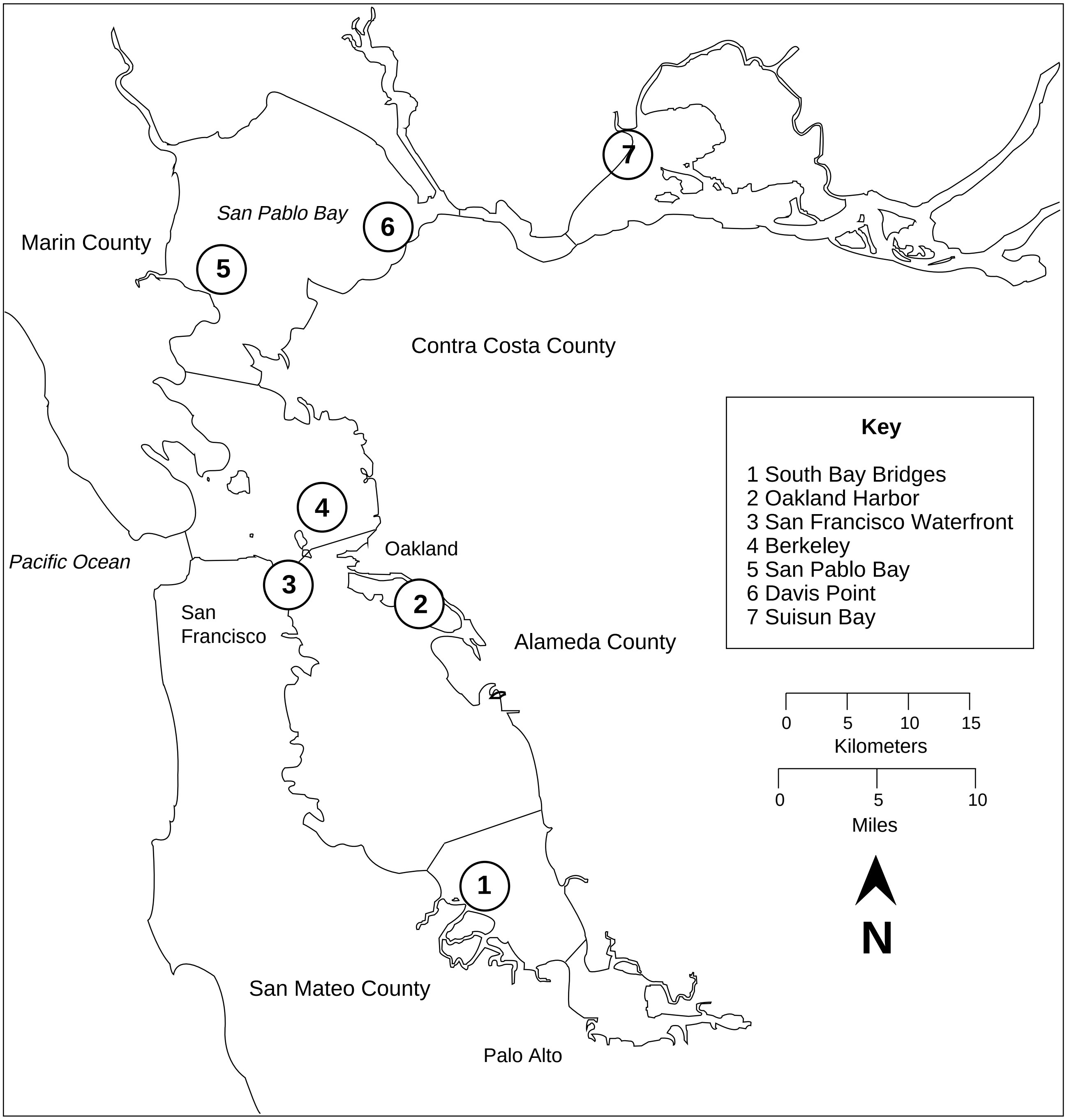


Figure 6.12. Sampling locations for 1997 RMP fish contamination monitoring.

ment of the data for variation in length was useful in evaluation of trends in mercury concentrations in space and time. Data obtained for individual striped bass suggest the existence of two groups of striped bass in the Bay, one with higher mercury concentrations than the other. The reason that striped bass of similar size might display this sort of variability is unknown at this time.

Concentrations of trace organics were highest in white croaker and shiner surfperch. Overall, PCBs exceeded the screening value in 51 of 72 samples. All of the white croaker and shiner surfperch samples exceeded the screening value for PCBs. Other trace organics had lower numbers of samples above screening values: 27 of 72 for dieldrin (including all 14 white croaker samples),

Table 6.4. Summary statistics by species for mercury and organochlorines. Data are medians.

	Number of Composites Analyzed	Number in Composite	Length (cm)	Mercury (µg/kg wet)	Lipid %	Sum of Aroclors (ng/g)	Sum of PCB Congeners (ng/g wet)	Sum of DDTs (ng/g wet)	Sum of Chlordanes (ng/g wet)	Dieldrin (ng/g wet)
Halibut	8	1	71	0.27	0.34	ND	14	6.6	1.6	0.2
Jacksmelt	12	5	26	0.09	1.85	45	37	34	3.4	0.8
Leopard Shark	8	3	101	0.88	0.24	13	11	5.3	1.1	0.2
Shiner Surfperch	15	20	12	0.11	2.52	179	134	54	8.8	1.7
Striped Bass	11	3	57	0.42*	0.82	34	27	16	3.0	0.8
Sturgeon	4	3	132	0.27	1.30	33	35	17	4.1	1.0
White Croaker	14	5	25	0.19	7.04	306	237	85	18	4.5

Table 6.5. Summary of concentrations above screening values for each species. Numerator indicates the number above the screening value, denominator indicates the number of samples analyzed.

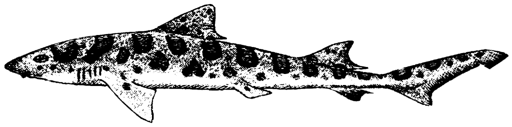
	Mercury (µg/g wet)	Sum of Aroclors (ng/g wet)	Sum of DDTs (ng/g wet)	Sum of Chlordanes (ng/g wet)	Dieldrin (ng/g wet)	ITEQs (pg/g wet)
Screening value	0.233	23	69	18	1.5	0.15
Halibut	5/8	1/8	0/8	0/8	0/8	
Jacksmelt	1/12	10/12	0/12	0/12	1/12	
Leopard Shark	8/8	1/8	0/8	0/8	0/8	
Shiner Surfperch	0/15	15/15	4/15	3/15	9/15	
Striped Bass	23/23	7/11	0/11	0/11	2/11	1/1
Sturgeon	3/4	3/4	0/4	0/4	1/4	
White Croaker	4/14	14/14	12/14	8/14	14/14	6/6
All Species	44/84	51/72	16/72	11/72	27/72	7/7

16 of 72 for DDTs, and 11 of 72 for chlordanes. Species with low lipid content in their muscle tissue, such as halibut and leopard shark, had the lowest concentrations of trace organics.

Dibenzodioxins and dibenzofurans were measured in six samples of white croaker and one sample of striped bass. ITEQs (dioxin toxic equivalents due to dibenzodioxins and dibenzofurans) in these samples were all above the screening value of 0.15 pg/g wet weight. Total TEQs (including the contributions of dioxin-like dibenzodioxins, dibenzofurans, and PCBs) in these seven samples averaged 9.7 pg/g wet weight, with a minimum of 3.7 pg/g and a maximum of 19.7 pg/g. Dioxin-like PCBs accounted for 83% of total TEQs. Dibenzofurans and dibenzodioxins accounted for 10% and 7%, respectively, of total TEQs.

Spatial Patterns

Significant variation in contaminant concentrations among locations was observed in the three species (white croaker, shiner surfperch, and jacksmelt) employed to evaluate spatial patterns. Spatial variation in wet-weight concentrations was observed, indicating variation in potential human exposure to contaminants of concern. Oakland Harbor had significantly elevated wet-weight concentrations of mercury (in shiner surfperch and jacksmelt), PCBs (shiner surfperch, white croaker, and jacksmelt), DDTs (shiner surfperch), and chlordanes (shiner surfperch, white croaker, and jacksmelt).



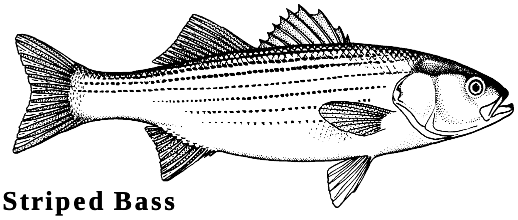
Leopard Shark

Spatial variation was also evaluated by adjusting the data for the important factors length and lipid content. These adjusted data may provide a better indication of spatial and temporal variation in contamination of the Bay. Length-adjusted mercury concentrations were relatively high at Oakland Harbor and San Francisco Waterfront (in jacksmelt). Lipid normalized concentrations of PCBs (in jacksmelt and shiner surfperch), DDTs (shiner surfperch), chlordanes (jacksmelt and shiner surfperch), and dieldrin (shiner surfperch) were elevated at Oakland Harbor. Lipid normalized PCB concentrations at Oakland Harbor were 11 times higher than at the sampling location with the lowest PCB concentration. The observation of similar spatial patterns in multiple species support the conclusion that the Oakland Harbor location exhibits elevated concentrations of multiple contaminants. These findings are consistent with observations of high concentrations of PCBs and organochlorine pesticides in sediment at this location (Hunt *et al.*, 1999). Overall, the results of the sampling for spatial patterns suggest that shiner surfperch and jacksmelt are useful indicators of spatial variation in contamination in the Bay.

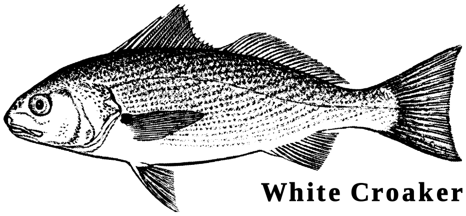
Temporal Trends

Mercury concentrations in 1997 were not significantly different from concentrations in 1994. In 1997 lipid-normalized concentrations of PCBs were significantly lower than in 1994 in shiner surfperch, white croaker, and striped bass, suggesting a possible general decline in PCBs in the Bay. Significantly lower concentrations were also observed for lipid-normalized DDTs (striped bass), chlordanes (striped bass and white croaker), and dieldrin (striped bass and shiner surfperch). Decreasing concentrations of these synthetic chemicals would be consistent with restrictions on their use that have been in place for many years. Lipid-normalized dioxin ITEQs were also significantly lower in 1997 than in 1994.

Continued monitoring will be required to establish whether the apparent decreases observed for PCBs, organochlorine pesticides, and dioxin ITEQs are real indications of declining masses of contaminants in the Bay. Other possible causes of these apparent declines include variation in the physiology or behavior of the fish sampled, changes in the structure of the Bay's food web, variation in analytical methods, or simply short-term fluctuation that is not indicative of a persistent long-term trend. The reason for the large differences in lipid concentrations observed in 1994 and 1997 are not understood and further emphasize the need for continued monitoring to determine trends over time. Continued fish tissue monitoring will also allow detection of changes that have not yet been indicated by results from just two sampling events (1994 and 1997).



Striped Bass



White Croaker

Other Conclusions

The use of multiple species for evaluating spatial and temporal trends proved to be valuable. Consistent trends were observed for multiple species, lending greater confidence to conclusions about spatial and temporal variation. The use of multiple species also offers the advantage of increasing the likelihood of obtaining target species, whose distribution in the Bay varies considerably.

Fish size (or age) and lipid content were identified as important factors influencing accumulation of persistent contaminants. Trophic level is probably also an important factor accounting for some of the variation in these results, but the trophic levels of the species sampled in the Bay are not well characterized. Understanding and accounting for these factors is essential to evaluation of spatial and temporal trends in contaminant concentrations.

Substantially lower concentrations of trace organics were measured in white croaker fillets with the skin removed. Concentrations of PCBs, DDTs, chlordanes, dieldrin, and dioxin ITEQs were reduced by 30–50%. These reductions were associated with lipid concentrations that were 33% lower in the fillets without skin. For some samples, skin removal resulted in reduction of chlordane and DDT concentrations to below screening values.

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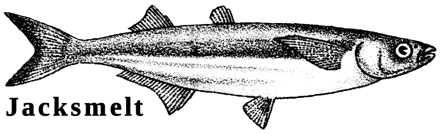
Alyce Ujihara, California Department of Health Services
Dan Watson, City of San Jose
Kristine Wong, Save San Francisco Bay Association
Steven Zeiger, Marin County Stormwater Pollution Prevention Program


Jacksmelt

Adrienne Yang and Nicole David worked on formatting the report and graphics. Jung Yoon and Samir Arora managed the data. Gabriele Marek assisted with contract management.

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CHAPTER 7

Related Monitoring Activities

Benthic Foraminifers in the Regional Monitoring Program's San Francisco Estuary Samples

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Doris Sloan, University of California, Berkeley, CA

Introduction

For over three decades, sand-sized protozoans known as foraminifers have made contributions to our understanding of environmental problems in urban areas (Alve, 1991; Clark, 1971; Ellison *et al*., 1986; Watkins, 1961). Benthic foraminiferal assemblages are particularly sensitive pollution indicators in estuarine and coastal areas (Alve, 1995) because they vary spatially and temporally in relation to environmental variables and can respond to almost imperceptible physical change in the environment due to pollutants. Foraminifers also have similar distributions to those of shallow marine invertebrates (Buzas and Culver, 1991, 1993), and can therefore act as proxies for larger organisms in polluted environments. In addition, the ability of foraminifers to respond to environmental degradation is enhanced because they reproduce quickly, as often as every three months to one year (Murray, 1991).

Benthic foraminifers are also useful in environmental studies because they are easily acquired, since they live primarily in the uppermost centimeters of sediment (Buzas, 1977; Collison, 1980) and are very abundant in marine and estuarine habitats (Buzas, 1978; Lankford, 1959); one study estimated that the maximum foraminiferal density at a single site was greater than 4 million living individuals per square meter with a sediment thickness of 1 cm (Sen Gupta, 1971). As primary consumers, foraminifers occupy a position near the bottom of the trophic structure of marine and estuarine communities, making them critical components of many, if not all, food chains (Lipps, 1983; Lipps and Valentine, 1970). They feed on items which cannot be utilized by most larger invertebrates, such as diatoms, bacteria, nannoplankton, detritus, small arthropods, small sea urchins, and other foraminifers (Lipps, 1983; Lipps and Valentine, 1970; Murray, 1991). They, in turn, are eaten by copepods, planktonic larvae, crabs, worms, scaphopods, shrimp, gastropods, fish, and other foraminifers. Any change at this low trophic level due to environmental degradation is worth investigating because it may subsequently be transmitted up the food chain.

The response of foraminiferal assemblages to industrial and municipal pollution has been documented in San Francisco Bay (van Geen *et al*., 1993) and in many other areas, including Southern California (Bandy *et al*., 1964a, 1964b, 1965a, 1965b; Seiglie, 1968; Watkins, 1961), the eastern United States (Ellison *et al*., 1986), and in many other countries (e.g., Canada, Norway, England, the Mediterranean, and the Caribbean). These and other studies have shown that the distribution of benthic foraminifers is affected by organic enrichment of the sediments, increased heavy metal loading, and other anthropogenic contamination. Foraminiferal response to heavy metal pollution, in particular, has been well documented with local extinctions resulting in barren zones where contamination levels are high, and in transitional to less polluted levels with assemblage modifications due to loss of diversity, disturbance of live activities and test deformation (double or enlarged apertures, twinning, protuberances, reduced chamber size, or twisted chamber arrangements; Alve, 1995).

Evidence suggests that *Trochammina hadai* Uchio, a foraminifer which is abundant in many Japanese estuaries (Figure 7.1.; Matoba, 1970; Matsushita and Kitazato, 1990; Uchio, 1962; and references therein), is a particularly valuable pollution indicator in that country because it dominates the foraminiferal assemblages in the most contaminated brackish water locations (Kitazato, oral communication, 1998). For example, core top sediment from Yokohama Port yielded 100% *T. hadai* (Toyoda and Kitazato, 1995), and assemblages with >50% *T. hadai* have been observed in the stressed environments of Hamana Lake (Ikeya, 1977), Matsushima Bay (Matoba, 1970), and Akkeshi Bay (Morishima and Chiji, 1951). Often these extreme abundances are found near the heads of the bays, suggesting that high input of anthropogenic organic matter may support these assemblages (Kitazato, written communication, 1998).

We first discovered *T. hadai* in the San Francisco Estuary in 1995 in sediment collected in 1993 near the San Francisco International Airport and Marin Islands (McGann, 1995; McGann and Sloan, 1996). Since then we have conducted a detailed investigation of past literature and archived foraminiferal samples (Arnal *et al.*, 1980;

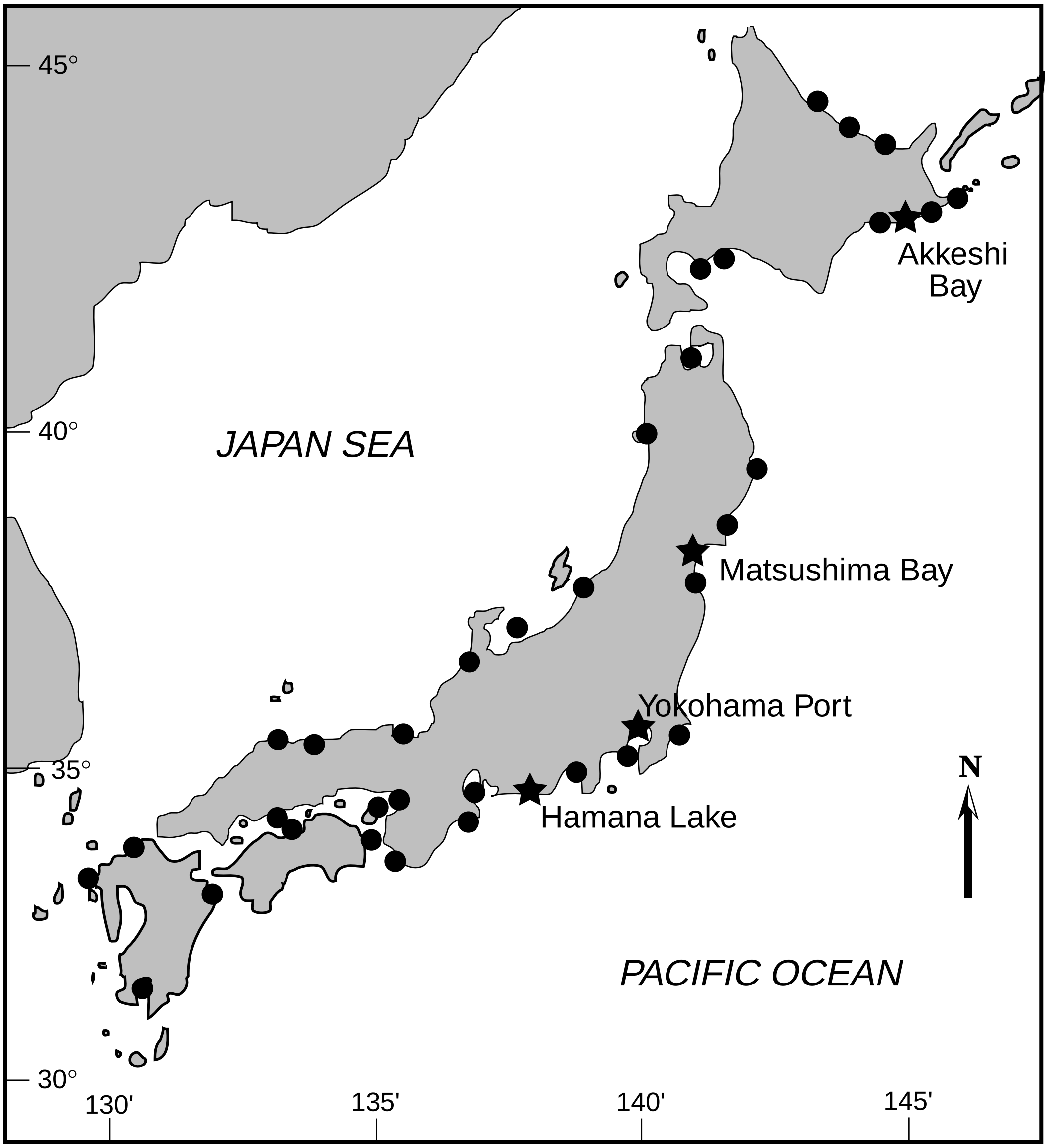

Figure 7.1. Location of the Japanese foraminiferal studies reporting the presence of *Trochammina hadai*. Sites with foraminiferal assemblages characterized by >50% *T. hadai* indicated by a star.

Locke, 1971; Means, 1965; Quinterno, 1968; Slater, 1965), and have determined that the species appears to have been introduced into the Estuary between 1981 and 1983. The earliest sample in which *T. hadai* has been found in the San Francisco Estuary is in one of four samples collected in 1983 from the southern Bay, where it constituted 3% of the foraminiferal fauna. By 1986–1987, *T. hadai* was present at all 46 stations in the southern Bay, dominating the assemblage with up to 89% of the foraminifers at these sites. The species was also found in all of nine sediment samples collected from central and southern Bay stations in 1990–1993, constituting up to 56% of the foraminifers.

Trochammina hadai could have been transported to the Estuary in the sediment associated with oysters used for commercial mariculture (Carlton, 1979), as ship hull fouling (WHOI, 1952), in anchor mud (Carlton and Geller, 1993), in ballast water, or in sediment from ballast tanks (Galil and Hülsmann, 1997). Yet, regardless of the mechanism by which the species was introduced, environmental conditions within the Estuary at the time of its arrival had to be conducive to the species' growth and reproduction in order for it to not only survive, but proliferate, as the evidence suggests. Japanese studies have indicated that the environment preferred by *T. hadai* is a very stressed one. Could the same be said for its new habitat in the San Francisco Estuary?

Because of the discovery of this invasive foraminiferal species in the Estuary, we approached the San Francisco Estuary Institute to join their Regional Monitoring Program with the intent to:

1. Investigate the spatial and temporal distribution of all foraminiferal species in the San Francisco Estuary. The last survey was completed over 1.5 decades ago (1980–1981; Sloan, unpublished data).
2. Monitor the present distribution and abundance of the invasive Japanese species *T. hadai*.
3. Determine what effect the introduction of *T. hadai* has had on the native foraminiferal assemblage in the San Francisco Estuary.
4. Note any associations between sites where foraminifers indicative of environmental stress, including specific species (e.g., *T. hadai*) and morphological abnormalities, have been recovered and the concentration of contaminants in the sediments at those sites as determined by the Regional Monitoring Program.

In this paper we report on the results of 2.5 years of bi-annual sampling (August 1995–1997) of foraminifers in the San Francisco Estuary.

Methods

Bulk sediment samples for microfaunal analysis were collected at 26 stations during the wet (February) and dry seasons (August). Sediment was obtained by subsampling the upper 2.5 cm of two successive van Veen grabs. An effort was made to obtain approximately 200 cm^3 of sediment at each site. In the laboratory, sediment samples were wet-sieved through nested 0.063 mm, 0.150 mm, and 1.0 mm screens to segregate the size fractions and remove the silt and clay-sized particles. Sediment remaining on the screens was transferred to filter paper and air-dried. Foraminifers were extracted exclusively from the coarser fraction (> 0.150 mm) and the < 0.150 mm fraction was archived. Analyzing only the larger size-fraction allows for faunal comparison with previous provincial studies in the eastern Pacific Ocean because most studies used this size fraction. Each sample was split with the aid of a microsplitter into an aliquot containing at least 300 benthic foraminifers, and all specimens were picked and identified from this aliquot. If the sample contained < 300 foraminifers, all that were present were picked. Sandy samples containing few foraminifers were subjected to sodium polytungstate floatation methods in order to concentrate the foraminifers before picking. The slides and residues of this study are on file at the U.S. Geological Survey in Menlo Park, California.

A cluster analysis of the relationships between the foraminiferal assemblages at the various sampling sites during the 2.5-year study was conducted using Data Desk statistical software.

Table 7.1. Common and minor foraminiferal species recovered in the RMP samples.

Common Species:

Ammonia beccarii (Linné),
Elphidella hannai (Cushman and Grant)
Elphidium excavatum (Terquem)
Trochammina hadai Uchio
Trochammina inflata (Montagu)

Minor Species:

Elphidium gunteri Cole
Haynesina germanica (Ehrenberg)
Jadammina macrescens (Brady)
Miliammina fusca (Brady)
Trochammina kellettae Thalmann

Results

Benthic Foraminiferal Assemblages

A total of 49 species of benthic foraminifers were recovered from the San Francisco Estuary sediment samples collected from August 1995–1997. Of these species, only five are common and five more are minor (Table 7.1). With the exception of *H. germanica*, these species are common in estuaries along the Pacific seaboard of North America (Murray, 1991) and have been used as ecological markers in sediments dated ~125,000 years before present in San Francisco Bay (Sloan, 1980, 1992).

A Q-mode cluster analysis of those samples with > 200 specimens grouped them into three clusters and numerous outliers. The vast majority of samples were joined into a single cluster. These samples are characterized by a dominant *T. hadai* assemblage (> 50%), with high abundances of *A. beccarii* and lower percentages of *E. excavatum*. This foraminiferal assemblage occurs in the "core" of the Estuary; that is, the center of San Pablo Bay, the central Bay, and the southern Bay down to Redwood Creek. Here the salinity ranges from approximately 28–32 ppt.

The second cluster grouped the Petaluma River samples and the August 1996 Pinole Point sample. These contain a foraminiferal fauna consisting of dominant *T. inflata* and lesser abundances of *A. beccarii* and *T. hadai*. *Haynesina germanica* and *Elphidium* spp. occur in this fauna as well, but are generally less frequent.

The last cluster joined the southern Bay stations of San Bruno Shoal and the Dumbarton Bridge. The overlying water is less saline than that to the north, and sediments obtained here include a varied foraminiferal assemblage dominated by *A. beccarii* and *E. excavatum*, lesser amounts of *H. germanica* and *T. hadai*, and rare *T. inflata*.

The stations in Suisun Bay and the extreme southern Bay were either outliers or were not included in the cluster analysis because of the low number of foraminifers obtained there. All of these stations are characterized by overlying waters with very low salinity and have similar foraminiferal faunas, with arenaceous species replacing calcareous forms. The common estuarine foraminifers *A. beccarii* and *E. excavatum* have been replaced by *T. inflata*, *M. fusca*, and *J. macrescens*. In contrast, the Sacramento River, San Joaquin River, and Guadalupe River stations contained no foraminifers, with the water here considered to be too fresh to support these organisms (Bradshaw, 1957, 1961).

Two other stations present somewhat unique foraminiferal faunas: Richardson and Horseshoe bays. The Richardson Bay sample from August 1995 is characterized by an unusually high percentage of *T. hadai* (86%) and *T. inflata* (12%), compared to the abundances of these species for February 1996–August 1997 (> 40% and > 5%, respectively). The lack of calcareous foraminiferal species in this sample suggests that it has been subjected to conditions conducive to dissolution. Further investigation of this sample is warranted.

Horseshoe Bay supports an unusual foraminiferal fauna for the San Francisco Estuary because it contains typical coastal marine species such as *Bucella frigida* (Cushman), *Cibicides lobatulus* (Walker and Jacob), *Nonionella stella* Cushman and Moyer, *Rosalina globularis* d'Orbigny, and *Bulimina denudata* Cushman and Parker, as well as abundant estuarine species *E. hannai*, *A. beccarii*, *T. hadai*, and *E. excavatum*. Such an "open ocean" fauna is not surprising due to this station's proximity to the Pacific Ocean.

A preliminary comparison of wet and dry season foraminiferal faunas at the 26 sites examined yielded variable results. Numbers of *T. hadai* in samples collected in February 1996 along the shipping channel through the northern Bay, San

Pablo Bay, and the central Bay near the Golden Gate are approximately half of the dry season values for August 1995 and August 1996 (Sloan and McGann, 1996). These abundances demonstrate the impact of decreased salinity, reflecting high freshwater inflow. However, in the southern Bay, although salinity decreased at all stations in February 1996, *T. hadai* abundances at most stations increased slightly. Unfortunately, the foraminiferal recovery in February 1997 was so poor at many of the stations that a similar trend could not be discerned. Separate Q-mode cluster analyses of August 1995–February 1996 and August 1996–February 1997 foraminiferal faunas were unable to discriminate between the wet- and dry-season samples. These data suggest that although minor fluctuations in species abundances exist, generally similar faunas were found to occur at each site throughout the year.

Invasive Foraminiferal Species *Trochammina hadai*

Trochammina hadai has dominated 32% of the sites throughout the 2.5 years of the RMP study (Figure 7.2a–e). The species was found at 17 sites where it constituted up to 93% of the foraminiferal fauna, but was not found at 7 locations in the extreme northern and southern ends of the Bay. This investigation has also found that the percent abundance of *T. hadai* in the Estuary has remained stable, albeit remarkably high, throughout the 2.5-year study period, and shows little, if any, seasonal alteration at all but a few sites along the shipping channel.

The species is abundant in RMP samples taken from the mud flats to a depth of 13 m (SFEI, 1996, 1997). It is euryhaline, living at salinities as low as 12–15 ppt, but is more prevalent where salinities range from 17.5–30 ppt. The species tolerates water temperatures from 11–19 °C, is more abundant on muddy rather than sandy substrates, and thrives in the Estuary's year-round saturated oxygen conditions. These environmental parameters are consistent with its distribution in Japan's estuaries and harbors (Matoba, 1970; Matsushita and Kitazato, 1990; Uchio, 1962).

While this 2.5-year study of San Francisco Estuary foraminifers has proven too short to determine what effect the introduction of *T. hadai* has had on the native foraminiferal assemblage, a core recovered from near San Francisco International Airport suggests that, at least for this one location in the Estuary, a profound change in the foraminferal population has occurred over the last 3,500 years (McGann, 1995). Until the appearance of *T. hadai*, the foraminiferal assemblage was dominated (55–85%) by *E. excavatum*. With *T. hadai*'s arrival, *E. excavatum* dropped to 19% of the foraminifers at 1–2.5 cm depth in the core, and has continued to decline to an average of 5% in the southern Bay. Continued analysis of the RMP's sediment samples and cores from other sources may allow us to better understand the timing and geographic extent of this faunal takeover.

Discussion

Pollution Effect on the Foraminifers

Although it must be noted that results of this phase of the study are only preliminary, we have found no foraminiferal barren zones at stations which have oceanographic conditions suggesting they should be present, though many stations in the RMP are characterized as having high concentrations of trace elements in the sediments (SFEI, 1997). In addition, very few specimens exhibited the typical abnormal test morphologies associated with contaminated environments. Instead, only occasional deformed chambers were recovered; well within the range considered normal for foraminiferal faunas (Alve, 1995).

The only other type of foraminiferal test deformation seen, which may be due to the presence of contaminants in the sediment, is a distinct reddish-brown encrustation or precipitate on the tests of a few specimens from Richardson Bay. This "growth" is similar to that seen on specimens recovered in the vicinity of Hunter's Point in San Francisco Bay, particularly in the region of the Navy docks and nearby power plant (McGann *et al.*, 1998). These areas are considered to be among the most polluted in the Bay, especially with regard to the heavy metals arsenic, chromium,

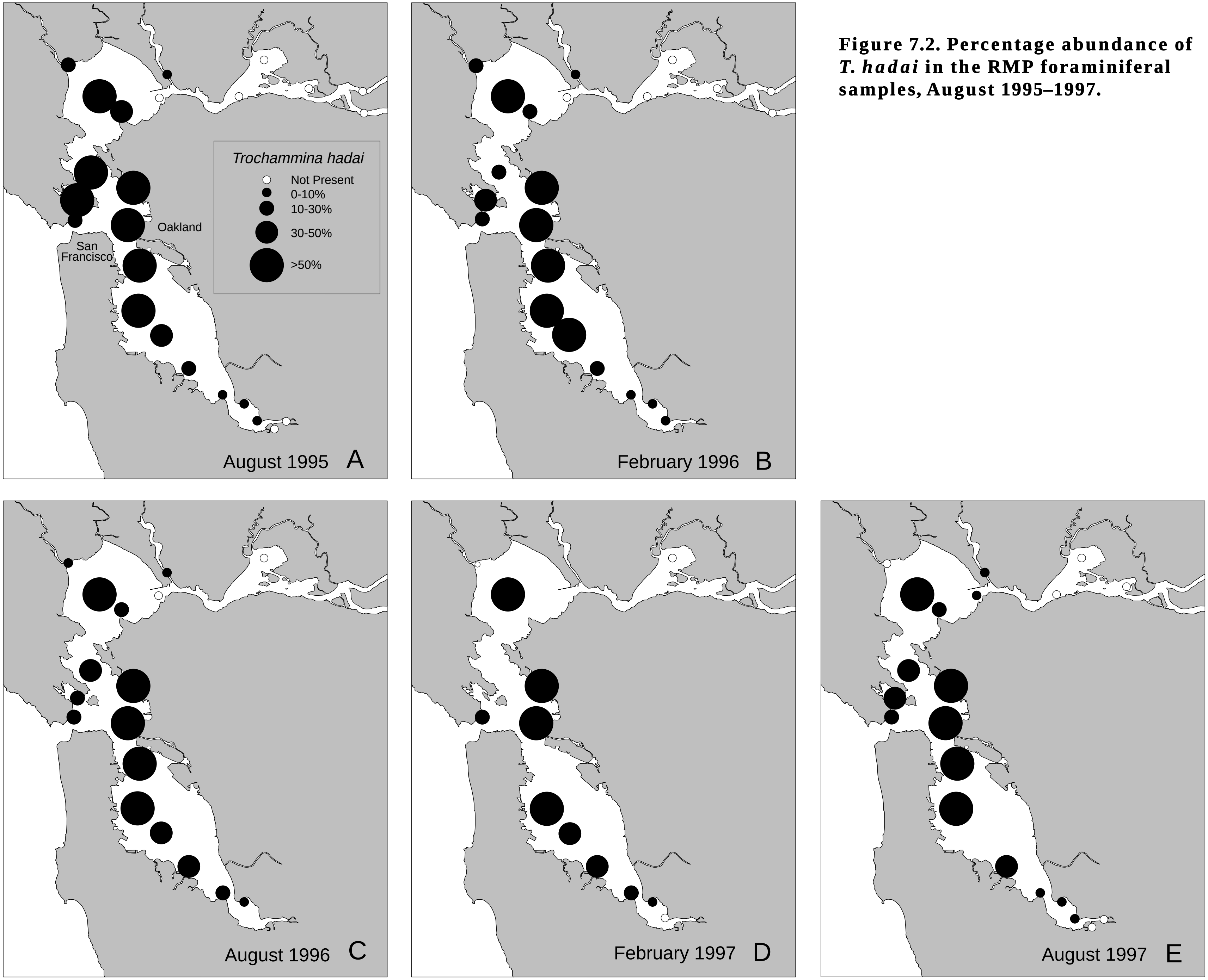

Figure 7.2. Percentage abundance of *T. hadai* in the RMP foraminiferal samples, August 1995–1997.

cadmium, copper, lead, nickel, zinc, and mercury. Benthic foraminifers recovered from the Hunter's Point region in 1986 and again in 1997 exhibit the encrustation. At a minimum, as with the Richardson Bay specimens, affected specimens display the encrustation on the dorsal side, usually at the proloculus, with one or more "iron-beads". In extreme cases, such as those seen at Hunter's Point, dorsal and ventral sides are heavily involved, resulting in all chambers being obscured, although the area immediately surrounding the aperture is never affected. This phenomenon may be due to the fact that the streaming of pseudopodia in this area is sufficient to retard the precipitate's growth (Kitazato, written communication, 1998) and suggests that the encrustation is not a post-mortem effect. EDAX and microprobe analyses of this encrustation demonstrates that it is composed of iron, phosphorus, aluminum, magnesium, sodium, and manganese.

The encrustation occurs almost exclusively on the tests of the exotic Japanese foraminifer *Trochammina hadai*. Of the two Hunter's Point samples collected in 1986, *T. hadai* comprises 59–66% of the foraminiferal assemblages, with two-thirds to three-fourths of these specimens displaying some evidence of the encrustation. In the Richardson Bay RMP samples, only *T. hadai* specimens are affected. The fact that nearly all of the affected foraminifers are specimens of *T. hadai* suggests that the encrustation is a chemical effect which occurs at or near the sediment surface, as *T. hadai* lives with its dorsal side up and dominates the foraminiferal assemblage in the uppermost 1 cm of sediment (Matsushita and Kitazato, 1990), although it has also been observed living on the sediment surface (Kitazato, written communication, 1998).

In contrast to the association noted in Japan, our preliminary investigation found no evidence of any relationship between the abundance of *T. hadai* and the level of contaminants in the San Francisco Estuary, except for the rare encrusted specimens recovered in Richardson Bay. Further study in the Estuary may help clarify whether, in fact, *T. hadai* can be considered a pollution-index species anywhere else besides Japan.

Further Work

The RMP's foraminiferal study described in this report has, after only 2.5 years of monitoring, enhanced our knowledge of the basic distribution of foraminifers within the San Francisco Estuary, and, specifically, the dominance of the introduced Japanese species *T. hadai*. Additional research is warranted to further characterize the temporal and spatial patterns of foraminifers within the Estuary, particularly since the conventional water characteristics (salinity, temperature, etc.) and concentrations of contaminants vary from year to year. We plan to expand the present data set by utilizing RMP archived sediment samples to investigate foraminiferal assemblages in the Estuary from the inception of the monitoring program to our initial involvement. Archived material has already been obtained for March 1993–February 1995. Among other things, we should be able to determine if the depauperate calcium carbonate foraminiferal assemblage noted in Richardson Bay in August 1995 is an anomalous occurrence, and if the pattern of dominance by *T. hadai* in the Estuary can be documented for a longer time period.

We also feel the study should shift to an investigation of the distribution of living foraminifera, enabling us to determine their absolute abundances within the San Francisco Estuary and where the foraminiferal species actually live, as opposed to where their tests are transported after death. From these data we can gain insight into the seasonal effects of river discharge and pollutants on the foraminiferal assemblages and also possible food web alterations with the presence of the organic matter-loving species *T. hadai*.

Acknowledgments

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Speciation of Nickel in South San Francisco Bay

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Introduction

Data collected as part of the RMP indicate that nickel concentrations in South San Francisco Bay occasionally exceed the U.S. EPA's proposed water quality criterion for marine waters of 8.2 mg/L (i.e., 140 nM). The two main sources of freshwater in South San Francisco Bay are wastewater effluent and surface runoff. Dissolved nickel concentrations are typically highest in South San Francisco Bay during summer, when the input of surface runoff is small relative to wastewater discharges. Dissolved nickel concentrations decrease during winter, when surface runoff greatly exceeds wastewater discharges.

The U.S. EPA's water quality criteria have been criticized because they do not consider site-specific factors that affect pollutant toxicity. Attempts to consider site-specific factors in regulations, such as the water effects ratio (WER) and the total maximum daily load (TMDL), must consider the different forms of nickel discharged by each source, because the toxicity of metals to aquatic organisms is positively correlated with the concentration of dissolved, uncomplexed metal (Sunda and Lewis, 1978; Sunda *et al*., 1978; Anderson and Morel, 1978).

Results of previous studies (Sedlak *et al*., 1997; Bedsworth and Sedlak, 1998) indicate that most of the nickel discharged by wastewater treatment plants consists of a strongly complexed form of nickel, $NiEDTA^{2-}$. In contrast, nickel in surface runoff in South San Francisco Bay consists mostly of uncomplexed nickel or weak nickel-organo complexes. The stronger complexes are thought to be significantly less toxic to aquatic organisms than uncomplexed nickel or weak nickel-organo complexes. Therefore, an assessment of the effects of nickel in South San Francisco Bay needs to consider the relationship between source speciation and nickel fate, transport, and toxicity in San Francisco Bay.

To assess the effect of speciation on nickel toxicity in South San Francisco Bay, data are needed on nickel speciation in the water column. The only available data on nickel speciation in South San Francisco Bay consist of two measurements made near the Dumbarton Bridge that indicated that approximately 60% of the dissolved nickel was complexed by a strong ligand (Donat *et al*., 1994). To further assess temporal and spatial variability in the speciation of nickel in San Francisco Bay and the relationship between nickel sources and speciation, samples collected during the 1997 RMP were analyzed for nickel speciation. The purpose of the study was to assess seasonal patterns in nickel speciation resulting from varying contributions from different nickel sources and to evaluate the stability of $NiEDTA^{2-}$ complexes discharged to San Francisco Bay.

Materials and Methods

Surface water samples were collected during the 1997 RMP. After collection, filtered samples were stored on ice and transported to the University of California at Berkeley, where they were frozen until analysis. Samples were analyzed for nickel speciation using competitive ligand exchange/cathodic stripping voltammetry (CSV) as described elsewhere (Donat *et al*., 1994; Bedsworth and Sedlak, 1998). Direct measurements of $NiEDTA^{2-}$ were not performed because the concentrations of the complex were expected to be near or below the limit of quantification in all samples, except those collected immediately proximate to the outfall of the San Jose/Santa Clara Water Pollution Control Plant (SJSC WPCP).

Results

Concentrations of dissolved nickel in San Francisco Bay ranged from 7 to 160 nM (i.e., 0.4 to 9.4 mg/L; Figure 7.3 and Table 7.2). Highest dissolved nickel concentrations were observed in sample C-3-0, which is located near the outfall of SJSC WPCP. During summer, when the contribution of surface runoff was small, the concentration of nickel measured at this location (i.e., 160 nM) was similar to the concentration measured in the effluent of the SJSC WPCP (dissolved nickel concentrations in the effluent of the SJSC WPCP typically range from 70 to 160 nM or 4.1 to 9.4 mg/L). Given the low salinity of the sample (i.e., 11) and the absence of other sources of freshwater, it may be concluded that this sample is approximately 2/3 wastewater effluent (based on a wastewater effluent salinity of 0 and seawater salinity of 34). During winter, when the volume of surface runoff was equal to or greater than the volume of wastewater effluent, the concentration of dissolved nickel measured at this location decreased to 56 nM (i.e., 3.3 mg/L), which is similar to the concentration of dissolved nickel detected in runoff samples from Coyote Creek and the Guadalupe River (dissolved nickel in surface runoff during dry weather range from approximately 15 to 40 nM or 0.9 to 2.3 mg/L as reported by Sedlak *et al.*, 1997). The speciation of nickel in samples from South San Francisco Bay was consistent with the expected seasonal contributions from wastewater effluent and surface runoff: most of the nickel in samples collected from sites

Table 7.2. Speciation and concentration of nickel in San Francisco Bay (see Figure 7.3).

Location	Salinity (ppt)	TSS (mg/L)	Concentration (nM) $[Ni_{diss}]$	$[Ni_{tot}]$	$[NiL_1^{Ni}]$	$[NiL'_{csv}]$
January 1997						
San Jose	1	26	56	339	19	37
Coyote Creek	3	116	45	455	18	27
South Bay	1	14	43	142	4	39
Dumbarton Bridge	1	3	47	209	22	25
Redwood Creek	3	3	26	193	8	18
San Bruno	5	2	22	109	7	15
Oyster Point	8	1	34	42	14	20
Alameda	3	1	21	39	2	19
Golden Gate	28	2	11	19	7	4
April 1997						
San Jose	1	215	83	174	71	12
Coyote Creek	11	18	78	251	64	14
South Bay	12	40	47	132	13	34
Dumbarton Bridge	15	13	43	76	11	32
Redwood Creek	21	15	41	50	15	26
San Bruno	24	5	28	34	21	7
Oyster Point	21	6	35	21	32	3
Alameda	17	6	13	18	< 2	13
Golden Gate	34	2	7	14	< 2	7
July 1997						
San Jose	11	166	160	381	114	46
Coyote Creek	25	69	78	71	56	22
South Bay	25	98	30	123	17	13
Dumbarton Bridge	26	81	57	74	31	26
Redwood Creek	25	45	45	77	20	25
San Bruno	27	34	46	61	21	25
Oyster Point	28	6	58	42	38	20
Alameda	27	7	36	53	8.5	27
Golden Gate	30	3	9.6	10	3.1	6.5

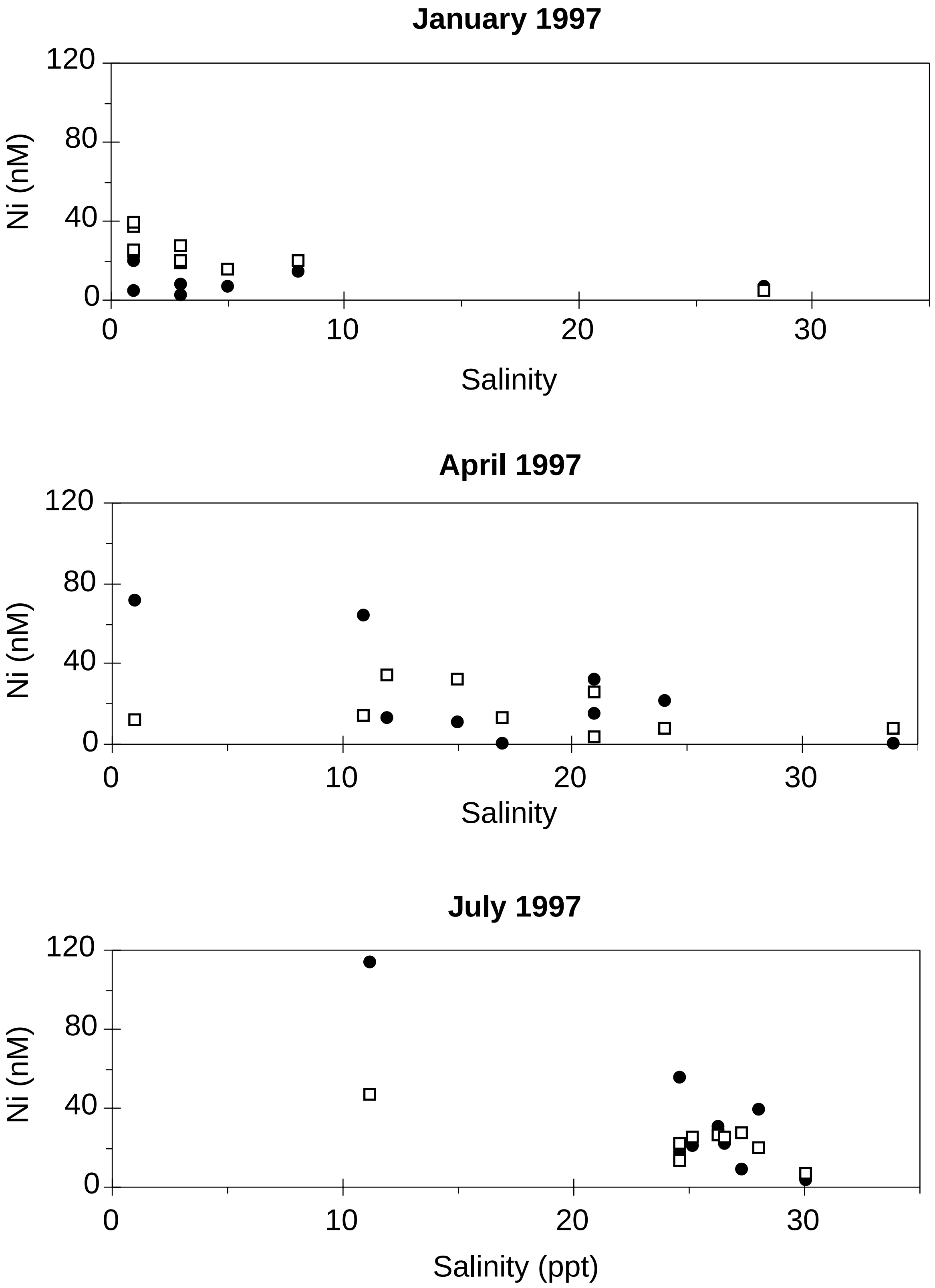

Figure 7.3. Speciation and concentration of nickel in San Francisco Bay (see Table 7.2).

in South San Francisco Bay during summer was complexed, whereas complexed nickel generally accounted for less than half of the dissolved nickel in samples collected during winter.

Samples collected in other sections of San Francisco Bay generally contained lower concentrations of dissolved nickel. The lowest concentration of dissolved nickel was usually observed in the sample collected near the Golden Gate. As the high salinity water from the Golden Gate area mixed with the freshwater coming from South San Francisco Bay, nickel concentrations decreased.

Discussion

Measurements of nickel speciation in wastewater effluents and in surface runoff can be used along with equilibrium predictions and the results of the laboratory experiments to predict the effect of different sources on nickel speciation in South San Francisco Bay. As discussed elsewhere (Bedsworth and Sedlak, 1998), most of the dissolved nickel in wastewater effluent consists of $NiEDTA^{2-}$, while the dissolved nickel in surface runoff consists of weaker nickel-organo complexes. Furthermore, results of equilibrium predictions and laboratory experiments (Sedlak *et al.*, 1997) indicate that $NiEDTA^{2-}$ in the effluent of the SJSC WPCP will not dissociate after it mixes with water from San Francisco Bay. The speciation of nickel in South San Francisco Bay should therefore exhibit seasonal differences: in summer, when most of the nickel entering the system consists of stable $NiEDTA^{2-}$ complexes, high concentrations of strong nickel complexes should be present. During winter, when nickel entering South San Francisco Bay consist of approximately equal amounts of strongly complexed nickel from wastewater effluent and weaker nickel complexes from surface runoff, the percentage of complexed nickel should decrease.

Analysis of data collected during 1997 are consistent with this hypothesis: the highest concentrations of complexed nickel are observed during summer and approximately equal concentrations of complexed and uncomplexed nickel are observed during winter. During winter, the concentrations of strongly complexed nickel are approximately equal throughout South San Francisco Bay. During all three seasons, concentrations of complexed nickel reach a level that is approximately constant north of the Dumbarton Bridge. The decrease in complexed nickel concentrations with distance from the wastewater outfalls suggests that the wastewater treatment plants that discharge to South San Francisco Bay are responsible for the complexed nickel.

The complexed nickel in the wastewater effluent appears to follow conservative behavior as it mixes with seawater. As discussed by Flegal *et al.* (1991), the concentration of a conservative pollutant should exhibit a linear decrease with increasing salinity. Although the data exhibit considerable scatter, the concentration of complexed nickel is consistent with our expectations. The trend is most evident during July, when the highest concentrations of complexed nickel are present. The relationship is less pronounced in April and is absent in January because the concentrations of complexed nickel decrease.

In contrast to the complexed nickel data, concentrations of uncomplexed nickel are approximately equal throughout San Francisco Bay. This suggests that there is an internal source of uncomplexed nickel in San Francisco Bay. A likely source of uncomplexed nickel are the bay sediments, which range from approximately 50 to 100 mg/kg. Although these sediments are likely to be strongly bound by sulfides and organic matter, resuspension of sediments could be responsible for the low concentrations of uncomplexed nickel observed in the surface waters.

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CHAPTER 8

Other Monitoring Activities

Sacramento River Watershed Program

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Introduction

The Sacramento River Watershed Program (SRWP) is a stakeholder-driven effort to restore and protect beneficial uses and maintain the economic and social vitality of the Sacramento River Basin. Stakeholders include representatives of local municipalities and districts, local watershed conservancies, state and federal agencies, water districts, agriculture, mining, forest products, environmental organizations, landowners, universities, and technical consultants. The program was initiated in 1996 by the Sacramento Regional County Sanitation District (SRCSD), the Central Valley Regional Water Quality Control Board, and EPA Region IX through federal funding derived from the Sacramento River Toxic Pollutant Control Program (SRTPCP). The SRCSD has been awarded $4.4 million in four separate annual authorizations to perform the tasks included in the SRTPCP workplan. Tasks include supporting the SRWP and implementing a water quality monitoring program in the Sacramento River Basin. Significant public and private support of the SRWP has been provided through in-kind services and participation in subcommittee activities of the program.

Water Quality Monitoring Program

A major emphasis of the SRWP and SRTPCP to date has been on the development and implementation of an integrated water quality monitoring program for the Sacramento River Basin. The program was developed through a subcommittee process which included the following key steps: developing goals and objectives, identifying and understanding ongoing monitoring programs, identifying water quality constituents of concern to various stakeholder groups, developing and evaluating various straw proposals for monitoring, selecting a preferred monitoring plan which capitalized on existing monitoring efforts, selecting parties to perform sampling and analysis tasks, and implementing the monitoring plan. The constituents monitored under the first-year SRWP monitoring program include:

- water column and sediment toxicity
- bioaccumulative substances in fish tissue (mercury, PCBs, organochlorine pesticides)
- pathogens (Cryptosporidium, Giardia, coliform bacteria)
- trace metals (mercury, cadmium, copper, chromium, lead, nickel, zinc, arsenic)
- organic carbon (total and dissolved)
- biological indicators (benthic invertebrates, attached algae, habitat)
- conventional parameters (e.g., pH, temperature, dissolved oxygen, hardness, total suspended solids, electrical conductivity)

The first-year monitoring effort is comprised of regular monitoring events (monthly, semi-annual, and/or annual) at over sixty sites on the Sacramento main stem, major tributaries, and selected smaller tributaries. The long-term goal of the SRWP monitoring program is to develop a coordinated, cost-efficient, long-term program to identify the causes, effects, and extent of water quality constituents that affect beneficial uses, and to develop a baseline for the assessment of the success of control strategies and improvement projects. Information from the monitoring program will be used to improve the understanding of conditions in the watershed. The goal for the first-year monitoring effort is to determine conditions in the main stem of the Sacramento River to assess the degree to which beneficial uses are attained or impaired.

Annual reports will be produced at the end of each year of SRWP monitoring. The first-year monitoring effort will be completed in June 1999. An annual report for the first year will be completed in December 1999. Data from the program will be placed in a publicly accessible electronic database managed by the Department of Water Resources. Data will be available over the internet through a SRWP homepage with links to the Interagency Ecological Program.

Public Outreach and Education

Another significant component of the ongoing SRWP is outreach and education to build support for watershed management activities, establish links between stakeholders, and promote knowledge and awareness of the watershed. The Public Outreach and Education Subcommittee organizes general stakeholder meetings and educational workshops to achieve these goals. The Subcommittee oversees production of a quarterly newsletter for the SRWP and monthly calendar of events for the SRWP and other watershed activities.

Coordination with other Programs

The Sacramento River Watershed Program has been developed in coordination with a number of ongoing monitoring efforts. These include the Sacramento CMP Ambient Monitoring Program, the U.S. Geological Survey National Water Quality Assessment (USGS NWQA) project for the Sacramento River, Regional Water Quality Control Board toxicity testing in the Sacramento Valley, the Department of Water Resources Northern District tributary monitoring program, and the Department of Pesticide Regulation Dormant Spray Monitoring Program. Coordination has included adopting compatible sampling and analytical methods, coordinating sample collections, sharing sampling duties, restructuring program elements, and agreeing to share data.

Results of SRWP Monitoring

Results to date from SRWP sponsored monitoring is limited to fish tissue and water column toxicity data. Each of these program elements was started as a pilot study ahead of the first-year monitoring effort, which began in June 1998.

Fish tissue results are from a sampling effort performed in September 1997. The work was performed by a team comprised of staff from the San Francisco Estuary Institute, Department of Fish and Game, and Long Marine Laboratory at the University of California, Santa Cruz.

Species tested included white catfish taken from seven sites in the lower watershed and rainbow trout taken from five sites in the upper watershed. Parameters analyzed include mercury, PCBs, and chlorinated pesticides. The purpose of fish tissue monitoring is to determine whether levels of these chemicals are of concern to consumers of fish, including both humans and upper trophic level fish and wildlife. Results of the 1997 fish tissue monitoring effort are summarized in Table 8.1. These results indicate that mercury levels in catfish are of potential concern, while mercury levels in rainbow trout are not of concern. Levels of PCBs are of potential concern at some locations.

Water column toxicity testing for the SRWP started in 1996. The purpose of this testing effort was to further characterize spatial and temporal distribution of ambient toxicity in the main stem and major tributaries of the Sacramento River, and to determine the toxicants responsible for observed toxicity. Three-species freshwater testing protocols from the U.S. EPA were used in the performance of this work. These bioassays measure survival, growth, and/or reproduction of sensitive forms of the following test species: *Ceriodaphnia dubia* (water flea—primary consumer); *Selanastrum capricornutum* (algae—primary producer); and *Pimephales promelas* (fathead minnow—secondary consumer).

Samples were taken from thirteen sites in the Sacramento River basin, ranging from the Sacramento River at Freeport (near Sacramento) to the upper Sacramento River (above Lake Shasta). Samples were collected approximately monthly at most sites. Results of testing for the period August 1996 through July 1997 indicated the following:

- Fathead minnow impairment was observed at most sites, with the exception of the Colusa Basin Drain and Sacramento Slough. Impairment included acute and

Table 8.1. Fish tissue mercury and organochlorine results for the 1997 SRWP. Concentrations are wet weight.

Species/Stations	# Fish in composite	Mean length (mm)	% Lipid	Mercury (ppm)	Sum of PCBs (ppb)	Sum of Aroclors (ppb)	Sum of Chlordanes (ppb)	Sum of DDTs (ppb)	Dieldrin (ppb)
Rainbow Trout									
Pit River above Shasta	1	332		0.047	.	.	.	.	.
McCloud River above Shasta	5	274		0.053	.	.	.	.	.
Sacramento River above Shasta	5	321		0.064	.	.	.	.	.
Sacramento River below Keswick	5	366	3.99	0.032	24	27	3	26	0.6
Sacramento River @ Bend Bridge near Red Bluff	5	313	2.54	0.031	7	ND	2	3	ND
White Catfish									
Sacramento Slough	5	274		0.438	.	.	.	.	.
Colusa Basin Drain	5	288		0.304	.	.	.	.	.
Feather River near Nicolaus	5	264	0.49	0.391	10	ND	4	36	1.0
Sacramento River @ Alamar/Vet. Bridge	5	249	0.84	0.553	11	15	3	43	1.1
American River @ Discovery Park	4	274	0.49	0.470	59	81	8	62	0.7
Sacramento River @ RM 44	5	256	1.55	0.390	33	47	9	68	2.4
Sacramento River @ RM 44 Duplicate	5	258	0.92	0.285	9	13	3	33	1.0
Cache Slough near Ryer Island Ferry	5	271		0.415	.	.	.	.	.
Cache Slough near Ryer Island Ferry Duplicate	5	279		0.552	.	.	.	.	.

chronic mortality. Most frequent mortalities were seen in higher quality, softer waters (McCloud River, Sacramento River at Red Bluff). Toxicity identification evaluation (TIE) work has indicated that a pathogen may be responsible for the observed toxicity.

- Reduced algae growth was observed at only two sites (Pit River and Arcade Creek). TIE work on Arcade Creek samples indicated that the toxicant was a non-polar organic chemical.
- *Ceriodaphnia* mortality was observed at Arcade Creek and at the Upper Sacramento River above Lake Shasta. Impaired *Ceriodaphnia* reproduction was observed at all sites. TIE work indicated that much of the observed *Ceriodaphnia* toxicity was linked to diazinon and/or chlorpyrifos. Toxicity identification evaluation work in the Upper Sacramento River linked observed toxicity to nickel.

Future Direction

The SRWP is continuing to move forward in the areas described above and is also projecting activity in the following areas. These activities are being developed and implemented by the SRWP Subcommittees, with review and approval by the general stakeholder group.

- Monitoring Program: A plan for the second-year monitoring plan is in place. The plan closely resembles the first-year plan, with the following changes: addition of selected sites no longer covered by the USGS NWQA program, expansion of the fish tissue monitoring effort, expansion of tributary monitoring, and addition of chemical analyses to a subset of the toxicity testing samples. Efforts are underway by the Monitoring Subcommittee to develop a plan for the third-year monitoring effort. The Subcommittee will consider results from first-year monitoring before finalizing the third-year plan.

- Public Outreach and Education: The Public Outreach and Education Subcommittee has formed a communications workgroup comprised of representatives from the following major stakeholder groups: California Cattlemen's Association, Friends of the River, California Rice Industry, Forest Products Association, Western Crop Protection Association, and several others. The workgroup is developing a public information effort to promote stewardship in the watershed, by both industries and private citizens.
- Site-Specific Objectives: Examine possibility of developing site-specific objectives for selected water quality parameters in the Sacramento River Basin. Such enforceable objectives would be tailored to local or regional conditions and would be scientifically defensible. The objectives setting process would comply with federal and state laws and regulations.
- Water Quality Management: The Toxics Subcommittee is considering candidate constituents for selection for pilot efforts in water quality management. The goal is to employ an interest-based, stakeholder-driven approach in the development and implementation of measures to address the selected constituents and to improve environmental conditions and beneficial use attainment in the watershed.
- SRWP Institutional Structure: SRWP stakeholders will be evaluating alternatives for the long-term structure of the program. The goal is to select and implement a long-term structure for management, administration, and funding which meets the interests of stakeholders. Numerous options will be examined, drawing from experiences in other similar groups across the country.

Sacramento Coordinated Water Quality Monitoring Program

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Introduction

The Sacramento Coordinated Water Quality Monitoring Program (CMP) is a cooperative voluntary program initiated and implemented by the Sacramento Regional County Sanitation District (SRCSD), the City of Sacramento (City), and the County of Sacramento Water Resources Division (County). These three public agencies are responsible for the management of all municipal wastewater and most stormwater in the Sacramento urban area within Sacramento County. The CMP was established in July 1991 through a Memorandum of Understanding between these entities.

The fundamental purpose of the CMP is to develop high-quality data to aid in the development and implementation of water quality policy and regulations in the Sacramento area.

The Ambient Monitoring Program (Ambient Program) is the primary water quality monitoring element of the CMP. Sampling under the Ambient Program began in December 1992 and continues at present on a monthly basis. Additionally, episodic storm events are sampled in coordination with the Sacramento Stormwater Program.

Five river sites are now monitored under the Ambient Program, three on the Sacramento River (at Veteran's Bridge near Alamar Marina, at Freeport Bridge, and at River Mile 44 downstream of the Sacramento metropolitan area) and two on the American River (at Nimbus Dam and at Discovery Park near the confluence with the Sacramento River; see Figure 8.1). The monitoring sites have been selected to provide water quality data upstream and downstream of the influence of urban inputs from the Sacramento community.

The historic emphasis of the Ambient Program has been on trace metals monitoring—total recoverable and dissolved metals—using clean techniques and low detection limits. Other parameters monitored under the Ambient Program include organophosphate pesticides (diazinon, chlorpyrifos), total and fecal coliform bacteria, fecal streptococci, total organic carbon, dissolved organic carbon, pH, temperature, dissolved oxygen, hardness, total suspended solids, and electrical conductivity.

Annual reports have been produced each year of the CMP. The latest (1997) Annual Report for the Sacramento CMP presented the results of Ambient Program monitoring completed through December 1997. The next Annual Report will cover data collected through December 1998 and is scheduled for release in spring 1999.

Coordination With Sacramento River Watershed Program

The Sacramento CMP and the Sacramento River Watershed Program (SRWP) are being coordinated at several levels. The SRWP monitoring program (which started as a complete program in June 1998) has been developed in coordination with a number of ongoing monitoring efforts, including the CMP Ambient Monitoring Program. The CMP sampling team will take samples for analysis by the SRWP at four of the five CMP sampling sites. The analytical results produced by the CMP will be combined with other data collected under the SRWP.

The CMP and SRWP have cooperated in the joint sponsorship of the State of the (Sacramento River) Watershed 1997 conference held in October 1997 in Sacramento. This second annual conference was highlighted by awards given to local organizations which distinguished themselves in watershed stewardship. The CMP is a contributor to the November 1998 State of the (Sacramento) River conference which is being sponsored by the Sacramento River Preservation Trust.

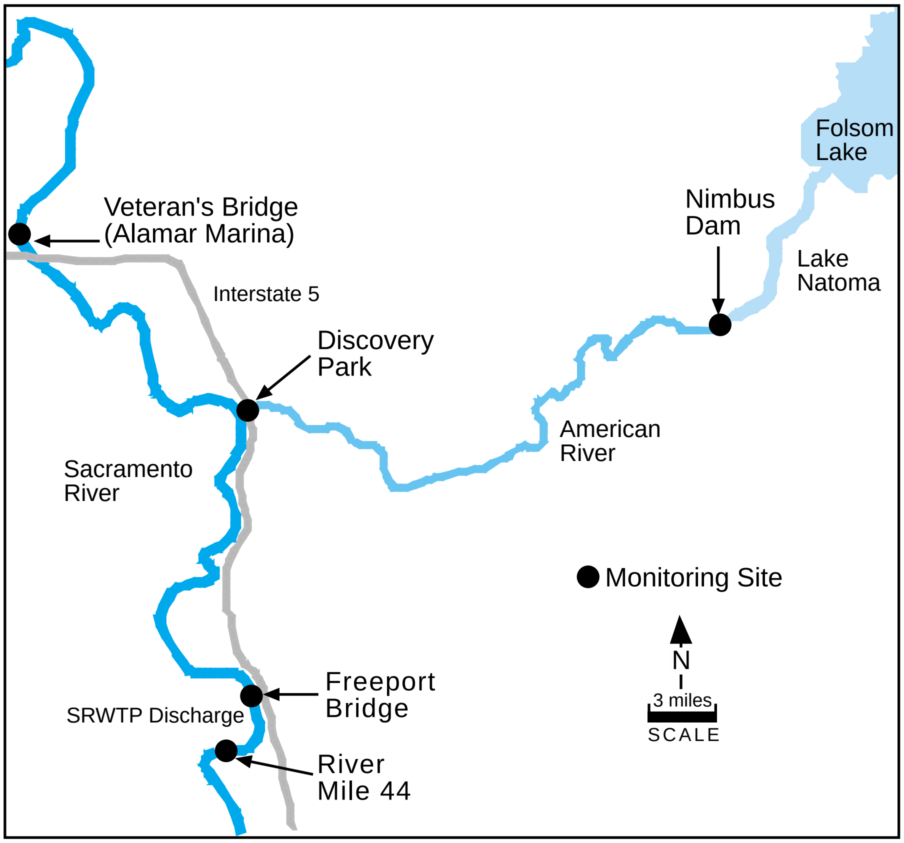


Figure 8.1. Ambient Program monitoring stations.

Results of CMP Monitoring

Based on Ambient Program results for the period December 1992 to December 1997, ambient water quality characteristics of the American and Sacramento rivers is summarized as follows:

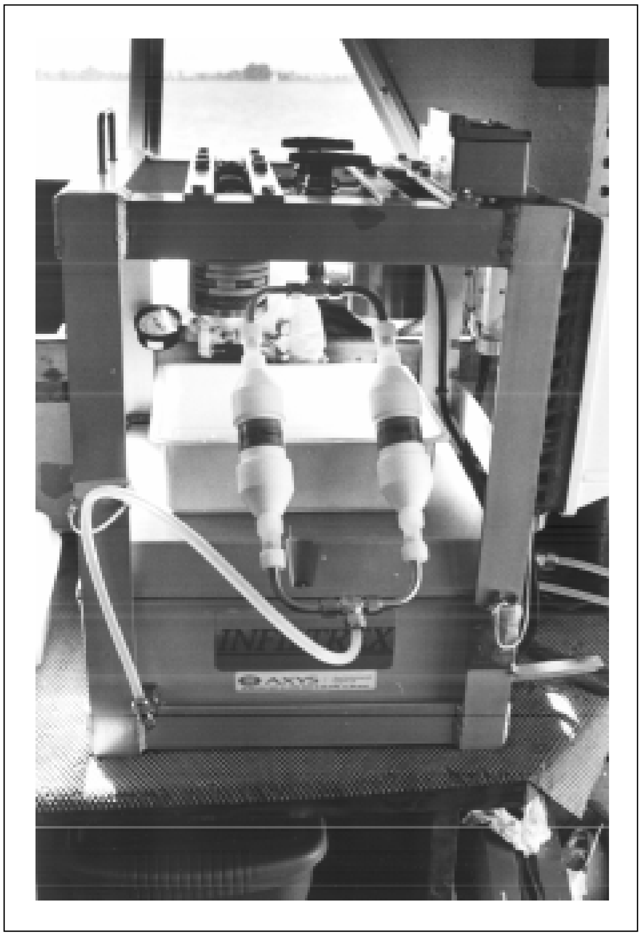
- With few exceptions, ambient water quality characteristics monitored by the Ambient Program meet applicable regulatory standards in both rivers.
- Although observed mercury concentrations in each river meet regulatory criteria proposed in the August 1997 California Toxics Rule, mercury has been identified as a pollutant of concern due to levels in some species of fish.
- Sacramento River water quality characteristics are significantly influenced by flow volumes, with pollutant concentrations decreasing with decreasing flow. This influence is complex, because flows are influenced by regulated dam releases and precipitation throughout the watershed. The effect of flows on quality is largely consistent with the resuspension and transport of sediment-associated metals and other constituents.
- Water quality of the American River near Sacramento is not greatly influenced by changes in flow.
- Statistically significant differences between upstream and downstream locations were observed for some measured water quality parameters. In all cases these changes were small as a percentage of observed concentrations. With the exception of coliform bacteria levels, the differences had no significant impact on compliance with regulatory standards.

Future Direction

The CMP Steering Committee annually reviews the Program and considers appropriate adjustments. At its August 1998 meeting, the Steering Committee decided to add several trace organic constituents to the Ambient Program. The trace organics to be monitored include diazinon, chlorpyrifos, carbofuran, malathion, methyl parathion, polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol, and 2,4,6-trichlorophenol. The basis for selection of these constituents is listing of upstream waters on the 1998 303(d) impaired waters list, identification as a constituent of concern by the Sacramento Stormwater Program, or identification as a constituent of potential concern by Sacramento Regional County Sanitation District. Specialized laboratories capable of producing data at pre-established low detection levels will be contracted to perform this monitoring.

Public outreach and education efforts will continue at the local level. The CMP monitoring effort will continue to be coordinated closely with the activities of the Sacramento River Watershed Program.

Appendices



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Appendix A
Description of Methods

Water Sampling

One of the objectives of the RMP is to evaluate if water quality objectives are met at sampled stations. Therefore, the sampling and analysis methods must be able to detect, and wherever possible quantify, substances below these levels. In order to attain the low detection levels used in the RMP (see *Appendix B*), ultra-clean sampling methods are used in all sampling procedures (Flegal and Stukas, 1987; EPA Method 1669, 1995).

Water samples are collected approximately one meter below the water surface using peristaltic and gear-driven pumps. The sampling ports for both the organic chemistry and trace element samplers are attached to aluminum poles that are oriented up-current from the vessel and upwind from equipment and personnel. The vessel is anchored and the engines turned off. Total (or near-total) and dissolved fractions of Estuary water are measured for trace elements. Particulate and dissolved fractions are measured for trace organics, and totals are calculated.

The RMP used the polyurethane foam plug sampler to collect water for trace organics analyses during the first four years of the Program (Risebrough *et al*., 1976; de Lappe *et al*., 1980; 1983) and began to phase in a new, modified, commercially available resin extraction sampler in 1996, beginning with side-by-side comparisons of both sampling systems. XAD resins have been used throughout the world to measure synthetic organic contaminants in both water and air (Infante *et al*., 1993). The sampler comparisons were continued in 1997, and results from both years are presented in *Appendix D*. Beginning with the 1997 monitoring year, the custom-manufactured AXYS system (AXYS Environmental Systems, Ltd., Sidney, B.C.) has been used to collect all RMP water samples for analysis of trace organic pollutants. It consists of a constant-flow, gear-driven positive displacement pump, $^1/_2$ inch Teflon® tubing, 1 µm glass fiber cartridge particulate filter, and two parallel Teflon® columns filled with XAD-2 resin with a particle size range of 300–900 µm. Aberlite XAD-2 resin is a macroreticular, styrene-divinylbenzene copolymer, nonionic bead. Each bead is an agglomeration of microspheres. This spong-like structure offers excellent physical and chemical stability. The discrete pores allow rapid mass transfer of analytes, and the mesh size ensures very little, if any, back pressure during use. The hydrophobic chemical nature of the resin leads to excellent capability of concentrating hydrophobic contaminants.

The sample water is first passed through a coarse screen as it moves into the Teflon® intake line to remove large particles that may interfere with sample collection; particles greater than 140 µm are removed as the sample water passes through the inline pre-filter. The water then passes through the pump head and through a pressure gauge, before it goes through one of two parallel four-inch diameter wound glass fiber filters (1 µm). Using two filters allows a quick change to the second filter if the first filter becomes clogged, without interrupting sample collection. Material retained on the glass fiber filter (or filters) becomes the particulate fraction. After passing through the filter, the water is split and routed through two Teflon® columns, packed with 85 mL of XAD-2 resin. Two filters are used simultaneously to increase the flow to approximately 1.3 L/min. The compounds which are adsorbed to the XAD resin are classified as the dissolved fraction. Lastly, the water passes through a flow meter and out the exit tube where the extracted water volume is verified with 20 L carbouys.

Field blanks are taken for both the resin columns and the glass fiber filters. The two column field blanks are collected by leaving both ends of a column open while the filled sample columns are being loaded into the sampler. Similarly, the two glass fiber filter field blanks are collected by exposing a filter to the air while loading the sample filters into the cartridges. The blanks receive the same analytical treatment in the laboratory as the field samples.

For trace metals, water samples are collected using a peristaltic pump system equipped with C-Flex tubing in the pump head. Sample aliquoting is conducted on deck on the windward side of the ship to minimize contamination from shipboard sources (Flegal and Stukas, 1987). Filtered water samples are obtained by placing an acid-cleaned polypropylene filter cartridge (Micron Separations, Inc., 0.45 µm pore size) on the outlet of the pumping system. Unfiltered water samples are pumped directly into acid-cleaned containers. Prior to collecting water, several liters of water are pumped through the system, and sample bottles are rinsed five times before filling. The bottles are always handled with polyethylene-gloved "clean hands". The sample tubing and fittings are acid-cleaned polyethylene or Teflon®, and the inlets and outlets are kept covered except during actual sampling. Samples are acidified within two weeks in a class 100 trace metal laboratory, except for chromium samples, which are acidified and extracted within a hour of collection.

Samples for conventional water quality parameters are collected using the same apparatus as for trace metals; however, containers are only rinsed three times, and the "clean hands" procedure is unnecessary.

Water samples are collected for toxicity tests using the same pumping apparatus as for the collection of the trace organic samples, but are not filtered. Five gallons of water are collected and placed in ice chests for transfer at the end of each cruise day to the testing laboratory. Two field blanks are collected each cruise by filtering (0.45 µm) water known to be non-toxic from the Bodega Marine Laboratory.

Sediment Sampling

Sediment sampling is conducted using a Young-modified van Veen grab with a surface area of 0.1 m^2. The grab is made of stainless steel and the jaws and doors are coated with Dykon® (formerly known as Kynar®) to achieve chemical inertness. All scoops, buckets, and stirrers used to collect and homogenize sediments are also constructed of Teflon® or stainless steel coated with Dykon®. Sediment sampling equipment is thoroughly cleaned prior to each sampling event. In order to further minimize sample contamination, gloves are worn by personnel handling the sample.

A sub-core of sediment is removed for measurement of porewater ammonia. Then, the top 5 cm of sediment is scooped from each of two replicate grabs and mixed in a Dykon®-coated bucket to provide a single composite sample for each station. Between sample grabs, the compositing bucket is covered with aluminum foil to prevent airborne contamination. After two sediment samples have been placed into the compositing bucket, the bucket is taken into the ship's cabin and thoroughly mixed to obtain a uniform, homogeneous mixture. Aliquots are subsequently split for each analytical laboratory, for archive samples, and for sediment toxicity tests. The quality of grab samples is ensured by requiring each sample to satisfy criteria concerning depth of penetration and disturbance of the sediment within the grab.

Benthic Infauna

Benthic infauna samples are comprised of primarily sedentary invertebrate organisms that burrow in or live on the surface of sediments. One sample is taken at each of the nine RMP sediment stations with a Ponar grab sampler. Lead weights are added to or removed from the outside of the grab as appropriate to the sediment type in order to control depth of penetration. Incomplete closure of the grab results in rejection of the sample. The retrieved grab is placed on a stand designed with a stainless steel funnel directed to a sample bucket. Once the grab has passed acceptance criteria (complete closure, no evidence of sediment washout through the doors, even distribution of sediment in the grab, minimum disturbance of the sediment surface, and minimum overall sediment depth appropriate for the sediment type), the grab jaws are opened, and the sediment is dumped into a five-gallon plastic bucket. The sample is then moved to a wash table for sieving through two screens stacked on top of each other. The top screen has a 1 mm mesh size, and the smaller screen retains animals in its 0.5 mm mesh. The material retained in each screen is gently washed into separate, labeled sample jars. A wash bottle with seawater is used to rinse any material on the inside screen frame and canning funnel into the sample jar. Any organisms remaining on the screens are carefully picked off with forceps and placed in the appropriate sample jars. Jars are taken to the formalin station where seawater is decanted from the sample jars with 0.25 mm Nitex mesh. Relcant (isotonic $MgCl_2$) is added to the sample through the mesh to a level approximately one third higher than the sample level. The sample is allowed to sit in the relaxant for 15 to 30 minutes, the relaxant is decanted, and 10% buffered formalin is added to the sample through the screen lid. As a final step, two to three drops of stain (rose bengal solution) are added to the sample for ease of organism identification.

Bivalve Bioaccumulation Sampling

Generally, bivalves are collected from uncontaminated sites and transplanted to fifteen stations in the Estuary during the wet season (February through May) and the dry season (June through September). Contaminant concentrations in the animals' tissues and the animals' biological condition (expressed as the ratio of dry weight and shell cavity volume) are measured before deployment (referred to as time zero or background samples) and at the end of the 90–100 day deployment period. Since the RMP sites encompass a range of salinities, three species of bivalves are used, according to the expected salinities in each area and the known tolerances of the organisms. The mussel (*Mytilus californianus*) is collected from Bodega Head and stored in running seawater at the Bodega Marine Laboratory until deployment at the stations west of Carquinez Strait, which are expected to have the highest salinities. *Mytilus californianus* will survive exposure to salinities as low as 5 ppt (Bayne, 1976). Oysters (*Crassostrea gigas*) are obtained from Tomales Bay Oyster Company (Marshall, California) and deployed at moderate-salinity sites closest to Carquinez Strait and in the extreme South Bay. *Crassostrea gigas* tolerates salinities as low as 2 ppt. In 1997, the freshwater clam *Corbicula fluminea* was collected from Putah Creek for the wet-season deployment and moved to the University of California, Davis (UCD) for depuration and deployed at sites with the lowest salinities. *Corbicula fluminea* tolerates salinities from 0 ppt to perhaps 10 ppt (Foe and Knight, 1986). Clams were collected from the San Joaquin River for dry-season deployment. The effects of high, short-term flows of freshwater on the transplanted bivalves west of Carquinez Strait are minimized by deploying the bivalves near the bottom where density gradients tend to maintain higher salinities. All bivalves are kept on ice after collection and deployed within 24–48 hours.

Because of the unavailability of clams at Lake Isabella, the RMP's traditional reference site, clams were collected from Putah Creek and the San Joaquin River and conditioned at a pond fed by Davis well water and located at the UCD Institute of Ecology. Additionally, the condition of animals from the control sites at UCD (*Corbicula fluminea*), Bodega Head (*Mytilus californianus*), and Tomales Bay (*Crassostrea gigas*) was determined at the end of each deployment period in order to sort out Estuary effects from natural factors affecting bivalve condition. Survival during deployment was also measured. Composites of tissue were made from 40–60 individual bivalves from each site before and after deployment for analyses of trace contaminants.

Within each species, animals of approximately the same size are used. Mussels are between 49–81 mm shell length, oysters are between 71–149 mm, and clams are 25–36 mm. One-hundred-fifty oysters and 160 mussels and clams are randomly allocated for deployment at the appropriate sites, with the same number being used as travel blank (time zero) samples for analysis of tissue and condition before deployment. At each site, oysters are divided among five nylon mesh bags, and mussels and clams are divided among four nylon mesh bags.

Moorings are associated with pilings or other permanent structures. Mooring installation, bivalve deployment, maintenance, and retrieval are all accomplished by SCUBA divers. The deployed samples are checked approximately half-way through the 90-day deployment period to ensure consistent exposure. Moorings and nylon bags are checked for damage and repaired, and fouling organisms are removed.

Upon retrieval, the bags of bivalves are placed into polyethylene bags and taken to the surface. On the vessel, the number of dead organisms are noted. Twenty percent of the live organisms are allocated for condition measurement, and the remainder are equally split for analyses of trace metal and organic compounds. Bivalves used for trace organic analyses are rinsed with reagent grade water to remove extraneous material, shucked using a stainless steel knife (acid-rinsed), and homogenized (until liquefied) in a combusted mason jar using a Tissumizer or Polytron blender. Bivalves used in trace element analyses are shucked with stainless steel knives, gonads are removed, and remaining tissue is rinsed with ultrapure water and placed in acid cleaned, plastic coated, glass jars. The sample is then homogenized (until liquefied) using a Brinkmann homogenizer equipped with a titanium blade.

Based on findings by Stephenson (1992) during the RMP Pilot Program, bivalve guts are not depurated before homogenization for tissue analyses, although gonads are removed from organisms for trace metal analyses. Stephenson (1992) found that, with the exception of lead and selenium, no significant differences exist in trace metal concentrations between mussels depurated for 48 hours in clean Granite Canyon seawater before homogenization and undepurated mussels. However, sediment in bivalve guts may contribute to the total tissue contaminant concentration.

For a more detailed description of field methods, see *RMP News*, Volume 4, Issue 2 (Gold and Bell, 1998).

Analytical Methods

Conventional Water Quality Parameters

Samples for dissolved nutrients are analyzed using the Lachat QuikChem 800 System Nutrient Autoanalyzer (Ranger and Diamond, Lachat Instruments, 1994). The QuickChem methods used are: 31-114-27-1 for silicates, 31-107-06-1 for ammonia, 31-107-04-1 for nitrate/nitrite, and 31-115-01-3 for phosphate. Chlorophyll and phaeophytin are measured using a fluorometric technique with filtered material from 200 mL samples (Parsons *et al*., 1984). Shipboard measurements for temperature, salinity, pH, and dissolved oxygen content are made using a hand-held Solomat 520 C multi-functional chemistry and water quality monitor. Dissolved organic carbon (DOC) is measured using high-temperature catalytic oxidation with a platinum catalyst (Fitzwater and Martin, 1993). Total suspended sediments (TSS) are determined using method 2540D in Standard Methods for the Examination of Water and Wastewater (Greenberg *et al*., 1992).

A Sea-Bird SBE19 Conductivity, Temperature, and Depth probe (CTD) is used to measure water quality parameters at depths throughout the water column. CTD casts are taken at each site during water and sediment sampling. At each site, the CTD is lowered to approximately one meter below the water surface and allowed to equilibrate to ambient temperature for 3 minutes. The CTD is then lowered to the bottom at approximately 0.15 meters per second, and raised. Only data from the down cast are kept. Data are downloaded onboard the ship, and processed in the laboratory using software supplied by Sea-Bird.

The CTD measures temperature, conductivity, pressure, dissolved oxygen, and backscatter at a sampling rate of two scans per second. These data are edited and averaged into 0.25 m depth bins during processing. Also during processing, salinity (based on conductivity measurements), oxygen, time, and depth (based on pressure) are calculated. Although the CTD data are not detailed in this report, SFEI maintains these data in its database.

Trace Elements

In water, total and dissolved (0.45 µm filtered) concentrations of mercury, arsenic, selenium, chromium, copper, nickel, lead, silver, and zinc are measured. Mercury, arsenic, and selenium samples are obtained from the same field sample. The mercury sub-samples are photo-oxidated with the addition of bromium chloride, and quantified using a cold-vapor atomic fluorescence technique. Arsenic and selenium are analyzed by hydride-generation atomic absorption with cryogenic trap preconcentration based on a method described in Liang *et al*. (1994) and Cercelius *et al*. (1986).

Chromium samples are collected separately. The suspended particulates undergo hydrofluoric acid digestion, and the dissolved chromium is co-precipitated with a ferrous hydroxide scavenger (Cranston and Murray, 1978). Chromium is quantified by graphite furnace atomic absorption spectrometry (GFAAS).

The remaining trace elements in water are measured using the APDC/DDDC organic extraction and preconcentration method (Bruland *et al*., 1985; Flegal *et al*., 1991) and then quantified by GFAAS.

Results for cadmium, chromium, copper, nickel, lead, silver, and zinc are reported by the laboratory in weight/weight units (µg/kg). For use in this report, those values are reported as µg/L, without taking account of the difference in density between Estuary water and distilled water. This difference was not taken into account because it is much less than the precision of the data, which was on the order of 10%. In some instances, dissolved metal concentrations are reported as higher than total (dissolved + particulate) metal concentrations. This is due to expected analytical variation in the methods of analysis, particularly at concentrations near the detection limits. Such results should be interpreted as no difference between dissolved and total concentrations, or that the total fraction of metals is in the dissolved phase.

Sediments are digested with *aqua regia* to obtain “near-total” concentrations of aluminum, silver, cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc (Flegal *et al*., 1981). The metals are quantified by inductively coupled plasma atomic emission spectrometry (ICP-AES) or by ICP-MS. The method chosen for RMP sediment analysis is comparable to standard EPA procedures (Tetra Tech, 1986), but does not decompose the silicate matrix of the sediment. Because of this, any element tightly bound as a naturally occurring silicate may not be fully recovered.

Bivalve tissue samples are digested with *aqua regia* to obtain near-total concentrations of trace elements similar to techniques used in the California State Mussel Watch Program (e.g., Flegal *et al*., 1981; Smith *et al*., 1986) and consistent with the RMP Pilot Program (Stephenson, 1992). The trace metals are quantified by ICP-AES or ICP-MS. Hydride generation coupled with atomic absorption spectroscopy is used to quantify arsenic. Mercury is quantified using a cold-vapor atomic fluorescence technique, and selenium using the methods of Cutter (1986). Butyltins are measured following NOAA Status and Trends Mussel Watch Project methods described in NOAA Technical Memorandum NOS/ORCA/CMBAD71 vol. IV (NOAA, 1993). This technique involves extracting the sample with hexane and the chelating agent tropolone and measuring the butyltin residues by capillary gas chromatography. Concentrations are expressed in total tin per gram of tissue dry weight.

Trace Organics

For water samples, each of the two resin columns (each sample is contained in two parallel resin columns) and filters containing the particulate fraction are spiked with extraction surrogates. In 1997, electron capture detector (ECD) surrogates consisted of PCB 103 and PCB 207 for the first fraction, and pentachloronitorobenzene for fractions 2 and 3. The mass spectral detector (MSD) surrogate consisted of deutereated acenaphthalene. The XAD columns are eluted in reverse with methanol and methylene chloride in a method similar to the filter cartridges. The separate extracts are then combined and separated into three fractions. Extraction methods are based upon standard EPA and AXYS extraction protocols.

The extracts are subjected to Florisil column chromatography resulting in three fractions, a PCB/aliphatic, a pesticide/aromatic fraction, and a polar third fraction, which contains diazinon and other polar pesticides. Chlorinated hydrocarbons (CH) are analyzed on a Hewlett Packard 6890 capillary gas chromatograph utilizing electron capture detectors (GC/ECD). A single 2 µL splitless injection is directed onto two 60 m x 0.25 mm columns of different polarity (DB-17 and DB-5) using a y-splitter to provide two-dimensional confirmation of each analyte. The quantitation internal standards utilized for the CH analysis are dibromo-octafluorobiphenyl (DOB) for fractions 1 and 3, and DOB or PCB 209 for Fraction 2. Analyte concentrations are corrected for surrogate losses prior to reporting. PAHs are quantified in the F-2 fraction by analysis on a Hewlett-Packard 6890 capillary gas chromatograph equipped with a 5971A mass spectral detector (GC/MS). A 2 µL splitless injection is chromatographed on a DB-5 column and analyzed in a selected ion monitoring (SIM) mode. The quantitation internal standard utilized for the PAH analysis when samples are at 100 µL is hexamethyl benzene (HMB). Dibromo-octafluorobiphenyl is used as an internal standard for diazinon.

Sediment samples are analyzed based on the methods followed by NOAA’s Status and Trends Program. Samples are extracted according to EPA Method 3545 (acclerated solvent extraction) using elevated temperature ($100\,^0$C) and pressure (1500–2000 pso) to achieve analyte recoveries equivalent to those from Soxhlet extraction, using less solvent and taking significantly less time. This extraction procedure is applicable to the extraction of all compounds of interest to the RMP. Surrogate standards are added prior to extraction to account for methodological analyte losses. ECD surrogates consist of DOB, PCB 103, and PCB 198. The extract is concentrated and purified using a combined silica/alumina column purification to remove matrix interferences. Internal standard solutions are tetrachloro-m-xylene (TCMX) and dibutyl chlorendate (DBC). Chlorinated hydrocarbons are quantified in sediment extracts via high-resolution capillary gas chromatography using GC/ECD. Dual-column confirmation on 30-m long, 0.25-mm internal diameter fused silica capillary columns with DB-5 and DB-17 bonded phase is conducted.

Tissue samples are homogenized and macerated, and the eluate is dried with sodium sulfate, concentrated, and purified using a combination of EPA Method 3611 alumina column purification and EPA Method 3630 silica gel purification to remove matrix interferences. PAHs and their alkylated homologues in both sediment and tissue extracts are quantified by GC/MS in the SIM with a temperature-programmable gas chromatograph with a 30-m long, 0.32-mm internal diameter fused silica capillary column with DB-5MS bonded phase. Surrogates for PAHs consisted of naphthalene-d8, acenaphthene-d10, phenanthrene-d10, chrysene-d12, and perylene-d12. In 1997, PCBs in tissue were quantified according to EPA Method 1668 (isotope dilution techniques) using high-resolution gas GC/MS. Pesticides in tissue were quantified via high-resolution capillary gas chromatography using GC/ECD. Dual-column confirmation on 30-m long, 0.25-mm internal diameter fused silica capillary columns with DB-5 and DB-17 bonded phase was conducted on tissue samples also.

Aquatic Bioassays

Water column toxicity is evaluated using a 48-hour bivalve embryo development test and a seven-day growth test using the estuarine mysid *Mysidopsis bahia*. The bivalve embryo development test is performed according to ASTM standard method E 724-89 (ASTM, 1991). The mysid test is based on EPA test method 1007. Larval *Mytilus* spp. are used in both sampling periods. The mysid growth and survival test consists of an exposure of 7-day old *Mysidopsis bahia* juveniles to different concentrations of Estuary water in a static system during the period of egg development and is used during both sampling periods. Appropriate salinity adjustments are made for Estuary water from sampling stations with salinities below the test species’ optimal ranges. Reference toxicant tests with copper chloride and potassium dichromate are performed for the bivalve and mysid tests, respectively. These tests are used to determine if the responses of the test organisms are relatively consistent over time.

The salinities of the ambient samples and the control/diluent (Evian spring water) are adjusted to 5 ppt using artificial sea salts (Tropic Marin). The test concentrations are 100%, 50%, and control, each with eight replicates, and with 20 larvae per replicate. Waste, dead larvae, excess food, and 80% of the test water are siphoned from the test chambers daily, and general water chemistry parameters of dissolved oxygen, pH, and salinity are recorded before and after each water change.

Sediment Quality Characteristics

Sediment size fractions are determined with a grain-size analyzer based on x-ray transmission (Sedigraph 5100). Total organic carbon is analyzed according to the standard method for the Coulometrics CM 150 Analyzer made by UIC, Inc. This method involves measurements of transmitted light through a cell. The amount of transmitted light is related to the amount of carbon dioxide evolved from a combusted sample. Spectrophotometric analyses of sulfides in sediment porewater are performed using a method adapted from Fonselius (1985) with variations from Standard Methods (APHA, 1985).

Sediment Bioassays

The RMP uses two sediment bioassays: a ten-day acute mortality test using the estuarine amphipod *Eohaustorius estuarius* exposed to whole sediment using ASTM method E 1367 (ASTM, 1992), and a sediment elutriate test where larval bivalves are exposed to the material dissolved from whole sediment in a water extract using ASTM method E 724-89 (ASTM, 1991). Elutriate solutions are prepared by adding 100 g of sediment to 400 mL of Granite Canyon seawater, shaken for 10 seconds, allowed to settle for 24 hours, and carefully decanted (EPA and COE, 1977; Tetra Tech, 1986). Larval mussels (*Mytilus* spp.) are used in both sampling periods, with percent normally developed larvae as the measurement endpoint.

Bivalve Condition and Survival

The condition of bivalves is a measure of their general health following exposure to Estuary water for 90–100 days. Measurements are made on subsamples of specimens before deployment and on the deployed specimens following exposure. Dry weight (without the shell) and the volume of the shell cavity of each bivalve is measured. Bivalve tissue is removed from the specimens and dried at 60°C in an oven for 48 hours before weighing. Shell cavity volume is calculated by subtracting shell volume of water displaced by a whole live bivalve less the volume of water displaced by the shell alone. The condition index is calculated by taking the ratio of tissue dry weight and the shell cavity volume.

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Appendix B
Quality Assurance Tables

The following section contains summaries of quality assurance (QA) information for the 1997 Regional Monitoring Program (RMP). A description of the RMP's QA program can be found in the *1996 Quality Assurance Program Plan* available from the San Francisco Estuary Institute.

Table 1. Quality assurance and control summary for laboratory analyses of water (trace elements). Cruise 13: January 97, Cruise 14: April 97, and Cruise 15: August 97

Analysis type: water trace elements, dissolved

Cruise #	Parameter	Units	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	No. Blanks/ Batch
13	Ag	μg/L	0.0003	0.0001	15	2	25	NA	12/24
13	As	μg/L	0.002	0.0630	25	3	25	3	2/20
13	Cd	μg/L	0.0003	0.00001	15	3	25	1	12/24
13	Cr	μg/L	0.0250	0.0150	15	29	25	3	8/24
13	Cu	μg/L	0.0058	0.0025	15	3	25	0	12/24
13	Hg	μg/L	0.0001	0.0001	25	5	25	3	2/20
13	Ni	μg/L	0.0054	0.0008	15	2	25	12	12/24
13	Pb	μg/L	0.0028	0.0005	15	1	25	17	10/24
13	Se	μg/L	0.005	0.0220	35	13	35	6	2/20
13	Zn	μg/L	0.0008	0.0023	15	3	25	27	12/24
14	Ag	μg/L	0.0003	0.0004	15	11	25	NA	12/24
14	As	μg/L	0.002	0.0510	25	2	25	6	2/20
14	Cd	μg/L	0.0003	0.00003	15	1	25	7	12/24
14	Cr	μg/L	0.0250	0.0060	15	4	40	21	7/24
14	Cu	μg/L	0.0054	0.0120	15	7	25	4	12/24
14	Hg	μg/L	0.0001	0.0001	25	2	25	16	2/20
14	Ni	μg/L	0.00001	0.0046	15	9	25	14	12/24
14	Pb	μg/L	0.0028	0.0018	15	4	25	2	12/24
14	Se	μg/L	0.005	0.0200	35	6	35	1	2/20
14	Zn	μg/L	0.0008	0.0170	15	4	25	21	12/24
15	Ag	μg/L	0.0003	0.0001	15	0	25	NA	12/24
15	As	μg/L	0.002	0.0600	25	4	25	1	2/20
15	Cd	μg/L	0.0003	0.0003	15	5	25	13	12/24
15	Cr	μg/L	0.0250	0.0040	15	2	40	10	4/24
15	Cu	μg/L	0.0058	0.0140	15	10	25	23	12/24
15	Hg	μg/L	0.0001	0.0001	25	7	25	6	2/20
15	Ni	μg/L	0.0054	0.0121	15	8	25	11	12/24
15	Pb	μg/L	0.0028	0.0025	15	.	25	NA	12/24
15	Se	μg/L	0.005	0.0200	35	9	35	21	2/20
15	Zn	μg/L	0.0008	0.0131	15	7	25	10	12/24

[1] Relative standard deviation (between 3 or more samples) or relative percent difference (between 2 samples).

[2] There are no SRM certified values for silver.

Table 1 (continued). Quality assurance and control summary for laboratory analyses of water (trace elements).

Analysis type: water trace elements, total

Cruise #	Parameter	Units	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	No. Blanks/ Batch
13	Ag	µg/L	0.0012	0.0005	15	20	25	NA	24/24
13	As	µg/L	0.0020	0.0630	25	3	25	3	2/20
13	Cd	µg/L	0.0004	0.00002	15	8	25	23	24/24
13	Cr	µg/L	0.3530	0.0830	15	12	40	19	7/24
13	Cu	µg/L	0.0066	0.0143	15	3	25	3	24/24
13	Hg	µg/L	0.0001	0.0001	25	5	25	3	2/20
13	Ni	µg/L	0.0095	0.0235	15	11	25	3	24/24
13	Pb	µg/L	0.0050	0.0008	15	8	25	55	24/24
13	Se	µg/L	0.0050	0.0200	35	13	35	6	2/20
13	Zn	µg/L	0.0074	0.0093	15	10	25	3	23/24
14	Ag	µg/L	0.0012	0.0008	15	21	25	29	24/24
14	As	µg/L	0.0020	0.0510	25	2	25	6	2/20
14	Cd	µg/L	0.0004	0.0002	15	5	25	16	24/24
14	Cr	µg/L	0.3530	0.0020	15	10	40	3	4/24
14	Cu	µg/L	0.0066	0.0110	15	7	25	2	24/24
14	Hg	µg/L	0.0001	0.0001	25	3	25	2	2/20
14	Ni	µg/L	0.0095	0.0135	15	12	25	9	24/24
14	Pb	µg/L	0.0050	0.0029	15	10	33	32	8/24
14	Se	µg/L	0.0050	0.0200	35	6	35	1	2/20
14	Zn	µg/L	0.0074	0.0246	15	4	25	2	24/24
15	Ag	µg/L	0.0012	0.0001	15	NA	25	NA	22/24
15	As	µg/L	0.0020	0.0600	25	4	25	1	2/20
15	Cd	µg/L	0.0004	0.0003	15	4	25	17	24/24
15	Cr	µg/L	0.3530	0.1040	15	5	40	7	2/20
15	Cu	µg/L	0.0066	0.0071	15	7	25	1	24/24
15	Hg	µg/L	0.0001	0.0001	25	7	25	6	2/20
15	Ni	µg/L	0.0095	0.0025	15	13	25	8	24/24
15	Pb	µg/L	0.0050	0.0041	15	NA	25	NA	24/24
15	Se	µg/L	0.0050	0.0200	35	9	33	21	24/24
15	Zn	µg/L	0.0074	0.0082	15	4	25	3	24/24

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[1] Relative standard deviation (between 3 or more samples) or relative percent difference (between 2 samples).

[2] There are no SRM certified values for silver.

Table 2. Quality assurance and control summary for laboratory analyses of water (organics).

Cruise 13: January 97, Cruise 14: April 97, and Cruise 15: August 97

Analysis type: water organics, dissolved & particulate
(Total values are calculated as the sum of dissolved and particulate data.)

Cruise #	Parameter	Units	MDL Target	MDL Measured Dissolved and Particulate	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Measured[2] (% recovery)
13	PAHs	pg/L	50	100	20	0–18	
13	PCBs	pg/L	50	1	20	1–49	
13	Chlorpyrifos	pg/L	50	1	20	1	
13	Diazinon	pg/L	50	204	20	0	
13	Other Pesticides	pg/L	50	7	20	0–33	
14	PAHs	pg/L	50	100	20	0–4	
14	PCBs	pg/L	50	1	20	0–88	
14	Chlorpyrifos	pg/L	50	1	20	6	
14	Diazinon	pg/L	50	204	20	0.2–4	
14	Other Pesticides	pg/L	50	7	20	ND–26	
15	PAHs	pg/L	50	100	20	0–10	
15	PCBs	pg/L	50	1	20	0–30	
15	Chlorpyrifos	pg/L	50	1	20	6	
15	Diazinon	pg/L	50	204	20	0–4	
15	Other Pesticides	pg/L	50	7	20	0–29	

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[1] Relative standard deviation (between 3 or more samples) or relative percent difference (between 2 samples).

[2] Not analyzed, because no standard reference available and matrix spikes not feasible

Table 3. Quality assurance and control summary for laboratory analyses of sediment.
Cruise 13: February 97, and Cruise 15: August 97

Analysis type: sediment trace elements

Cruise #	Parameter	Units	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	No. Blanks/ Batch
13	Ag	mg/kg	0.0012	0.01–0.03	15	14	25	5	2/24
13	Al	mg/kg	70	8.5–21.4	15	2	25	0	2/24
13	As	mg/kg	1.6	0.05	25	4	25	13	2/20
13	Cd	mg/kg	0.00002	0.01–0.03	15	3	25	6	2/24
13	Cr	mg/kg	9.44	0.85–2.47	15	3	40	15	2/24
13	Cu	mg/kg	4.57	0.43–1.07	15	3	25	9	2/24
13	Fe	mg/kg	140	1.42–3.57	15	1	25	12	2/24
13	Hg	mg/kg	0.005	10	35	2	25	10	2/20
13	Mn	mg/kg	27	0.14–0.41	15	2	25	4	2/24
13	Ni	mg/kg	4.26	1.13–3.29	15	3	25	8	2/24
13	Pb	mg/kg	0.1	0.04–0.08	15	3	25	0	2/24
13	Se	mg/kg	2.2	0.004	35	19	35	7	2/20
13	Zn	mg/kg	18.9	8.5–24.7	15	3	25	4	2/24
15	Ag	mg/kg	0.0012	0.05–0.07	15	10	25	9	2/24
15	Al	mg/kg	70	13.1–28.2	25	4	25	13	2/24
15	As	mg/kg	1.6	0.05	25	12	25	2	2/20
15	Cd	mg/kg	0.00002	0.04–0.1	15	9	25	12	2/24
15	Cr	mg/kg	9.4	1.3–2.8	15	6	40	2	2/24
15	Cu	mg/kg	4.57	0.7–1.1	15	1	25	4	2/24
15	Fe	mg/kg	140	2.2–4.7	15	1	25	13	2/24
15	Hg	mg/kg	0.005	10	35	18	25	0	2/20
15	Mn	mg/kg	27	0.22–0.47	15	1	25	3	2/24
15	Ni	mg/kg	4.26	1.7–3.8	15	2	25	8	2/24
15	Pb	mg/kg	0.01	0.1–0.3	15	6	25	1	2/24
15	Se	mg/kg	2.2	0.004	35	5	35	1	2/20
15	Zn	mg/kg	18.9	13–28.2	15	1	25	1	2/24

Analysis type: sediment organics

Cruise #	Parameter	Units	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	Blank Frequency
13	PAHs	µg/kg	5	1.3–13.4	20	18	20		5% min.
13	PCBs	µg/kg	1	0.2–2.1	20	8	20		5% min.
13	Pesticides	µg/kg	1	.	20	.	20		5% min.
15	PAHs	µg/kg	5	0.7–18.2	20	19	20		5% min.
15	PCBs	µg/kg	1	0.1–1.8	20	16	20		5% min.
15	Pesticides	µg/kg	1	.	20	.	20		5% min.

[1] Relative standard deviation (between 3 or more samples) or relative percent difference (between 2 samples).

. not available

Table 4. Quality assurance and control summary for laboratory analyses of bivalve tissue.
Cruise 13: February 97, and Cruise 15: August 97

Analysis type: tissue trace elements

Cruise #	Parameter	Units	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	No. Blanks/ Batch
13	Ag	mg/kg	0.0012	0.03	30	4	35	4	3/24
13	As	mg/kg	1.6	1.5	25	10	25	18	2/20
13	Cd	mg/kg	0.00002	0.02	30	2	25	2	3/24
13	Cr	mg/kg	9.44	0.04	30	9	25	6	3/24
13	Cu	mg/kg	4.57	0.1	30	1	25	3	3/24
13	Hg	mg/kg	1	1	35	10	25	11	2/20
13	Ni	mg/kg	4.26	0.04	30	0	25	3	3/24
13	Pb	mg/kg	0.1	0.1	30	1	25	5	3/24
13	Se	mg/kg	2.2	0.009	35	6	35	29	2/20
13	Zn	mg/kg	18.9	0.1	30	0	25	5	3/24
15	Ag	mg/kg	0.0012	0.03–0.14	25	2	30	5	3/24
15	As	mg/kg	1.6	1	25	7	25	16	2/20
15	Cd	mg/kg	0.00002	0.007–0.033	25	2	30	2	3/24
15	Cr	mg/kg	9.4	0.02–0.08	25	2	60	8	3/24
15	Cu	mg/kg	4.57	0.03–0.12	25	4	30	0	3/24
15	Hg	µg/kg	1	0.002	35	4	25	4	2/20
15	Ni	mg/kg	4.26	0.04–0.17	25	0	30	4	3/24
15	Pb	mg/kg	0.01	0.05–0.23	25	0	30	1	3/24
15	Se	mg/kg	2.2	0.008	35	13	35	17	2/20
15	Zn	mg/kg	18.9	0.03–0.16	25	3	30	2	3/24

Analysis type: tisssue organics

Cruise #	Parameter	Units	QA batch#	MDL Target	MDL Measured	Precision Target (+/- %)	Precision Measured (rsd)[1]	Accuracy Target (+/- %)	Accuracy Measured (+/- %)	Blank Frequency
13	PAHs	µg/kg	M1693	5	7	± 20	29	± 20	2	5% min.
13	PCBs	µg/kg	M1693	1	1	± 20	24	± 20	6	5% min.
13	Pesticides	µg/kg	M1693	1	1	± 20	NA	± 20	19	5% min.
15	PAHs	µg/kg	M1772	5	6	± 20	19	± 20	20	5% min.
15	PCBs	µg/kg	M1772	1	1	± 20	16	± 20	3	5% min.
15	Pesticides	µg/kg	M1772	1	1	± 20	NA	± 20	7	5% min.

[1] Relative standard deviation (between 3 or more samples) or relative percent difference (between 2 samples).

Table 5. Reference toxicant and QA information for the aquatic bioassays.

	Salinity (‰)	EC50*	EC25**	QA Notes:
February				
Mytilus edulis	30	12.9–14.1	.	San Jose, Sunnyvale, Coyote Creek, and Redwood Creek bioassays failed to pass QA at initial testing and were retested on January 27th the 28th (5-6 days after collection date).
Mysidopsis bahia	25	5.5–5.8	4.1–4.4	
August				
Mytilus edulis	30	12.0–12.6	.	
Mysidopsis bahia	25–30	5.3–7.3	.	

*Concentration of reference toxicant at which 50% of the organisms show effects.
**Concentration of reference toxicant at which 25% of the organisms show effects.

Table 6. Physical/chemical measurements of test solutions and QA information for the sediment bioassays. na means data not available, nd means measurement below the detection limit of 0.01 mg/L.

	LC$_{50}$/EC$_{50}$[1] (CdCl$_2$) mg/L	Salinity (‰)	Unionized Ammonia mg/L	Hydrogen Sulfide[2] mg/L	QA Notes
February					
Eohaustorius estuarius	7.52	20+/-3	n.d.–0.016	nd	Amphipod survival in all control samples was 98 ±3%, indicating test organisms were healthy and not affected by test conditions.
***Mytilus galloprovincialis* embryos**	4.33	28	n.d.–0.015	nd	Mean % normal development of test controls was 94 ±7%, above protocol minimum of 70%.
August					
Eohaustorius estuarius	8.65	20+/-3	0.005–0.026	na	Amphipod survival in all control samples was 99 ±2% indicating test organisms were healthy and not affected by test conditions.
Mytilus galloprovincialis embryos	3.39	28	0.008–0.192	nd	Mean % normal development of test controls was 90 ±6%, above protocol minimum of 70%. San Jose, Coyote Creek, South Bay, and Napa River test samples had dissolved oxygen (DO) concentrations below 60% saturation. Low DO at Coyote Creek and Napa River might have contributed to the toxic “hit” at those stations.

[1] LC$_{50}$: Lethal effects concentration of reference toxicant at which 50% of the organisms die.
EC$_{50}$: Effects concentration of reference toxicant at which 50% of the organisms exhibit effects.

[2] From the overlying water

Appendix C
Data Tables

Table 1. Conventional water quality parameters, 1997.
* = not available at the time of report production, . = no data, NA = not analyzed.

Station Code	Station	Date	Cruise	Ammonia	Chlorophyll-a	Conductivity	DO	DOC	Hardness	Nitrate	Nitrite	pH	Phaeophytin	Phosphate	Salinity	Silicates	Temperature	TSS
				mg/L	µmho	mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	pH	mg/m3	mg/L	o/oo	mg/L	°C	mg/L
BG20	Sacramento River	1/29/97	13	0.06	0.8	0.09	9.4	2.8	49	0.2	0.010	7.6	1.5	0.07	0.0	7	10.9	174
BG30	San Joaquin River	1/29/97	13	0.18	0.6	0.11	8.4	4.3	43	0.7	0.022	7.1	1.5	0.13	0.0	6	12.1	70
BF40	Honker Bay	1/28/97	13	0.06	0.8	0.09	NA	3.1	57	0.3	0.012	7.6	1.5	0.08	0.0	8	12.0	196
BF20	Grizzly Bay	1/28/97	13	0.05	0.8	0.09	NA	3.1	57	0.3	0.012	6.5	1.5	0.08	0.0	8	11.2	166
BF10	Pacheco Creek	1/28/97	13	0.09	0.6	0.09	11.5	3.5	46	0.4	0.012	7.4	1.4	0.09	0.0	6	11.1	126
BD50	Napa River	1/28/97	13	0.08	0.7	0.16	9.2	3.7	60	0.5	0.014	7.4	2.6	0.09	0.0	9	11.4	229
BD40	Davis Point	1/27/97	13	0.12	0.9	0.11	11.9	3.7	48	0.5	0.017	6.9	1.4	0.09	0.0	6	11.0	117
BD30	Pinole Point	1/27/97	13	0.10	1.2	0.15	9.7	3.4	59	0.4	0.016	7.4	2.5	0.08	0.0	7	9.8	178
BD20	San Pablo Bay	1/27/97	13	0.09	0.7	1.04	9.5	3.0	138	0.4	0.015	7.6	1.3	0.08	0.5	7	10.3	110
BD15	Petaluma River	1/27/97	13	0.34	2.2	0.59	7.2	8.2	109	0.8	0.042	7.1	11.4	0.50	0.3	6	13.1	279
BC60	Red Rock	1/23/97	13	0.10	1.1	8.38	9.2	2.2	1420	0.3	0.009	7.5	0.4	0.05	6.0	6	9.2	20
BC41	Point Isabel	1/23/97	13	0.08	1.2	19.30	8.2	2.2	.	0.3	0.006	7.8	0.4	0.05	11.9	5	10.2	12
BC30	Richardson Bay	1/23/97	13	0.11	1.7	23.39	8.2	2.4	.	0.3	0.008	7.6	0.9	0.06	14.7	4	11.2	10
BC20	Golden Gate	1/24/97	13	0.04	1.2	40.19	10.5	1.3	.	0.1	0.004	7.9	0.4	0.06	28.4	1	11.6	3
BC10	Yerba Buena Island	1/23/97	13	0.10	2.6	19.81	11.8	2.3	.	0.3	0.008	7.7	0.7	0.05	12.1	5	10.8	10
BB70	Alameda	1/23/97	13	0.13	3.3	19.09	10.3	2.5	.	0.6	0.017	7.8	0.8	0.11	12.0	5	10.7	7
BB30	Oyster Point	1/21/97	13	0.10	1.8	23.20	9.2	2.0	.	0.3	0.009	7.8	0.7	0.05	15.4	4	10.0	7
BB15	San Bruno Shoal	1/21/97	13	0.13	2.6	20.29	9.4	2.3	.	0.4	0.014	7.8	0.6	0.07	12.9	4	10.0	6
BA40	Redwood Creek	1/22/97	13	0.16	2.2	19.00	8.7	2.6	.	0.6	0.020	7.8	1.7	0.11	12.1	5	10.6	45
BA30	Dumbarton Bridge	1/21/97	13	0.22	2.3	12.38	8.6	4.0	.	0.9	0.044	7.7	2.2	0.28	7.2	6	10.5	81
BA20	South Bay	1/21/97	13	0.27	1.1	12.38	8.5	3.5	.	1.9	0.053	7.7	2.8	0.27	7.5	6	10.6	98
BA10	Coyote Creek	1/22/97	13	0.20	2.1	14.90	8.8	3.1	.	1.2	0.031	7.8	1.8	0.23	10.0	6	10.4	69
C-3-0	San Jose	1/22/97	13	0.24	1.1	4.38	8.3	3.7	783	2.4	0.044	7.6	4.1	0.38	3.7	8	11.7	166
C-1-3	Sunnyvale	1/22/97	13	0.84	5.8	0.22	8.9	4.9	103	1.3	0.159	7.7	6.0	0.66	0.1	5	11.7	263
BW10	Standish Dam	2/7/97	13	0.03	0.8	0.34	8.1	2.5	181	1.8	0.013	8.1	1.1	0.19	0.1	8	12.4	106
BW15	Guadalupe River	2/7/97	13	0.04	0.4	0.49	7.5	4.3	265	1.7	0.013	7.8	0.9	0.20	0.2	10	13.5	57
BG20	Sacramento River	4/23/97	14	0.07	12.1	0.19	8.3	1.7	74	0.3	0.015	7.9	9.0	0.06	0.0	7	17.6	29
BG30	San Joaquin River	4/23/97	14	0.03	3.8	0.20	8.4	2.2	70	0.4	0.009	7.8	2.5	0.07	0.0	6	18.3	22
BF40	Honker Bay	4/22/97	14	0.12	2.3	2.75	11.3	2.2	330	0.4	0.031	7.7	8.3	0.08	1.6	7	17.7	146
BF20	Grizzly Bay	4/22/97	14	0.09	0.9	8.89	10.9	2.0	925	0.4	0.023	7.5	2.8	0.09	5.0	6	17.6	60
BF10	Pacheco Creek	4/23/97	14	0.14	1.9	12.41	7.5	1.9	.	0.4	0.027	7.6	4.3	0.09	7.2	5	16.7	61
BD50	Napa River	4/22/97	14	0.13	1.8	22.54	9.8	2.1	.	0.3	0.019	7.4	1.6	0.10	13.8	4	16.8	37
BD40	Davis Point	4/21/97	14	0.09	7.1	26.26	10.9	1.6	.	0.3	0.015	7.8	4.7	0.09	16.5	3	16.4	44
BD30	Pinole Point	4/21/97	14	0.06	6.8	31.26	12.5	1.8	.	0.2	0.011	8.1	3.2	0.08	19.7	3	16.2	6
BD20	San Pablo Bay	4/21/97	14	0.04	10.1	36.63	10.6	1.7	.	0.2	0.008	7.7	3.9	0.07	22.9	2	15.7	21
BD15	Petaluma River	4/21/97	14	0.03	13.6	30.56	10.2	2.3	.	0.0	ND	8.0	7.1	0.10	18.8	2	18.8	37
BC60	Red Rock	4/14/97	14	0.08	1.9	34.58	7.3	1.5	.	0.3	0.008	7.7	1.3	0.06	21.6	2	14.5	5
BC41	Point Isabel	4/14/97	14	0.03	5.5	41.20	7.1	1.6	.	0.2	0.005	7.8	2.2	0.05	26.5	1	14.9	5
BC30	Richardson Bay	4/14/97	14	0.08	1.7	41.75	6.6	1.2	.	0.3	0.006	8.1	1.3	0.06	26.1	2	13.6	3
BC20	Golden Gate	4/15/97	14	0.07	0.5	46.57	11.0	1.1	.	0.3	0.006	7.7	0.4	0.06	29.3	1	12.7	2
BC10	Yerba Buena Island	4/14/97	14	0.16	8.0	41.20	9.4	1.4	.	0.3	0.008	8.1	1.7	0.06	25.6	2	14.5	5
BB70	Alameda	4/15/97	14	0.03	6.0	37.94	10.6	2.0	.	0.1	0.006	8.3	1.8	0.05	24.2	1	17.4	1
BB30	Oyster Point	4/16/97	14	0.08	5.0	41.08	7.4	1.7	.	0.2	0.008	7.8	2.4	0.05	25.8	1	14.0	2
BB15	San Bruno Shoal	4/16/97	14	0.04	5.0	38.83	8.9	1.8	.	0.1	0.008	8.1	3.3	0.05	24.1	1	15.2	2
BA40	Redwood Creek	4/16/97	14	0.03	8.5	35.84	10.1	2.5	.	0.1	0.010	8.2	5.5	0.07	22.2	1	16.8	3
BA30	Dumbarton Bridge	4/16/97	14	0.03	22.3	32.47	10.5	2.8	.	0.7	0.026	8.3	7.1	0.19	20.3	2	18.4	3
BA20	South Bay	4/16/97	14	0.14	14.0	29.42	7.9	3.1	.	1.5	0.061	8.0	4.8	0.34	18.6	3	18.9	14
BA10	Coyote Creek	4/17/97	14	0.36	12.9	23.59	6.1	4.1	.	4.1	0.136	7.6	10.8	0.70	14.0	5	20.8	116
C-3-0	San Jose	4/17/97	14	0.82	4.7	18.30	4.6	5.0	.	4.2	0.207	7.4	3.2	1.05	8.1	6	19.7	26
C-1-3	Sunnyvale	4/17/97	14	0.69	10.3	2.54	5.2	7.6	470	13.5	0.248	7.6	10.9	2.84	1.4	10	21.1	95
BW10	Standish Dam	4/9/97	14	0.65	14.3	NA	6.9	4.9	1010	8.5	0.252	7.1	11.6	1.01	4.5	9	17.8	129
BW15	Guadalupe River	4/7/97	14	0.33	11.8	NA	5.4	3.6	850	5.3	0.161	7.2	12.9	0.64	2.0	10	17.1	1565
BG20	Sacramento River	8/6/97	15	0.05	2.1	0.50	7.4	1.7	85	0.2	0.020	7.8	2.2	0.06	0.1	8	22.0	34
BG30	San Joaquin River	8/6/97	15	*	2.5	0.81	7.3	1.9	110	0.2	0.012	8.1	2.0	0.08	0.3	8	23.2	32
BF40	Honker Bay	8/5/97	15	0.05	2.1	5.38	7.6	2.0	533	0.4	0.011	7.9	1.9	0.09	2.9	8	22.2	53
BF20	Grizzly Bay	8/5/97	15	0.07	1.2	11.18	7.8	2.2	.	0.4	0.016	7.9	0.7	*	6.5	*	21.6	10
BF10	Pacheco Creek	8/5/97	15	*	1.4	10.55	8.2	1.9	.	0.5	0.017	7.7	2.3	0.10	6.2	*	21.1	71
BD50	Napa River	8/5/97	15	0.12	1.6	26.02	7.0	2.3	.	0.5	0.019	7.6	2.8	0.07	16.0	*	20.7	83
BD40	Davis Point	8/4/97	15	0.12	1.8	31.97	8.1	1.7	.	0.5	0.020	7.8	2.0	0.11	20.0	3	20.0	50
BD30	Pinole Point	8/4/97	15	0.13	1.7	32.48	8.1	1.7	.	0.5	0.019	7.8	1.2	0.11	20.4	*	20.0	30
BD20	San Pablo Bay	8/4/97	15	0.07	1.9	35.34	8.0	1.5	.	0.5	0.019	7.7	2.9	0.12	22.2	4	19.9	107
BD15	Petaluma River	8/4/97	15	0.18	8.8	37.50	7.2	2.9	.	0.5	0.021	7.6	3.7	0.21	23.8	5	23.3	165
BC60	Red Rock	7/30/97	15	0.14	2.2	46.53	7.5	1.2	.	0.3	0.013	7.7	1.2	0.07	30.3	2	17.1	6
BC41	Point Isabel	7/30/97	15	0.17	2.6	45.57	8.2	1.3	.	0.4	0.015	7.8	1.7	0.09	29.6	2	17.3	13
BC30	Richardson Bay	7/31/97	15	0.17	2.1	45.17	7.5	1.2	.	0.3	0.014	7.8	1.0	0.09	29.3	2	17.2	6
BC20	Golden Gate	7/31/97	15	0.11	4.9	48.02	9.1	1.0	.	0.2	0.008	7.8	1.3	0.05	31.2	1	15.3	2
BC10	Yerba Buena Island	7/30/97	15	0.42	2.7	46.08	7.7	1.6	.	0.4	0.015	7.6	1.2	0.12	29.9	2	18.1	6
BB70	Alameda	7/30/97	15	0.22	2.4	46.12	7.3	1.4	.	0.4	0.023	7.7	1.1	0.15	30.0	2	19.5	7
BB30	Oyster Point	7/28/97	15	0.18	1.7	45.47	6.8	1.6	.	0.5	0.021	7.7	0.9	0.14	29.5	2	19.4	6
BB15	San Bruno Shoal	7/28/97	15	0.14	2.0	44.67	7.0	2.2	.	0.4	0.016	7.8	0.8	0.22	28.9	*	21.9	5
BA40	Redwood Creek	7/29/97	15	0.13	2.6	44.97	6.9	2.5	.	0.4	0.019	7.7	1.8	0.27	29.1	4	23.1	15
BA30	Dumbarton Bridge	7/28/97	15	0.13	4.0	43.02	7.2	3.0	.	0.6	0.028	7.7	2.4	0.33	27.8	*	23.4	13
BA20	South Bay	7/28/97	15	0.18	4.5	41.61	6.2	3.4	.	0.8	0.044	7.6	2.4	0.41	26.8	*	23.3	40
BA10	Coyote Creek	7/29/97	15	0.18	5.6	41.81	6.2	3.4	.	0.9	0.049	7.6	1.7	0.44	27.0	5	23.3	18
C-3-0	San Jose	7/29/97	15	0.49	6.1	18.50	4.7	4.8	.	4.3	0.231	7.4	8.2	0.68	12.0	*	23.0	215
C-1-3	Sunnyvale	7/29/97	15	0.37	14.2	13.81	3.6	8.0	.	1.9	0.104	7.3	5.6	1.45	9.9	6	23.2	46
BW10	Standish Dam	8/1/97	15	0.05	14.3	1.12	6.9	2.3	377	2.7	0.026	8.3	10.7	0.05	0.0	*	24.1	21
BW15	Guadalupe River	8/1/97	15	0.05	4.6	4.58	6.9	2.0	767	3.1	0.051	7.9	3.7	0.25	2.3	*	22.8	93

Table 2. Dissolved concentrations of trace elements in water, 1997.

* = not available at the time of report production, . = no data, NA = not analyzed, ND = not detected. For MDLs see *Appendix B*.

Station Code	Station	Date	Cruise	Ag µg/L	As µg/L	Cd µg/L	Cr µg/L	Cu µg/L	Hg µg/L	Ni µg/L	Pb µg/L	Se µg/L	Zn µg/L
BG20	Sacramento River	1/29/97	13	0.0034	1.24	0.01	5.03	2.0	0.0033	3.1	0.405	0.10	1.9
BG30	San Joaquin River	1/29/97	13	0.0033	1.67	0.01	2.22	1.9	0.0084	1.9	0.415	0.15	2.1
BF40	Honker Bay	1/28/97	13	0.0007	1.20	0.00	2.98	1.7	0.0018	2.1	0.021	0.12	0.3
BF20	Grizzly Bay	1/28/97	13	0.0026	2.19	0.01	6.25	2.8	0.0077	4.5	0.492	0.13	3.6
BF10	Pacheco Creek	1/28/97	13	0.0036	1.33	0.01	4.59	2.3	0.0062	3.8	0.512	0.11	2.8
BD50	Napa River	1/28/97	13	0.0012	1.12	0.00	2.42	1.3	0.0044	2.5	0.066	0.11	0.6
BD40	Davis Point	1/27/97	13	0.0024	1.62	0.01	4.70	2.3	0.0077	3.7	0.420	0.16	2.6
BD30	Pinole Point	1/27/97	13	0.0011	1.22	0.01	1.36	1.5	0.0016	1.3	0.083	0.12	0.5
BD20	San Pablo Bay	1/27/97	13	0.0021	1.22	0.01	2.47	1.7	0.0031	2.1	0.253	0.11	1.2
BD15	Petaluma River	1/27/97	13	0.0057	2.66	0.03	8.79	4.2	0.0353	8.3	0.980	0.12	5.1
BC60	Red Rock	1/23/97	13	0.0010	1.22	0.02	0.27	1.3	0.0012	1.5	0.036	0.08	0.7
BC41	Point Isabel	1/23/97	13	0.0007	1.28	0.03	0.18	1.1	0.0008	1.4	0.012	0.10	0.6
BC30	Richardson Bay	1/23/97	13	0.0011	1.38	0.03	0.21	1.4	0.0012	1.5	0.026	0.07	2.4
BC20	Golden Gate	1/24/97	13	0.0010	1.43	0.02	0.11	0.4	0.0003	0.6	0.005	0.26	0.3
BC10	Yerba Buena Island	1/23/97	13	0.0010	1.47	0.03	0.17	1.2	ND	1.4	0.016	0.12	0.9
BB70	Alameda	1/23/97	13	0.0012	1.61	0.04	0.14	1.7	ND	1.7	0.019	0.18	0.9
BB30	Oyster Point	1/21/97	13	0.0006	1.60	0.03	0.22	1.0	0.0007	1.2	0.007	0.08	0.6
BB15	San Bruno Shoal	1/21/97	13	0.0009	1.74	0.04	0.16	1.4	0.0010	1.6	0.011	0.11	0.8
BA40	Redwood Creek	1/22/97	13	0.0010	1.87	0.04	0.20	1.4	0.0012	1.8	0.023	0.19	1.4
BA30	Dumbarton Bridge	1/21/97	13	0.0014	2.04	0.05	0.49	1.9	0.0024	2.9	0.102	0.53	3.2
BA20	South Bay	1/21/97	13	0.0010	2.17	0.04	0.51	1.8	0.0024	2.7	0.092	0.51	2.5
BA10	Coyote Creek	1/22/97	13	0.0007	1.99	0.03	0.39	1.6	0.0018	2.1	0.048	0.28	2.1
C-3-0	San Jose	1/22/97	13	0.0006	1.90	0.03	0.47	1.6	0.0020	2.8	0.065	0.58	4.0
C-1-3	Sunnyvale	1/22/97	13	0.0013	1.23	0.01	0.42	1.5	0.0041	1.6	0.061	0.35	3.0
BW10	Standish Dam	2/7/97	13	0.0016	1.23	0.01	.	1.4	0.0033	3.2	0.234	0.65	1.2
BW15	Guadalupe River	2/7/97	13	0.0004	1.05	0.01	.	0.8	0.0026	2.8	0.065	2.03	2.3
BG20	Sacramento River	4/23/97	14	NA	1.62	0.01	0.25	1.5	0.0008	1.3	0.025	0.12	0.5
BG30	San Joaquin River	4/23/97	14	NA	1.58	0.01	0.35	1.7	0.0012	1.0	0.084	0.21	0.8
BF40	Honker Bay	4/22/97	14	NA	1.82	0.02	1.24	2.1	0.0027	2.2	0.163	0.19	2.1
BF20	Grizzly Bay	4/22/97	14	NA	1.76	0.03	0.24	1.8	0.0009	1.6	0.013	0.23	0.5
BF10	Pacheco Creek	4/23/97	14	NA	1.83	0.04	0.17	1.8	0.0007	1.7	0.010	0.22	0.6
BD50	Napa River	4/22/97	14	NA	1.82	0.07	0.20	2.0	0.0008	2.2	0.010	0.20	0.8
BD40	Davis Point	4/21/97	14	NA	1.90	0.06	0.16	1.6	0.0006	1.8	0.007	0.20	0.3
BD30	Pinole Point	4/21/97	14	NA	1.88	0.07	0.15	1.5	0.0006	1.7	0.006	0.15	0.3
BD20	San Pablo Bay	4/21/97	14	NA	1.86	0.06	0.14	1.2	0.0005	1.4	0.002	0.14	0.2
BD15	Petaluma River	4/21/97	14	NA	2.38	0.08	0.19	2.3	0.0010	2.0	0.010	0.16	0.3
BC60	Red Rock	4/14/97	14	NA	1.79	0.08	0.15	1.5	0.0007	1.6	0.008	0.17	0.4
BC41	Point Isabel	4/14/97	14	NA	1.89	0.08	0.11	1.2	0.0008	1.4	0.010	0.09	0.2
BC30	Richardson Bay	4/14/97	14	NA	1.79	0.08	0.11	0.8	0.0005	1.0	0.011	0.14	0.4
BC20	Golden Gate	4/15/97	14	NA	1.81	0.09	0.11	0.4	0.0004	0.5	0.010	0.10	0.3
BC10	Yerba Buena Island	4/14/97	14	NA	2.02	0.08	0.11	1.1	0.0006	1.3	0.013	0.15	0.3
BB70	Alameda	4/15/97	14	NA	1.75	0.07	0.14	1.5	0.0007	1.3	0.018	0.14	0.2
BB30	Oyster Point	4/16/97	14	NA	1.62	0.08	0.13	1.1	0.0004	1.1	0.012	0.13	0.3
BB15	San Bruno Shoal	4/16/97	14	NA	2.00	0.07	0.12	1.6	0.0007	1.5	0.021	0.18	0.1
BA40	Redwood Creek	4/16/97	14	NA	2.29	0.08	0.24	2.4	0.0011	2.4	0.032	0.24	0.4
BA30	Dumbarton Bridge	4/16/97	14	NA	2.81	0.08	0.13	3.2	0.0019	2.9	0.061	0.31	0.8
BA20	South Bay	4/16/97	14	NA	3.03	0.10	0.20	3.6	0.0019	3.7	0.103	0.38	2.5
BA10	Coyote Creek	4/17/97	14	NA	3.57	0.10	0.18	4.1	0.0022	4.9	0.128	1.18	3.7
C-3-0	San Jose	4/17/97	14	NA	3.00	0.06	0.21	3.4	0.0017	5.6	0.260	1.49	9.4
C-1-3	Sunnyvale	4/17/97	14	NA	2.05	0.03	0.86	2.3	0.0041	3.4	0.246	2.14	10.5
BW10	Standish Dam	4/9/97	14	NA	3.23	0.06	0.20	2.7	0.0016	6.1	0.259	1.66	9.4
BW15	Guadalupe River	4/7/97	14	NA	3.34	0.04	0.26	2.5	0.0014	4.3	0.133	5.02	4.8
BG20	Sacramento River	8/6/97	15	NA	1.77	0.01	0.51	1.3	0.0013	1.0	*	0.04	0.6
BG30	San Joaquin River	8/6/97	15	NA	2.24	0.01	0.38	1.5	0.0013	0.8	*	0.07	0.5
BF40	Honker Bay	8/5/97	15	NA	2.34	0.02	0.37	1.5	0.0019	1.2	*	0.11	0.5
BF20	Grizzly Bay	8/5/97	15	NA	2.60	0.04	0.23	1.9	0.0012	1.4	*	0.12	0.4
BF10	Pacheco Creek	8/5/97	15	NA	2.47	0.04	0.42	1.5	0.0012	1.2	*	0.13	0.5
BD50	Napa River	8/5/97	15	NA	2.67	0.07	0.24	1.5	0.0012	1.7	*	0.18	0.5
BD40	Davis Point	8/4/97	15	NA	2.64	0.07	0.18	1.3	0.0004	1.2	*	0.21	0.4
BD30	Pinole Point	8/4/97	15	NA	2.56	0.09	0.18	1.5	0.0004	1.4	*	0.25	0.5
BD20	San Pablo Bay	8/4/97	15	NA	2.53	0.09	0.17	1.6	0.0005	2.0	*	0.18	0.4
BD15	Petaluma River	8/4/97	15	NA	3.91	0.15	0.21	3.6	0.0012	3.4	*	0.31	0.6
BC60	Red Rock	7/30/97	15	NA	2.02	0.08	0.11	1.1	0.0002	1.3	*	0.16	0.3
BC41	Point Isabel	7/30/97	15	NA	2.21	0.09	0.10	1.2	0.0003	1.4	*	0.11	0.4
BC30	Richardson Bay	7/31/97	15	NA	2.04	0.08	0.09	1.1	0.0004	1.0	*	0.10	0.8
BC20	Golden Gate	7/31/97	15	NA	1.72	0.05	0.10	0.3	ND	0.5	*	0.07	0.1
BC10	Yerba Buena Island	7/30/97	15	NA	2.14	0.09	0.10	1.2	0.0004	1.2	*	0.11	1.0
BB70	Alameda	7/30/97	15	NA	2.36	0.09	0.11	1.6	0.0004	1.5	*	0.13	0.5
BB30	Oyster Point	7/28/97	15	NA	2.43	0.09	0.11	1.8	0.0006	1.5	*	0.12	0.5
BB15	San Bruno Shoal	7/28/97	15	NA	3.01	0.12	0.13	2.2	0.0008	1.9	*	0.16	0.4
BA40	Redwood Creek	7/29/97	15	NA	3.32	0.11	0.12	2.3	0.0010	2.3	*	0.15	0.5
BA30	Dumbarton Bridge	7/28/97	15	NA	4.02	0.10	0.11	2.5	0.0014	2.6	*	0.26	0.7
BA20	South Bay	7/28/97	15	NA	4.32	0.10	0.15	3.2	0.0017	3.6	*	0.35	1.3
BA10	Coyote Creek	7/29/97	15	NA	4.52	0.12	0.14	3.1	0.0015	3.6	*	0.35	1.4
C-3-0	San Jose	7/29/97	15	NA	3.78	0.06	0.14	2.5	0.0012	6.5	*	0.87	11.5
C-1-3	Sunnyvale	7/29/97	15	NA	4.79	0.03	0.20	2.0	0.0018	4.5	*	1.07	3.1
BW10	Standish Dam	8/1/97	15	NA	2.82	0.01	0.56	1.3	0.0003	2.4	*	1.61	1.4
BW15	Guadalupe River	8/1/97	15	NA	2.36	0.01	0.29	1.2	0.0012	2.9	*	5.94	1.1

Table 3. Total or near total (▲) concentrations of trace elements in water, 1997.
* = not available at the time of report production, . = no data, NA = not analyzed, ND = not detected. For MDLs refer to Table 1 in *Appendix B*.

Station Code	Station	Date	Cruise	Ag▲	As	Cd▲	Cr	Cu▲	Hg	Ni▲	Pb▲	Se	Zn▲
				µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BG20	Sacramento River	1/29/97	13	NA	3.65	0.06	26.13	9.9	0.0377	21.8	2.35	0.14	18.2
BG30	San Joaquin River	1/29/97	13	NA	2.43	0.02	8.92	4.8	0.0156	4.8	1.21	0.17	7.6
BF40	Honker Bay	1/28/97	13	NA	4.25	0.06	41.37	10.9	0.0462	28.5	2.51	0.19	23.4
BF20	Grizzly Bay	1/28/97	13	NA	4.06	0.05	25.61	9.5	0.0295	20.8	2.37	0.18	21.1
BF10	Pacheco Creek	1/28/97	13	NA	3.16	0.04	17.95	7.6	0.0298	16.6	1.78	0.15	13.5
BD50	Napa River	1/28/97	13	NA	4.74	0.06	30.11	9.8	0.0708	21.3	3.87	0.23	25.0
BD40	Davis Point	1/27/97	13	NA	3.40	0.04	20.95	7.4	0.0344	12.8	1.87	0.18	13.9
BD30	Pinole Point	1/27/97	13	NA	4.39	0.07	39.95	10.3	0.0455	19.6	3.23	0.14	23.1
BD20	San Pablo Bay	1/27/97	13	NA	3.31	0.04	12.79	6.9	0.0276	22.9	2.24	0.14	15.4
BD15	Petaluma River	1/27/97	13	NA	4.62	0.08	52.55	12.4	0.1260	39.5	5.41	0.20	35.9
BC60	Red Rock	1/23/97	13	NA	1.62	0.03	4.56	2.8	0.0062	3.8	0.47	0.15	4.0
BC41	Point Isabel	1/23/97	13	NA	1.76	0.03	3.77	1.9	0.0037	2.6	0.27	0.15	2.3
BC30	Richardson Bay	1/23/97	13	NA	1.67	0.04	3.31	2.0	0.0044	2.6	0.45	0.11	4.6
BC20	Golden Gate	1/24/97	13	NA	1.46	0.02	1.19	0.5	ND	0.8	0.08	0.03	0.6
BC10	Yerba Buena Island	1/23/97	13	NA	1.47	0.03	3.28	1.8	0.0001	2.4	0.28	0.11	2.4
BB70	Alameda	1/23/97	13	NA	1.69	0.04	2.85	2.1	0.0041	2.4	0.25	0.18	2.4
BB30	Oyster Point	1/21/97	13	NA	1.94	0.03	3.03	1.5	0.0031	2.0	0.16	0.10	1.5
BB15	San Bruno Shoal	1/21/97	13	NA	1.79	0.04	3.01	1.7	0.0032	2.1	0.22	0.17	1.8
BA40	Redwood Creek	1/22/97	13	NA	2.50	0.05	7.62	3.5	0.0252	5.5	1.34	0.17	7.9
BA30	Dumbarton Bridge	1/21/97	13	NA	2.77	0.05	14.74	5.2	0.0338	9.7	2.77	0.63	9.7
BA20	South Bay	1/21/97	13	NA	2.90	0.06	17.16	5.3	0.0478	10.7	3.02	0.55	18.5
BA10	Coyote Creek	1/22/97	13	NA	2.54	0.04	13.99	4.1	0.0261	8.4	1.77	0.39	12.2
C-3-0	San Jose	1/22/97	13	NA	3.57	0.08	30.58	7.5	0.1040	18.2	5.11	0.62	30.2
C-1-3	Sunnyvale	1/22/97	13	NA	3.97	0.13	39.50	14.4	0.0927	36.7	11.91	0.56	77.6
BW10	Standish Dam	2/7/97	13	NA	2.61	0.05	.	5.3	0.0227	19.5	3.39	0.68	15.3
BW15	Guadalupe River	2/7/97	13	NA	1.65	0.05	.	3.8	0.0832	10.0	3.31	2.04	16.4
BG20	Sacramento River	4/23/97	14	NA	2.07	0.03	3.99	3.4	0.0074	4.6	*	0.18	6.1
BG30	San Joaquin River	4/23/97	14	NA	1.89	0.02	2.78	2.8	0.0056	2.7	*	0.20	3.6
BF40	Honker Bay	4/22/97	14	NA	4.42	0.07	18.27	9.7	0.0439	16.3	*	0.21	28.3
BF20	Grizzly Bay	4/22/97	14	NA	2.64	0.05	9.39	5.4	0.0156	8.6	*	0.17	12.4
BF10	Pacheco Creek	4/23/97	14	NA	2.98	0.06	11.47	5.7	0.0199	9.9	*	0.25	13.5
BD50	Napa River	4/22/97	14	NA	2.29	0.08	5.01	3.9	0.0081	5.5	*	0.18	7.5
BD40	Davis Point	4/21/97	14	NA	2.51	0.08	7.33	3.8	0.0110	6.3	*	0.21	8.5
BD30	Pinole Point	4/21/97	14	NA	1.82	0.09	1.13	1.9	0.0026	2.5	*	0.18	2.2
BD20	San Pablo Bay	4/21/97	14	NA	2.11	0.09	2.79	2.2	0.0048	3.1	*	0.15	4.1
BD15	Petaluma River	4/21/97	14	NA	2.75	0.10	5.46	4.0	0.0125	5.6	*	0.20	8.0
BC60	Red Rock	4/14/97	14	NA	1.82	0.08	1.49	1.7	0.0028	2.1	*	0.17	2.7
BC41	Point Isabel	4/14/97	14	NA	1.87	0.07	1.46	1.6	0.0052	1.9	*	0.10	2.1
BC30	Richardson Bay	4/14/97	14	NA	1.99	0.08	1.42	1.5	0.0032	2.0	*	0.12	3.1
BC20	Golden Gate	4/15/97	14	NA	1.77	0.06	0.32	0.6	0.0009	0.8	*	0.11	0.6
BC10	Yerba Buena Island	4/14/97	14	NA	2.11	0.07	1.41	1.8	0.0038	1.9	*	0.11	2.8
BB70	Alameda	4/15/97	14	NA	1.68	0.08	0.32	1.5	0.0012	1.0	*	0.16	0.9
BB30	Oyster Point	4/16/97	14	NA	1.69	0.08	0.45	1.2	0.0011	1.2	*	0.15	1.0
BB15	San Bruno Shoal	4/16/97	14	NA	2.13	0.08	0.33	1.9	0.0015	2.0	*	0.17	1.0
BA40	Redwood Creek	4/16/97	14	NA	2.44	0.08	0.66	2.7	0.0027	3.0	*	0.27	2.0
BA30	Dumbarton Bridge	4/16/97	14	NA	2.83	0.11	1.91	3.9	0.0054	4.5	*	0.43	4.7
BA20	South Bay	4/16/97	14	NA	3.69	0.13	6.00	5.3	0.0167	7.7	*	0.63	10.8
BA10	Coyote Creek	4/17/97	14	NA	4.61	0.12	19.49	7.6	0.0563	14.7	*	1.19	31.5
C-3-0	San Jose	4/17/97	14	NA	3.56	0.09	5.71	5.3	0.0180	10.2	*	1.50	24.3
C-1-3	Sunnyvale	4/17/97	14	NA	4.14	0.05	19.80	6.7	0.0751	15.2	*	2.20	45.4
BW10	Standish Dam	4/9/97	14	NA	4.90	0.09	11.56	7.3	0.0661	18.1	*	2.10	40.1
BW15	Guadalupe River	4/7/97	14	NA	17.70	0.38	125.92	47.0	0.6220	107.3	*	7.03	215.6
BG20	Sacramento River	8/6/97	15	NA	2.30	0.03	5.21	2.2	0.0056	4.2	*	0.08	4.9
BG30	San Joaquin River	8/6/97	15	NA	2.63	0.02	4.40	2.4	0.0079	3.2	*	0.09	3.9
BF40	Honker Bay	8/5/97	15	NA	3.05	0.03	7.75	3.4	0.0195	5.5	*	0.15	7.1
BF20	Grizzly Bay	8/5/97	15	NA	2.89	0.05	3.96	1.7	0.0837	3.4	*	0.15	3.7
BF10	Pacheco Creek	8/5/97	15	NA	3.55	0.06	12.30	4.4	0.0145	6.3	*	0.21	9.8
BD50	Napa River	8/5/97	15	NA	3.78	0.11	12.68	5.5	0.0176	9.5	*	0.21	11.4
BD40	Davis Point	8/4/97	15	NA	3.86	0.11	12.38	4.7	0.0189	8.4	*	0.29	10.0
BD30	Pinole Point	8/4/97	15	NA	3.08	0.09	4.62	3.3	0.0091	5.7	*	0.26	5.4
BD20	San Pablo Bay	8/4/97	15	NA	3.92	0.11	4.67	5.7	0.0255	9.7	*	0.26	12.7
BD15	Petaluma River	8/4/97	15	NA	6.05	0.19	28.48	9.3	0.0537	16.0	*	0.39	24.0
BC60	Red Rock	7/30/97	15	NA	2.35	0.09	2.21	1.6	0.0041	2.6	*	0.10	2.4
BC41	Point Isabel	7/30/97	15	NA	2.42	0.10	1.87	1.7	0.0034	2.8	*	0.13	1.7
BC30	Richardson Bay	7/31/97	15	NA	2.09	0.09	1.59	1.3	0.0020	2.2	*	0.09	1.4
BC20	Golden Gate	7/31/97	15	NA	1.81	0.06	0.30	0.5	0.0005	0.6	*	0.08	0.3
BC10	Yerba Buena Island	7/30/97	15	NA	2.22	0.10	1.39	1.5	0.0026	2.3	*	0.14	1.7
BB70	Alameda	7/30/97	15	NA	2.43	0.11	1.12	1.7	0.0022	3.1	*	0.13	1.4
BB30	Oyster Point	7/28/97	15	NA	2.45	0.11	1.85	1.9	0.0035	2.5	*	0.12	1.8
BB15	San Bruno Shoal	7/28/97	15	NA	3.14	0.14	2.19	2.8	0.0046	3.6	*	0.16	2.1
BA40	Redwood Creek	7/29/97	15	NA	3.57	0.13	3.37	2.7	0.0064	4.5	*	0.19	3.2
BA30	Dumbarton Bridge	7/28/97	15	NA	4.13	0.11	3.84	3.3	0.0142	4.3	*	0.27	5.0
BA20	South Bay	7/28/97	15	NA	4.76	0.11	7.19	4.5	0.0203	7.2	*	0.39	8.7
BA10	Coyote Creek	7/29/97	15	NA	4.37	0.14	3.56	3.5	0.0077	4.2	*	0.35	4.2
C-3-0	San Jose	7/29/97	15	NA	6.04	0.09	17.63	9.0	0.0991	22.4	*	1.27	43.6
C-1-3	Sunnyvale	7/29/97	15	NA	5.16	0.04	9.46	3.5	0.0185	8.2	*	1.06	11.5
BW10	Standish Dam	8/1/97	15	NA	3.21	0.03	16.48	2.1	0.0059	3.7	*	1.81	6.3
BW15	Guadalupe River	8/1/97	15	NA	3.97	0.03	3.62	4.3	0.0628	10.3	*	7.02	17.8

Table 4. Dissolved PAH concentrations in water samples, 1997.
HPAH = high molecular weight PAHS, LPAH = low molecular weight PAHs, M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of LPAHs (SFEI)	Biphenyl	Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	2,6-Dimethylnaphthalene	2,3,5-Trimethylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Dibenzothiophene	Fluorene	Phenanthrene	1-Methylphenanthrene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	4062	3442	506	286	474	405	ND	ND	239	122	ND	ND	377	864	169
BG30	San Joaquin River	1/29/97	13	5739	4725	277	492	659	654	164	ND	334	106	ND	ND	545	1265	229
BF20	Grizzly Bay	1/28/97	13	3290	2848	201	393	461	358	ND	ND	188	ND	ND	ND	450	659	138
BD50	Napa River	1/28/97	13	8455	6603	345	343	802	603	178	167	725	128	ND	ND	908	2031	373
BD40	Davis Point	1/27/97	13	6047	4531	250	283	601	587	127	ND	504	ND	ND	ND	697	1245	237
BD30	Pinole Point	1/27/97	13	5243	4265	232	482	644	576	151	ND	386	ND	ND	ND	689	880	225
BD20	San Pablo Bay	1/27/97	13	5374	4014	201	413	571	506	122	ND	323	ND	ND	ND	497	1219	162
BD15	Petaluma River	1/27/97	13	8764	6122	316	406	781	630	141	ND	610	145	ND	104	738	2005	246
BC60	Red Rock	1/23/97	13	7909	5598	346	148	513	513	153	ND	558	167	ND	ND	907	2038	255
BC20	Golden Gate	1/24/97	13	3580	2812	188	301	326	457	ND	ND	192	122	ND	ND	415	811	ND
BC10	Yerba Buena Island	1/23/97	13	20288	11154	298	425	557	721	ND	ND	973	ND	ND	ND	1854	5512	814
BB70	Alameda	1/23/97	13	5697	1102	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	331	771	ND
BA40	Redwood Creek	1/22/97	13	8389	1066	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	348	508	210
BA30	Dumbarton Bridge	1/21/97	13	5289	2402	243	384	210	279	ND	ND	104	178	ND	ND	253	589	162
BA10	Coyote Creek	1/22/97	13	7169	2621	158	547	231	284	ND	ND	175	150	ND	ND	322	606	148
C-3-0	San Jose	1/22/97	13	25605	15561	706	1767	2179	2598	893	458	469	454	260	194	1433	3280	870
BW10	Standish Dam	2/7/97	13	10197	7784	628	1638	1295	1642	208	169	194	420	ND	ND	558	696	336
BW15	Guadalupe River	2/7/97	13	13530	10074	750	1528	1402	1610	283	153	609	466	ND	ND	961	1909	403
BG20	Sacramento River	4/23/97	14	5340	3120	370	620	330	360	ND	ND	ND	ND	ND	ND	440	1000	ND
BG30	San Joaquin River	4/23/97	14	2110	1190	ND	290	140	190	ND	ND	ND	ND	ND	ND	170	400	ND
BF20	Grizzly Bay	4/22/97	14	5920	2920	180	760	200	300	ND	ND	230	ND	ND	ND	320	930	ND
BD50	Napa River	4/22/97	14	10440	4870	210	230	190	260	ND	ND	950	130	ND	210	720	1800	170
BD40	Davis Point	4/21/97	14	6560	3650	110	160	130	220	ND	ND	640	ND	ND	130	650	1500	110
BD30	Pinole Point	4/21/97	14	9830	6320	240	180	230	330	160	ND	960	150	ND	270	1100	2500	200
BD20	San Pablo Bay	4/21/97	14	4750	2990	ND	140	ND	180	ND	ND	540	ND	ND	140	590	1400	ND
BD15	Petaluma River	4/21/97	14	6720	3570	170	530	300	610	ND	ND	340	ND	ND	ND	420	1200	ND
BC60	Red Rock	4/14/97	14	4390	2710	150	ND	ND	150	ND	ND	390	ND	ND	130	490	1400	ND
BC20	Golden Gate	4/15/97	14	3300	2470	120	300	ND	190	ND	ND	430	ND	ND	ND	430	1000	ND
BC10	Yerba Buena Island	4/14/97	14	5510	3920	150	190	190	320	ND	ND	770	ND	ND	150	650	1500	ND
BB70	Alameda	4/15/97	14	1990	1420	ND	130	ND	ND	ND	ND	ND	ND	ND	ND	400	890	ND
BA40	Redwood Creek	4/16/97	14	20260	8120	370	410	240	390	240	150	840	220	150	410	1100	3300	300
BA30	Dumbarton Bridge	4/16/97	14	11800	8510	290	1100	400	570	240	ND	1100	260	ND	320	1300	2700	230
BA10	Coyote Creek	4/17/97	14	9170	3580	170	440	170	260	ND	ND	370	ND	ND	140	500	1400	130
C-3-0	San Jose	4/17/97	14	16380	8370	250	650	400	580	190	150	910	160	150	350	1000	3300	280
BW10	Standish Dam	4/9/97	14	39730	20940	980	910	1400	2100	680	580	2200	510	350	1000	2400	7000	830
BW15	Guadalupe River	4/7/97	14	32430	17310	1800	380	1100	1500	480	320	1900	420	300	600	1800	5800	910
BG20	Sacramento River	8/6/97	15	1380	580	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	180	400	ND
BG30	San Joaquin River	8/6/97	15	1980	900	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	610	ND
BF20	Grizzly Bay	8/5/97	15	10670	4930	ND	ND	ND	120	ND	ND	160	ND	ND	170	1200	3000	280
BD50	Napa River	8/5/97	15	11470	5140	ND	ND	ND	ND	ND	ND	630	160	ND	250	1200	2700	200
BD40	Davis Point	8/4/97	15	5560	2270	ND	ND	ND	ND	ND	ND	130	ND	ND	ND	490	1500	150
BD30	Pinole Point	8/4/97	15	4080	1910	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	510	1400	ND
BD20	San Pablo Bay	8/4/97	15	3960	1580	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	480	1100	ND
BD15	Petaluma River	8/4/97	15	3720	1110	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	250	740	120
BC60	Red Rock	7/30/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC20	Golden Gate	7/31/97	15	3020	1690	ND	480	160	200	ND	ND	210	ND	ND	ND	160	480	ND
BC10	Yerba Buena Island	7/30/97	15	14910	6780	180	420	180	210	130	120	1500	170	440	200	1100	1900	230
BB70	Alameda	7/30/97	15	7490	3580	160	290	ND	ND	ND	ND	660	110	180	150	570	1300	160
BA40	Redwood Creek	7/29/97	15	4470	1800	130	ND	ND	140	ND	ND	230	ND	ND	ND	340	960	ND
BA30	Dumbarton Bridge	7/28/97	15	2020	1720	ND	ND	ND	ND	ND	310	210	ND	M	M	1200	ND	M
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C-3-0	San Jose	7/29/97	15	12250	4610	ND	ND	ND	ND	ND	120	240	ND	ND	220	930	2700	400
BW10	Standish Dam	8/1/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BW15	Guadalupe River	8/1/97	15	12640	5120	120	ND	ND	ND	140	290	300	ND	ND	280	1100	2500	390

Table 4. Dissolved PAH concentrations in water samples, 1997 (continued).
HPAH = high molecular weight PAHS, LPAH = low molecular weight PAHs, M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of HPAHs (SFEI)	Benz(a)anthracene	Chrysene	Pyrene	Benzo(a)pyrene	Benzo(e)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Dibenz(a,h)anthracene	Perylene	Benzo(ghi)perylene	Fluoranthene	Indeno(1,2,3-cd)pyrene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	4062	620	ND	ND	232	ND	ND	ND	ND	ND	ND	ND	388	ND
BG30	San Joaquin River	1/29/97	13	5739	1014	ND	ND	356	ND	ND	ND	ND	ND	ND	ND	658	ND
BF20	Grizzly Bay	1/28/97	13	3290	442	ND	ND	148	ND	ND	ND	ND	ND	ND	ND	294	ND
BD50	Napa River	1/28/97	13	8455	1852	236	ND	634	ND	ND	ND	ND	ND	ND	ND	982	ND
BD40	Davis Point	1/27/97	13	6047	1516	205	ND	602	ND	ND	ND	ND	ND	ND	ND	709	ND
BD30	Pinole Point	1/27/97	13	5243	978	149	ND	314	ND	ND	ND	ND	ND	ND	ND	515	ND
BD20	San Pablo Bay	1/27/97	13	5374	1360	144	ND	421	ND	ND	ND	ND	ND	ND	ND	795	ND
BD15	Petaluma River	1/27/97	13	8764	2642	308	140	812	ND	ND	189	ND	ND	ND	ND	1193	ND
BC60	Red Rock	1/23/97	13	7909	2311	153	ND	900	ND	ND	ND	ND	ND	ND	ND	1258	ND
BC20	Golden Gate	1/24/97	13	3580	768	ND	ND	188	ND	ND	ND	ND	ND	ND	ND	580	ND
BC10	Yerba Buena Island	1/23/97	13	20288	9134	592	ND	2869	ND	ND	ND	ND	ND	ND	ND	5673	ND
BB70	Alameda	1/23/97	13	5697	4595	346	ND	1554	ND	ND	219	ND	ND	ND	ND	2476	ND
BA40	Redwood Creek	1/22/97	13	8389	7323	612	407	2370	ND	ND	642	208	ND	ND	ND	2707	377
BA30	Dumbarton Bridge	1/21/97	13	5289	2887	297	128	890	ND	126	243	ND	ND	ND	ND	1203	ND
BA10	Coyote Creek	1/22/97	13	7169	4548	393	227	1537	ND	ND	397	132	ND	ND	ND	1673	189
C-3-0	San Jose	1/22/97	13	25605	10044	1124	617	3654	ND	ND	465	154	ND	ND	ND	3745	285
BW10	Standish Dam	2/7/97	13	10197	2413	471	208	855	ND	ND	126	ND	ND	ND	ND	753	ND
BW15	Guadalupe River	2/7/97	13	13530	3456	700	283	1198	ND	ND	178	ND	ND	ND	ND	1097	ND
BG20	Sacramento River	4/23/97	14	5340	2220	ND	ND	920	ND	ND	ND	ND	ND	ND	ND	1300	ND
BG30	San Joaquin River	4/23/97	14	2110	920	ND	ND	570	ND	ND	ND	ND	ND	ND	ND	350	ND
BF20	Grizzly Bay	4/22/97	14	5920	3000	190	130	1200	ND	ND	180	ND	ND	ND	ND	1300	ND
BD50	Napa River	4/22/97	14	10440	5570	350	170	2100	ND	150	200	ND	ND	ND	ND	2600	ND
BD40	Davis Point	4/21/97	14	6560	2910	190	ND	1200	ND	ND	120	ND	ND	ND	ND	1400	ND
BD30	Pinole Point	4/21/97	14	9830	3510	210	ND	1400	ND	ND	ND	ND	ND	ND	ND	1900	ND
BD20	San Pablo Bay	4/21/97	14	4750	1760	140	ND	680	ND	ND	ND	ND	ND	ND	ND	940	ND
BD15	Petaluma River	4/21/97	14	6720	3150	210	ND	1400	ND	150	190	ND	ND	ND	ND	1200	ND
BC60	Red Rock	4/14/97	14	4390	1680	ND	ND	680	ND	ND	ND	ND	ND	ND	ND	1000	ND
BC20	Golden Gate	4/15/97	14	3300	830	ND	ND	180	ND	ND	ND	ND	ND	ND	ND	650	ND
BC10	Yerba Buena Island	4/14/97	14	5510	1590	ND	ND	590	ND	ND	ND	ND	ND	ND	ND	1000	ND
BB70	Alameda	4/15/97	14	1990	570	ND	ND	200	ND	ND	ND	ND	ND	ND	ND	370	ND
BA40	Redwood Creek	4/16/97	14	20260	12140	970	550	3600	ND	970	1400	400	ND	ND	ND	3500	750
BA30	Dumbarton Bridge	4/16/97	14	11800	3290	250	120	1200	ND	140	180	ND	ND	ND	ND	1400	ND
BA10	Coyote Creek	4/17/97	14	9170	5590	450	270	1600	ND	480	690	200	ND	ND	ND	1500	400
C-3-0	San Jose	4/17/97	14	16380	8010	530	280	3000	ND	340	430	130	ND	ND	ND	3100	200
BW10	Standish Dam	4/9/97	14	39730	18790	1200	730	7200	ND	1000	1300	380	ND	ND	130	6200	650
BW15	Guadalupe River	4/7/97	14	32430	15120	1100	540	5400	ND	910	1300	370	ND	ND	ND	4800	700
BG20	Sacramento River	8/6/97	15	1380	800	ND	ND	340	ND	ND	ND	ND	ND	ND	ND	460	ND
BG30	San Joaquin River	8/6/97	15	1980	1080	130	ND	310	ND	ND	ND	ND	ND	ND	ND	640	ND
BF20	Grizzly Bay	8/5/97	15	10670	5740	290	210	1600	ND	150	190	ND	ND	ND	ND	3300	ND
BD50	Napa River	8/5/97	15	11470	6330	320	170	2300	ND	ND	140	ND	ND	ND	ND	3400	ND
BD40	Davis Point	8/4/97	15	5560	3290	230	140	870	ND	140	210	ND	ND	ND	ND	1700	ND
BD30	Pinole Point	8/4/97	15	4080	2170	ND	ND	670	ND	ND	ND	ND	ND	ND	ND	1500	ND
BD20	San Pablo Bay	8/4/97	15	3960	2380	ND	ND	880	ND	ND	ND	ND	ND	ND	ND	1500	ND
BD15	Petaluma River	8/4/97	15	3720	2610	180	ND	970	ND	150	210	ND	ND	ND	ND	1100	ND
BC60	Red Rock	7/30/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC20	Golden Gate	7/31/97	15	3020	1330	ND	ND	460	ND	ND	ND	ND	ND	ND	ND	870	ND
BC10	Yerba Buena Island	7/30/97	15	14910	8130	360	170	2400	ND	ND	ND	ND	ND	ND	ND	5200	ND
BB70	Alameda	7/30/97	15	7490	3910	210	ND	1300	ND	ND	ND	ND	ND	ND	ND	2400	ND
BA40	Redwood Creek	7/29/97	15	4470	2670	170	ND	1100	ND	ND	ND	ND	ND	ND	ND	1400	ND
BA30	Dumbarton Bridge	7/28/97	15	2020	300	M	M	M	ND	140	160	ND	ND	ND	ND	M	ND
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C-3-0	San Jose	7/29/97	15	12250	7640	510	240	2900	ND	300	390	130	ND	ND	ND	3000	170
BW10	Standish Dam	8/1/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BW15	Guadalupe River	8/1/97	15	12640	7520	520	270	2800	ND	370	490	150	ND	ND	ND	2700	220

Table 5. Total (dissolved + particulate) PAH concentrations in water samples, 1997.
M = matrix interference, NA = not analyzed, ND = not detected, HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of LPAHs (SFEI)	Biphenyl	Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	2,6-Dimethylnaphthalene	2,3,5-Trimethylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Dibenzothiophene	Fluorene	Phenanthrene	1-Methylphenanthrene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	10886	4764	668	286	474	571	ND	ND	239	122	ND	ND	519	1459	426
BG30	San Joaquin River	1/29/97	13	10031	5132	277	492	659	654	164	ND	334	106	ND	ND	545	1485	416
BF20	Grizzly Bay	1/28/97	13	6477	3362	201	393	461	358	ND	ND	188	ND	ND	ND	450	960	351
BD50	Napa River	1/28/97	13	63685	23644	1727	343	1634	2191	957	688	725	128	455	ND	2643	8804	3349
BD40	Davis Point	1/27/97	13	12105	5782	250	283	777	856	127	ND	504	ND	ND	ND	841	1667	477
BD30	Pinole Point	1/27/97	13	18869	6422	425	482	912	980	151	ND	386	ND	ND	ND	915	1623	548
BD20	San Pablo Bay	1/27/97	13	13134	4621	201	413	571	506	122	ND	323	ND	ND	ND	497	1603	385
BD15	Petaluma River	1/27/97	13	57631	9578	316	406	781	630	141	ND	610	145	398	104	1120	4058	869
BC60	Red Rock	1/23/97	13	13861	6572	483	148	682	765	153	ND	558	167	ND	ND	907	2253	456
BC20	Golden Gate	1/24/97	13	5614	3036	188	301	326	457	ND	ND	192	122	ND	ND	415	1035	ND
BC10	Yerba Buena Island	1/23/97	13	26344	11926	298	425	557	870	ND	ND	973	ND	ND	ND	1854	6000	949
BB70	Alameda	1/23/97	13	28314	2304	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	468	1836	ND
BA40	Redwood Creek	1/22/97	13	86568	6242	314	124	270	430	152	ND	ND	163	576	ND	712	2764	737
BA30	Dumbarton Bridge	1/21/97	13	105868	12548	750	791	609	938	318	115	342	478	574	376	794	5462	1001
BA10	Coyote Creek	1/22/97	13	66999	8632	470	755	480	687	195	ND	337	358	360	179	687	3526	598
C-3-0	San Jose	1/22/97	13	167844	27802	1360	2098	2830	3695	1276	633	619	642	1289	492	2182	8714	1972
BW10	Standish Dam	2/7/97	13	59182	13545	1130	1638	1665	2339	467	169	194	420	210	ND	984	3192	1137
BW15	Guadalupe River	2/7/97	13	104150	20044	1238	1528	1746	2228	572	339	743	580	541	198	1587	7268	1476
BG20	Sacramento River	4/23/97	14	10800	3800	370	620	330	360	ND	ND	ND	ND	ND	ND	440	1680	ND
BG30	San Joaquin River	4/23/97	14	4480	1480	ND	290	140	190	ND	ND	ND	ND	ND	ND	170	690	ND
BF20	Grizzly Bay	4/22/97	14	20070	4280	180	760	200	300	ND	ND	230	ND	ND	ND	470	1930	210
BD50	Napa River	4/22/97	14	23130	6230	210	230	190	260	ND	ND	950	130	ND	210	900	2800	350
BD40	Davis Point	4/21/97	14	29130	6000	110	160	130	M	ND	ND	970	ND	ND	130	920	3200	380
BD30	Pinole Point	4/21/97	14	17810	6970	240	180	230	330	160	ND	960	150	ND	270	1100	3150	200
BD20	San Pablo Bay	4/21/97	14	22480	3670	ND	140	ND	180	ND	ND	540	ND	ND	140	590	2080	ND
BD15	Petaluma River	4/21/97	14	59650	7850	310	530	300	610	130	ND	340	180	290	240	820	3800	300
BC60	Red Rock	4/14/97	14	14520	3450	150	ND	ND	150	ND	ND	390	ND	ND	130	490	2020	120
BC20	Golden Gate	4/15/97	14	6440	2770	120	300	ND	190	ND	ND	430	ND	ND	ND	430	1300	ND
BC10	Yerba Buena Island	4/14/97	14	24010	4670	150	190	190	320	ND	ND	770	ND	ND	150	650	2250	ND
BB70	Alameda	4/15/97	14	8590	1690	ND	130	ND	ND	ND	ND	ND	ND	ND	ND	400	1160	ND
BA40	Redwood Creek	4/16/97	14	33830	8770	370	410	240	390	240	150	840	220	150	410	1100	3950	300
BA30	Dumbarton Bridge	4/16/97	14	100910	15860	590	1100	400	570	240	190	1100	450	M	870	2120	8000	230
BA10	Coyote Creek	4/17/97	14	234390	3500	270	440	170	260	120	ND	370	400	M	250	1220	M	M
C-3-0	San Jose	4/17/97	14	54350	10790	250	650	400	580	190	150	910	160	320	350	1210	5000	620
BW10	Standish Dam	4/9/97	14	313080	30290	980	910	1400	2100	680	1170	2200	1500	2250	1140	4700	9500	1760
BW15	Guadalupe River	4/7/97	14	445700	15480	3600	380	1100	1500	2680	M	3200	3020	M	M	M	M	M
BG20	Sacramento River	8/6/97	15	7640	1000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	180	820	ND
BG30	San Joaquin River	8/6/97	15	7490	900	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	290	610	ND
BF20	Grizzly Bay	8/5/97	15	18320	5310	ND	ND	ND	120	ND	ND	160	ND	ND	170	1200	3380	280
BD50	Napa River	8/5/97	15	40540	6840	ND	ND	ND	ND	ND	ND	630	160	140	250	1400	3800	460
BD40	Davis Point	8/4/97	15	45140	6630	ND	ND	ND	ND	ND	ND	330	ND	270	150	1190	4100	590
BD30	Pinole Point	8/4/97	15	19460	3370	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	800	2400	170
BD20	San Pablo Bay	8/4/97	15	63060	4780	ND	ND	ND	ND	ND	ND	ND	140	340	ND	760	3100	440
BD15	Petaluma River	8/4/97	15	152310	12700	730	ND	190	480	400	230	410	390	1100	520	1240	6140	870
BC60	Red Rock	7/30/97	15	13750	1120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	120	860	140
BC20	Golden Gate	7/31/97	15	4100	1690	ND	480	160	200	ND	ND	210	ND	ND	ND	160	480	ND
BC10	Yerba Buena Island	7/30/97	15	23900	7270	180	420	180	210	130	120	1500	170	440	200	1100	2390	230
BB70	Alameda	7/30/97	15	17630	4030	160	290	ND	ND	ND	ND	660	110	180	150	570	1750	160
BA40	Redwood Creek	7/29/97	15	28810	2740	130	ND	ND	140	ND	ND	230	ND	ND	ND	340	1740	160
BA30	Dumbarton Bridge	7/28/97	15	9120	640	ND	ND	ND	ND	ND	310	210	120	M	M	M	M	M
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C-3-0	San Jose	7/29/97	15	194710	17770	720	ND	220	540	420	330	640	470	1300	810	1930	9100	1290
BW10	Standish Dam	8/1/97	15	9860	2970	ND	ND	ND	870	ND	ND	2100	ND	M	M	ND	M	M
BW15	Guadalupe River	8/1/97	15	228130	21610	820	ND	ND	260	660	560	770	730	1600	1020	2300	11400	1490

Table 5. Total (dissolved + particulate) PAH concentrations in water samples, 1997 (continued).
M = matrix interference, NA = not analyzed, ND = not detected, HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of HPAHs (SFEI)	Benz(a)anthracene	Chrysene	Pyrene	Benzo(a)pyrene	Benzo(e)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Dibenz(a,h)anthracene	Perylene	Benzo(ghi)perylene	Fluoranthene	Indeno(1,2,3-cd)pyrene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	10886	6122	650	751	1155	ND	ND	1128	312	159	ND	ND	1216	751
BG30	San Joaquin River	1/29/97	13	10031	4899	382	581	971	ND	ND	840	293	ND	ND	ND	1324	508
BF20	Grizzly Bay	1/28/97	13	6477	3115	383	447	506	ND	ND	739	161	ND	ND	ND	703	176
BD50	Napa River	1/28/97	13	63685	40041	5468	4732	5737	ND	1492	6731	1513	1262	ND	4051	5219	3836
BD40	Davis Point	1/27/97	13	12105	6323	806	651	1444	ND	ND	951	297	143	ND	ND	1439	592
BD30	Pinole Point	1/27/97	13	18869	12447	1292	1408	2271	ND	ND	2237	793	305	ND	271	2175	1695
BD20	San Pablo Bay	1/27/97	13	13134	8513	958	987	1316	ND	ND	1764	563	237	ND	ND	1473	1215
BD15	Petaluma River	1/27/97	13	57631	48053	3878	3868	8240	ND	ND	9014	3185	1133	ND	4210	6489	8036
BC60	Red Rock	1/23/97	13	13861	7289	598	718	1588	ND	ND	1430	468	190	ND	ND	1790	507
BC20	Golden Gate	1/24/97	13	5614	2578	214	185	574	ND	214	343	128	ND	ND	ND	920	ND
BC10	Yerba Buena Island	1/23/97	13	26344	14418	1138	448	4000	ND	814	959	347	ND	ND	ND	6712	ND
BB70	Alameda	1/23/97	13	28314	26010	1738	1375	3540	ND	3374	4088	1448	555	ND	682	4306	4904
BA40	Redwood Creek	1/22/97	13	86568	80326	4966	6139	12830	ND	ND	13700	5730	1760	ND	8956	12522	13723
BA30	Dumbarton Bridge	1/21/97	13	105868	93320	5865	5733	13322	ND	11278	12100	5336	1744	ND	14241	10674	13027
BA10	Coyote Creek	1/22/97	13	66999	58367	3992	3812	10414	ND	7332	9887	3686	1039	ND	983	7819	9403
C-3-0	San Jose	1/22/97	13	167844	140042	11059	11234	18752	14321	13832	14550	8582	2621	865	14796	17018	12412
BW10	Standish Dam	2/7/97	13	59182	45637	4755	5021	5807	ND	3618	7072	2568	1198	ND	6102	5151	4345
BW15	Guadalupe River	2/7/97	13	104150	84106	7224	8369	13220	ND	8039	12045	4594	1716	559	10342	9815	8183
BG20	Sacramento River	4/23/97	14	10800	7000	630	600	1720	ND	580	750	200	ND	ND	ND	2300	220
BG30	San Joaquin River	4/23/97	14	4480	3000	290	290	940	ND	260	360	ND	ND	ND	ND	860	ND
BF20	Grizzly Bay	4/22/97	14	20070	15790	1990	1110	3800	ND	1300	2080	610	170	ND	130	3500	1100
BD50	Napa River	4/22/97	14	23130	16900	1850	980	4400	ND	1350	1900	540	160	ND	130	4600	990
BD40	Davis Point	4/21/97	14	29130	23130	2590	1300	5400	ND	2100	2920	860	260	ND	1800	4300	1600
BD30	Pinole Point	4/21/97	14	17810	10840	1070	580	2600	ND	1000	1300	410	ND	ND	ND	3100	780
BD20	San Pablo Bay	4/21/97	14	22480	18810	1940	880	3080	360	1700	2300	760	250	ND	2700	2540	2300
BD15	Petaluma River	4/21/97	14	59650	51800	5510	2700	9600	210	5150	6990	2100	740	ND	6800	6300	5700
BC60	Red Rock	4/14/97	14	14520	11070	1000	560	2280	ND	980	1300	420	130	ND	1100	2100	1200
BC20	Golden Gate	4/15/97	14	6440	3670	320	200	670	ND	320	420	120	ND	ND	200	1050	370
BC10	Yerba Buena Island	4/14/97	14	24010	19340	1900	990	3290	ND	1800	2400	810	250	ND	2700	2800	2400
BB70	Alameda	4/15/97	14	8590	6900	590	350	1190	ND	730	900	310	ND	ND	880	950	1000
BA40	Redwood Creek	4/16/97	14	33830	25060	2370	1430	5200	ND	2870	3800	1190	250	ND	ND	5100	2850
BA30	Dumbarton Bridge	4/16/97	14	100910	85050	11250	7120	1200	230	12140	16180	5100	1500	ND	15000	2330	13000
BA10	Coyote Creek	4/17/97	14	234390	230890	35450	22270	M	26000	27480	45690	12200	3300	9100	27000	M	22400
C-3-0	San Jose	4/17/97	14	54350	43560	4530	2480	9200	ND	4040	6030	1930	550	ND	3100	7500	4200
BW10	Standish Dam	4/9/97	14	313080	282790	31200	19730	49200	23000	24000	37300	11380	3000	8000	23130	33200	19650
BW15	Guadalupe River	4/7/97	14	445700	430220	88100	44540	M	49000	47910	M	95370	5600	22000	42000	M	35700
BG20	Sacramento River	8/6/97	15	7640	6640	720	580	1540	ND	650	940	270	ND	ND	ND	1760	180
BG30	San Joaquin River	8/6/97	15	7490	6590	840	480	1410	ND	590	820	250	ND	ND	210	1490	500
BF20	Grizzly Bay	8/5/97	15	18320	13010	1270	840	2700	ND	1070	1590	420	ND	ND	ND	4600	520
BD50	Napa River	8/5/97	15	40540	33700	3820	2070	6700	ND	3000	4540	1300	370	ND	1700	7600	2600
BD40	Davis Point	8/4/97	15	45140	38510	4230	2140	7770	ND	3540	5110	1500	420	ND	2400	8300	3100
BD30	Pinole Point	8/4/97	15	19460	16090	1700	900	3170	ND	1600	2300	710	210	ND	ND	4100	1400
BD20	San Pablo Bay	8/4/97	15	63060	58280	6400	3300	9980	ND	6200	8800	2500	700	ND	6500	9100	4800
BD15	Petaluma River	8/4/97	15	152310	139610	12180	5300	20970	12000	13150	20210	5200	1500	3000	19000	13100	14000
BC60	Red Rock	7/30/97	15	13750	12630	1600	850	2300	ND	1500	2200	680	200	ND	ND	2000	1300
BC20	Golden Gate	7/31/97	15	4100	2410	160	ND	600	ND	190	290	ND	ND	ND	ND	1170	ND
BC10	Yerba Buena Island	7/30/97	15	23900	16630	1340	790	3900	ND	960	1400	440	120	ND	ND	7000	680
BB70	Alameda	7/30/97	15	17630	13600	1310	670	2900	ND	1300	1800	560	160	ND	ND	3900	1000
BA40	Redwood Creek	7/29/97	15	28810	26070	2670	1400	4300	ND	2900	4400	1400	420	ND	980	4000	3600
BA30	Dumbarton Bridge	7/28/97	15	9120	8480	M	M	M	M	M	M	M	480	M	3900	M	4100
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C-3-0	San Jose	7/29/97	15	194710	176940	14510	6640	24900	15000	15300	27390	6730	1900	1400	26000	18000	19170
BW10	Standish Dam	8/1/97	15	9860	6890	1100	1200	M	560	1400	1900	530	M	200	ND	M	M
BW15	Guadalupe River	8/1/97	15	228130	206520	18520	8970	36800	21000	20370	37490	8250	2300	4900	ND	22700	25220

Table 6. Dissolved PCB concentrations in water samples, 1997.
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 008	PCB 018	PCB 028	PCB 031	PCB 033	PCB 044	PCB 049	PCB 052	PCB 056	PCB 060	PCB 066	PCB 070	PCB 074	PCB 087
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	55	1	4	5	4	NA	2	2	9	NA	ND	3	2	ND	1
BG30	San Joaquin River	1/29/97	13	60	ND	5	4	6	NA	2	3	5	NA	1	4	2	1	2
BF20	Grizzly Bay	1/28/97	13	46	4	3	2	5	NA	2	2	4	NA	ND	3	1	ND	1
BD50	Napa River	1/28/97	13	78	6	5	4	12	NA	2	2	5	NA	ND	5	2	1	1
BD40	Davis Point	1/27/97	13	65	1	4	3	2	NA	2	3	5	NA	ND	4	3	1	2
BD30	Pinole Point	1/27/97	13	75	3	6	4	15	NA	3	2	5	NA	ND	4	2	ND	2
BD20	San Pablo Bay	1/27/97	13	69	ND	4	3	8	NA	2	3	7	NA	ND	5	2	ND	2
BD15	Petaluma River	1/27/97	13	145	5	14	10	14	NA	6	7	11	NA	3	8	5	2	2
BC60	Red Rock	1/23/97	13	76	ND	4	3	7	NA	3	3	5	NA	1	4	3	ND	2
BC20	Golden Gate	1/24/97	13	42	1	2	2	3	NA	2	ND	4	NA	1	2	2	ND	1
BC10	Yerba Buena Island	1/23/97	13	119	2	7	5	5	NA	5	2	11	NA	3	5	4	2	3
BB70	Alameda	1/23/97	13	119	ND	6	5	4	NA	4	4	9	NA	3	5	4	2	4
BA40	Redwood Creek	1/22/97	13	241	11	28	21	17	NA	12	3	15	NA	7	11	6	2	3
BA30	Dumbarton Bridge	1/21/97	13	151	2	7	6	10	NA	6	2	12	NA	4	8	5	2	4
BA10	Coyote Creek	1/22/97	13	207	4	18	6	15	NA	7	8	16	NA	8	10	6	2	5
C-3-0	San Jose	1/22/97	13	425	10	44	41	39	NA	9	14	34	NA	15	17	13	4	8
BW10	Standish Dam	2/7/97	13	528	5	13	14	16	NA	10	12	27	NA	10	19	8	2	6
BW15	Guadalupe River	2/7/97	13	431	6	17	11	15	NA	14	11	32	NA	9	21	8	2	9
BG20	Sacramento River	4/23/97	14	146	9	11	12	15	NA	7	4	17	NA	2	5	5	2	3
BG30	San Joaquin River	4/23/97	14	66	2	4	4	5	NA	2	3	8	NA	1	1	2	1	2
BF20	Grizzly Bay	4/22/97	14	99	3	4	4	6	NA	3	3	10	NA	2	2	3	1	2
BD50	Napa River	4/22/97	14	139	4	6	8	6	NA	5	4	17	NA	2	4	4	2	3
BD40	Davis Point	4/21/97	14	75	4	6	2	5	NA	3	3	M	NA	1	2	2	ND	2
BD30	Pinole Point	4/21/97	14	69	3	5	4	5	NA	3	3	M	NA	2	2	2	ND	1
BD20	San Pablo Bay	4/21/97	14	80	3	4	4	4	NA	3	3	9	NA	2	2	3	1	2
BD15	Petaluma River	4/21/97	14	103	3	4	6	4	NA	3	4	14	NA	2	2	2	1	ND
BC60	Red Rock	4/14/97	14	105	2	4	6	ND	NA	3	3	11	NA	2	3	5	2	3
BC20	Golden Gate	4/15/97	14	57	2	5	4	6	NA	2	2	5	NA	1	2	2	ND	1
BC10	Yerba Buena Island	4/14/97	14	127	3	7	6	8	NA	4	4	11	NA	2	4	6	2	3
BB70	Alameda	4/15/97	14	82	2	1	8	5	NA	3	ND	7	NA	4	3	3	1	2
BA40	Redwood Creek	4/16/97	14	259	2	14	13	12	NA	10	2	21	NA	5	7	6	4	5
BA30	Dumbarton Bridge	4/16/97	14	206	3	8	9	8	NA	5	6	16	NA	4	7	11	3	6
BA10	Coyote Creek	4/17/97	14	241	3	13	11	12	NA	9	2	26	NA	4	6	7	3	4
C-3-0	San Jose	4/17/97	14	520	6	41	28	38	NA	28	10	52	NA	8	16	16	6	10
BW10	Standish Dam	4/9/97	14	474	10	40	26	26	NA	25	11	58	NA	9	12	14	5	9
BW15	Guadalupe River	4/7/97	14	262	5	23	19	14	NA	9	17	33	NA	M	M	M	M	6
BG20	Sacramento River	8/6/97	15	35	2	3	5	2	NA	1	2	M	NA	ND	1	2	ND	1
BG30	San Joaquin River	8/6/97	15	47	3	4	2	2	NA	2	3	M	NA	1	2	2	ND	1
BF20	Grizzly Bay	8/5/97	15	105	4	6	4	5	NA	3	3	12	NA	2	3	3	1	3
BD50	Napa River	8/5/97	15	155	5	7	12	10	NA	9	4	M	NA	3	6	7	2	4
BD40	Davis Point	8/4/97	15	77	2	2	3	6	NA	2	3	9	NA	2	2	3	1	2
BD30	Pinole Point	8/4/97	15	58	ND	3	2	3	NA	2	2	8	NA	1	2	2	ND	1
BD20	San Pablo Bay	8/4/97	15	137	8	8	27	ND	NA	ND	6	M	NA	ND	6	6	ND	ND
BD15	Petaluma River	8/4/97	15	207	11	15	14	34	NA	6	3	22	NA	3	6	5	2	3
BC60	Red Rock	7/30/97	15	117	ND	ND	M	ND	NA	4	3	23	NA	ND	2	5	5	3
BC20	Golden Gate	7/31/97	15	52	2	2	M	1	NA	3	3	8	NA	1	2	3	ND	2
BC10	Yerba Buena Island	7/30/97	15	98	2	5	M	5	NA	5	3	12	NA	2	3	4	2	2
BB70	Alameda	7/30/97	15	120	3	4	M	3	NA	4	3	12	NA	3	4	4	2	3
BA40	Redwood Creek	7/29/97	15	121	3	4	M	4	NA	5	3	12	NA	3	4	4	2	3
BA30	Dumbarton Bridge	7/28/97	15	209	8	10	11	14	NA	8	7	9	NA	4	8	9	2	5
BA10	Coyote Creek	7/29/97	15	244	4	9	M	11	NA	11	10	23	NA	5	7	8	3	6
C-3-0	San Jose	7/29/97	15	615	14	50	44	35	NA	32	29	51	NA	8	24	23	9	10
BW10	Standish Dam	8/1/97	15	500	5	24	19	18	NA	20	16	42	NA	9	16	13	4	10
BW15	Guadalupe River	8/1/97	15	604	8	31	26	32	NA	28	24	54	NA	9	21	19	8	11

Table 6. Dissolved PCB concentrations in water samples, 1997 (continued).
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI) pg/L	PCB 095 pg/L	PCB 097 pg/L	PCB 099 pg/L	PCB 101 pg/L	PCB 105 pg/L	PCB 110 pg/L	PCB 118 pg/L	PCB 128 pg/L	PCB 132 pg/L	PCB 138 pg/L	PCB 141 pg/L	PCB 149 pg/L	PCB 151 pg/L	PCB 153 pg/L
BG20	Sacramento River	1/29/97	13	55	4	ND	1	5	2	2	4	ND	ND	2	ND	2	M	3
BG30	San Joaquin River	1/29/97	13	60	6	ND	2	5	ND	5	2	ND	ND	1	ND	2	M	2
BF20	Grizzly Bay	1/28/97	13	46	4	ND	1	3	ND	3	2	ND	1	1	ND	2	M	2
BD50	Napa River	1/28/97	13	78	7	1	2	5	ND	4	2	ND	ND	2	ND	3	M	4
BD40	Davis Point	1/27/97	13	65	6	ND	2	5	1	6	4	ND	ND	2	ND	3	M	4
BD30	Pinole Point	1/27/97	13	75	7	ND	2	5	ND	4	3	ND	ND	2	ND	3	M	3
BD20	San Pablo Bay	1/27/97	13	69	7	1	3	4	ND	4	3	ND	ND	2	ND	3	M	4
BD15	Petaluma River	1/27/97	13	145	10	2	4	8	ND	6	5	ND	1	4	ND	5	3	6
BC60	Red Rock	1/23/97	13	76	9	2	3	8	ND	6	3	ND	ND	2	ND	4	1	4
BC20	Golden Gate	1/24/97	13	42	4	ND	2	4	ND	2	2	ND	2	2	ND	2	ND	2
BC10	Yerba Buena Island	1/23/97	13	119	12	2	4	10	ND	7	6	ND	1	4	ND	6	3	6
BB70	Alameda	1/23/97	13	119	12	3	5	10	1	8	6	ND	1	4	ND	5	3	7
BA40	Redwood Creek	1/22/97	13	241	14	3	12	15	1	10	7	1	2	7	1	9	1	12
BA30	Dumbarton Bridge	1/21/97	13	151	13	3	5	10	1	8	8	ND	2	5	ND	7	4	9
BA10	Coyote Creek	1/22/97	13	207	17	3	6	11	2	10	9	ND	2	6	ND	8	5	11
C-3-0	San Jose	1/22/97	13	425	34	5	8	21	1	16	11	ND	3	9	2	14	8	15
BW10	Standish Dam	2/7/97	13	528	66	5	10	43	3	23	9	ND	9	18	9	54	30	39
BW15	Guadalupe River	2/7/97	13	431	54	7	10	31	2	26	10	2	5	13	5	31	15	24
BG20	Sacramento River	4/23/97	14	146	10	3	3	10	3	7	6	ND	ND	3	ND	4	M	6
BG30	San Joaquin River	4/23/97	14	66	6	1	2	5	ND	4	3	ND	ND	2	ND	3	M	4
BF20	Grizzly Bay	4/22/97	14	99	9	2	4	8	ND	5	5	ND	1	4	ND	5	4	6
BD50	Napa River	4/22/97	14	139	12	3	5	10	3	8	8	1	1	4	ND	5	4	8
BD40	Davis Point	4/21/97	14	75	8	2	3	6	1	5	4	ND	1	3	ND	3	3	5
BD30	Pinole Point	4/21/97	14	69	7	2	3	6	ND	5	3	ND	ND	2	ND	3	3	4
BD20	San Pablo Bay	4/21/97	14	80	8	2	3	6	ND	5	4	ND	ND	3	ND	4	3	4
BD15	Petaluma River	4/21/97	14	103	10	2	4	7	1	6	4	ND	1	3	ND	5	3	6
BC60	Red Rock	4/14/97	14	105	9	3	4	9	2	7	8	ND	1	3	ND	4	3	5
BC20	Golden Gate	4/15/97	14	57	5	1	2	4	ND	3	2	ND	ND	2	ND	2	2	3
BC10	Yerba Buena Island	4/14/97	14	127	10	3	6	11	2	8	8	ND	ND	4	ND	4	3	6
BB70	Alameda	4/15/97	14	82	10	2	2	5	2	5	5	ND	1	3	ND	3	2	4
BA40	Redwood Creek	4/16/97	14	259	20	5	8	18	3	16	14	2	5	11	2	13	6	17
BA30	Dumbarton Bridge	4/16/97	14	206	14	6	9	16	5	13	22	ND	2	8	1	6	3	11
BA10	Coyote Creek	4/17/97	14	241	19	4	8	14	2	13	10	1	4	10	2	13	5	15
C-3-0	San Jose	4/17/97	14	520	45	10	15	32	4	25	17	1	6	16	3	25	9	27
BW10	Standish Dam	4/9/97	14	474	39	8	10	27	4	24	16	2	4	13	3	20	10	21
BW15	Guadalupe River	4/7/97	14	262	M	M	M	M	4	22	16	2	5	14	2	16	9	18
BG20	Sacramento River	8/6/97	15	35	3	ND	ND	3	ND	3	2	ND	ND	1	ND	2	M	2
BG30	San Joaquin River	8/6/97	15	47	5	1	1	4	ND	3	2	ND	1	2	ND	2	2	3
BF20	Grizzly Bay	8/5/97	15	105	9	2	3	7	ND	7	4	ND	2	5	ND	5	3	6
BD50	Napa River	8/5/97	15	155	23	4	5	11	2	11	5	ND	3	4	ND	7	2	8
BD40	Davis Point	8/4/97	15	77	7	2	2	5	1	5	4	ND	1	3	ND	4	1	4
BD30	Pinole Point	8/4/97	15	58	5	1	2	4	ND	4	3	ND	1	2	ND	3	1	4
BD20	San Pablo Bay	8/4/97	15	137	14	ND	6	11	ND	12	8	ND	ND	7	ND	8	ND	11
BD15	Petaluma River	8/4/97	15	207	12	3	4	9	2	10	6	1	3	6	ND	8	4	10
BC60	Red Rock	7/30/97	15	117	9	1	3	7	ND	18	7	ND	2	10	ND	5	2	6
BC20	Golden Gate	7/31/97	15	52	7	2	2	5	ND	4	2	ND	ND	1	ND	2	1	2
BC10	Yerba Buena Island	7/30/97	15	98	10	3	3	7	1	7	5	ND	2	3	ND	5	2	5
BB70	Alameda	7/30/97	15	120	12	3	5	10	2	9	6	ND	2	5	ND	7	3	8
BA40	Redwood Creek	7/29/97	15	121	13	3	5	9	1	8	6	ND	3	5	ND	7	3	9
BA30	Dumbarton Bridge	7/28/97	15	209	17	4	6	15	5	13	11	2	4	7	ND	10	1	12
BA10	Coyote Creek	7/29/97	15	244	24	6	9	19	3	17	10	1	5	9	ND	14	5	14
C-3-0	San Jose	7/29/97	15	615	47	9	13	33	6	31	19	3	11	18	2	27	9	29
BW10	Standish Dam	8/1/97	15	500	57	7	6	32	4	32	11	3	14	17	4	33	20	26
BW15	Guadalupe River	8/1/97	15	604	56	9	14	36	7	34	22	4	12	20	3	33	14	34

Table 6. Dissolved PCB concentrations in water samples, 1997 (continued).
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 156	PCB 158	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	PCB 201	PCB 203	Hexachlorobenzene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	55	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	19
BG30	San Joaquin River	1/29/97	13	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	19
BF20	Grizzly Bay	1/28/97	13	46	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15
BD50	Napa River	1/28/97	13	78	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	15
BD40	Davis Point	1/27/97	13	65	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	24
BD30	Pinole Point	1/27/97	13	75	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	46
BD20	San Pablo Bay	1/27/97	13	69	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	30
BD15	Petaluma River	1/27/97	13	145	ND	ND	ND	ND	ND	2	ND	2	ND	ND	ND	ND	82
BC60	Red Rock	1/23/97	13	76	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
BC20	Golden Gate	1/24/97	13	42	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11
BC10	Yerba Buena Island	1/23/97	13	119	ND	1	ND	ND	ND	2	ND	2	ND	ND	ND	ND	11
BB70	Alameda	1/23/97	13	119	ND	ND	ND	ND	ND	2	ND	2	ND	ND	ND	ND	8
BA40	Redwood Creek	1/22/97	13	241	ND	ND	1	1	ND	3	ND	3	ND	ND	ND	ND	18
BA30	Dumbarton Bridge	1/21/97	13	151	ND	ND	1	1	1	3	1	3	ND	ND	ND	ND	12
BA10	Coyote Creek	1/22/97	13	207	ND	ND	1	1	2	4	ND	3	ND	ND	ND	3	15
C-3-0	San Jose	1/22/97	13	425	ND	4	3	3	2	7	2	4	ND	ND	2	4	37
BW10	Standish Dam	2/7/97	13	528	5	2	7	11	5	17	5	14	2	ND	ND	1	14
BW15	Guadalupe River	2/7/97	13	431	ND	1	5	7	3	11	3	8	2	ND	ND	ND	25
BG20	Sacramento River	4/23/97	14	146	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16
BG30	San Joaquin River	4/23/97	14	66	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	14
BF20	Grizzly Bay	4/22/97	14	99	ND	ND	ND	ND	ND	2	ND	2	ND	ND	ND	ND	6
BD50	Napa River	4/22/97	14	139	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	10
BD40	Davis Point	4/21/97	14	75	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	8
BD30	Pinole Point	4/21/97	14	69	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	8
BD20	San Pablo Bay	4/21/97	14	80	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	34
BD15	Petaluma River	4/21/97	14	103	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	7
BC60	Red Rock	4/14/97	14	105	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	14
BC20	Golden Gate	4/15/97	14	57	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15
BC10	Yerba Buena Island	4/14/97	14	127	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	17
BB70	Alameda	4/15/97	14	82	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	7
BA40	Redwood Creek	4/16/97	14	259	ND	2	2	2	2	5	2	5	1	ND	ND	ND	19
BA30	Dumbarton Bridge	4/16/97	14	206	ND	1	ND	ND	ND	2	ND	1	ND	ND	ND	ND	13
BA10	Coyote Creek	4/17/97	14	241	ND	1	3	2	2	5	2	5	1	ND	ND	ND	17
C-3-0	San Jose	4/17/97	14	520	1	3	ND	3	3	7	3	7	1	ND	ND	ND	21
BW10	Standish Dam	4/9/97	14	474	ND	2	4	3	3	8	2	7	1	ND	ND	ND	76
BW15	Guadalupe River	4/7/97	14	262	ND	2	4	ND	3	9	3	7	2	ND	ND	ND	67
BG20	Sacramento River	8/6/97	15	35	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
BG30	San Joaquin River	8/6/97	15	47	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
BF20	Grizzly Bay	8/5/97	15	105	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND	5
BD50	Napa River	8/5/97	15	155	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND	4
BD40	Davis Point	8/4/97	15	77	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	5
BD30	Pinole Point	8/4/97	15	58	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	2
BD20	San Pablo Bay	8/4/97	15	137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15
BD15	Petaluma River	8/4/97	15	207	ND	ND	1	ND	ND	3	ND	3	ND	ND	ND	ND	4
BC60	Red Rock	7/30/97	15	117	ND	1	ND	ND	2	1	ND	ND	1	ND	ND	ND	9
BC20	Golden Gate	7/31/97	15	52	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
BC10	Yerba Buena Island	7/30/97	15	98	ND	ND	ND	ND	ND	1	ND	1	ND	ND	ND	ND	6
BB70	Alameda	7/30/97	15	120	ND	ND	ND	ND	ND	2	ND	2	ND	ND	ND	ND	7
BA40	Redwood Creek	7/29/97	15	121	ND	ND	ND	ND	1	2	ND	3	ND	ND	ND	ND	4
BA30	Dumbarton Bridge	7/28/97	15	209	ND	ND	ND	ND	ND	2	ND	3	ND	ND	ND	ND	8
BA10	Coyote Creek	7/29/97	15	244	ND	1	ND	1	2	2	1	4	ND	ND	ND	ND	2
C-3-0	San Jose	7/29/97	15	615	1	1	3	3	3	7	3	8	ND	ND	ND	ND	81
BW10	Standish Dam	8/1/97	15	500	ND	2	4	6	3	10	3	9	1	ND	ND	ND	20
BW15	Guadalupe River	8/1/97	15	604	1	1	4	4	4	8	3	9	2	ND	ND	ND	7

Table 7. Total (dissolved + particulate) PCB concentrations in water samples, 1997.
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 008	PCB 018	PCB 028	PCB 031	PCB 033	PCB 044	PCB 049	PCB 052	PCB 056	PCB 060	PCB 066	PCB 070	PCB 074	PCB 087
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	119	1	5	6	5	NA	4	3	13	NA	ND	6	4	ND	2
BG30	San Joaquin River	1/29/97	13	117	ND	5	4	6	NA	4	3	11	NA	2	7	4	1	3
BF20	Grizzly Bay	1/28/97	13	80	4	3	4	5	NA	2	4	6	NA	ND	4	1	ND	1
BD50	Napa River	1/28/97	13	269	11	8	12	20	NA	2	6	10	NA	ND	M	M	M	1
BD40	Davis Point	1/27/97	13	131	1	4	5	4	NA	4	4	11	NA	1	8	4	1	3
BD30	Pinole Point	1/27/97	13	280	5	8	9	23	NA	6	6	10	NA	1	14	7	3	5
BD20	San Pablo Bay	1/27/97	13	143	ND	4	5	13	NA	3	5	11	NA	ND	8	4	ND	3
BD15	Petaluma River	1/27/97	13	472	7	17	19	25	NA	12	10	17	NA	11	24	14	7	5
BC60	Red Rock	1/23/97	13	143	ND	4	4	9	NA	3	5	9	NA	1	6	4	ND	3
BC20	Golden Gate	1/24/97	13	77	1	2	2	6	NA	2	ND	7	NA	1	3	4	ND	1
BC10	Yerba Buena Island	1/23/97	13	203	2	7	7	10	NA	5	3	15	NA	9	7	6	2	5
BB70	Alameda	1/23/97	13	321	3	6	6	12	NA	7	4	15	NA	9	11	9	4	7
BA40	Redwood Creek	1/22/97	13	3069	19	34	43	39	NA	94	47	165	NA	89	77	156	45	143
BA30	Dumbarton Bridge	1/21/97	13	1158	2	14	17	47	NA	17	15	32	NA	34	52	33	12	22
BA10	Coyote Creek	1/22/97	13	986	9	25	11	40	NA	17	11	30	NA	28	36	26	11	17
C-3-0	San Jose	1/22/97	13	2484	31	72	87	77	NA	34	43	98	NA	26	M	M	M	41
BW10	Standish Dam	2/7/97	13	5143	5	13	32	29	NA	25	24	53	NA	37	M	8	2	33
BW15	Guadalupe River	2/7/97	13	3663	6	23	38	42	NA	40	37	77	NA	53	M	M	2	55
BG20	Sacramento River	4/23/97	14	237	11	13	15	17	NA	9	5	24	NA	4	8	7	4	4
BG30	San Joaquin River	4/23/97	14	114	4	6	5	5	NA	2	3	16	NA	2	4	3	1	2
BF20	Grizzly Bay	4/22/97	14	287	6	7	9	10	NA	6	6	19	NA	4	8	7	3	5
BD50	Napa River	4/22/97	14	342	7	6	12	9	NA	8	6	24	NA	4	10	7	3	5
BD40	Davis Point	4/21/97	14	387	8	9	7	10	NA	7	5	M	NA	4	11	8	3	6
BD30	Pinole Point	4/21/97	14	195	5	6	7	9	NA	5	5	M	NA	2	5	5	ND	3
BD20	San Pablo Bay	4/21/97	14	231	5	4	M	8	NA	5	5	17	NA	6	6	6	2	4
BD15	Petaluma River	4/21/97	14	603	8	4	14	11	NA	9	9	26	NA	8	16	12	5	7
BC60	Red Rock	4/14/97	14	193	4	4	M	3	NA	5	5	22	NA	4	6	7	3	4
BC20	Golden Gate	4/15/97	14	85	5	7	M	9	NA	3	3	12	NA	1	2	2	ND	1
BC10	Yerba Buena Island	4/14/97	14	282	6	9	M	11	NA	6	6	21	NA	6	9	10	4	6
BB70	Alameda	4/15/97	14	214	4	3	M	8	NA	6	2	19	NA	8	9	7	3	5
BA40	Redwood Creek	4/16/97	14	515	2	14	16	13	NA	13	4	29	NA	10	15	11	6	9
BA30	Dumbarton Bridge	4/16/97	14	795	8	13	20	17	NA	13	13	56	NA	14	21	24	9	14
BA10	Coyote Creek	4/17/97	14	4547	22	52	97	57	NA	67	62	115	NA	72	136	107	51	70
C-3-0	San Jose	4/17/97	14	1736	11	54	50	61	NA	46	25	119	NA	48	51	45	18	29
BW10	Standish Dam	4/9/97	14	3635	23	124	M	M	NA	M	M	M	NA	M	M	M	M	63
BW15	Guadalupe River	4/7/97	14	M	25	M	239	154	NA	M	M	M	NA	M	M	M	M	M
BG20	Sacramento River	8/6/97	15	193	2	6	10	7	NA	5	7	M	NA	M	5	7	2	5
BG30	San Joaquin River	8/6/97	15	223	3	11	7	8	NA	7	9	M	NA	M	6	7	2	3
BF20	Grizzly Bay	8/5/97	15	259	7	6	8	8	NA	7	8	24	NA	5	8	8	1	5
BD50	Napa River	8/5/97	15	662	5	7	23	18	NA	21	21	M	NA	M	M	M	M	17
BD40	Davis Point	8/4/97	15	585	5	2	13	20	NA	13	17	33	NA	M	M	M	M	8
BD30	Pinole Point	8/4/97	15	395	5	9	9	11	NA	8	8	22	NA	13	12	10	3	5
BD20	San Pablo Bay	8/4/97	15	971	12	8	46	14	NA	11	34	M	NA	13	M	M	M	12
BD15	Petaluma River	8/4/97	15	1564	17	15	36	50	NA	17	24	48	NA	19	44	40	16	16
BC60	Red Rock	7/30/97	15	327	2	ND	M	3	NA	6	7	34	NA	3	8	10	5	6
BC20	Golden Gate	7/31/97	15	87	2	2	M	1	NA	3	4	14	NA	1	5	3	ND	2
BC10	Yerba Buena Island	7/30/97	15	311	3	5	M	9	NA	7	7	21	NA	6	9	9	3	6
BB70	Alameda	7/30/97	15	366	5	4	M	7	NA	7	6	21	NA	7	9	8	2	6
BA40	Redwood Creek	7/29/97	15	507	5	4	M	8	NA	10	9	26	NA	8	14	12	4	9
BA30	Dumbarton Bridge	7/28/97	15	833	12	10	22	23	NA	15	16	28	NA	14	26	21	7	13
BA10	Coyote Creek	7/29/97	15	855	6	9	M	19	NA	18	18	39	NA	16	23	19	9	15
C-3-0	San Jose	7/29/97	15	3044	24	50	139	115	NA	M	M	M	NA	55	M	M	M	M
BW10	Standish Dam	8/1/97	15	1839	5	24	29	26	NA	30	25	74	NA	M	32	27	7	18
BW15	Guadalupe River	8/1/97	15	3677	21	31	91	90	NA	102	71	119	NA	47	M	M	M	66

Table 7. Total (dissolved + particulate) PCB concentrations in water samples, 1997 (continued).
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 095	PCB 097	PCB 099	PCB 101	PCB 105	PCB 110	PCB 118	PCB 128	PCB 132	PCB 138	PCB 141	PCB 149	PCB 151	PCB 153
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	119	8	ND	3	9	3	8	7	ND	2	5	1	6	M	5
BG30	San Joaquin River	1/29/97	13	117	10	ND	4	5	ND	11	6	ND	2	5	1	6	M	5
BF20	Grizzly Bay	1/28/97	13	80	6	ND	2	6	ND	8	3	ND	2	3	ND	4	M	3
BD50	Napa River	1/28/97	13	269	M	1	23	14	5	21	14	2	11	13	3	14	M	26
BD40	Davis Point	1/27/97	13	131	10	ND	4	9	1	11	8	ND	ND	6	ND	7	M	9
BD30	Pinole Point	1/27/97	13	280	18	3	7	16	3	15	14	1	4	13	2	16	M	20
BD20	San Pablo Bay	1/27/97	13	143	11	3	4	9	1	9	8	ND	ND	7	ND	8	M	11
BD15	Petaluma River	1/27/97	13	472	20	8	21	25	5	23	24	3	6	25	3	22	10	34
BC60	Red Rock	1/23/97	13	143	13	2	5	12	ND	9	8	ND	6	6	ND	8	4	10
BC20	Golden Gate	1/24/97	13	77	7	ND	2	4	ND	5	5	ND	2	4	ND	4	1	6
BC10	Yerba Buena Island	1/23/97	13	203	17	4	6	14	ND	12	9	ND	3	9	ND	10	5	14
BB70	Alameda	1/23/97	13	321	21	6	11	20	7	19	15	3	4	18	2	17	8	27
BA40	Redwood Creek	1/22/97	13	3069	394	100	132	325	29	200	157	11	53	100	20	149	49	142
BA30	Dumbarton Bridge	1/21/97	13	1158	56	15	37	69	19	57	70	9	23	70	10	57	24	104
BA10	Coyote Creek	1/22/97	13	986	48	13	27	50	15	48	65	8	20	55	7	54	22	85
C-3-0	San Jose	1/22/97	13	2484	M	5	8	107	17	104	151	ND	85	159	46	204	76	255
BW10	Standish Dam	2/7/97	13	5143	M	5	45	213	16	116	59	31	259	258	129	554	220	579
BW15	Guadalupe River	2/7/97	13	3663	M	7	68	181	30	176	110	42	175	263	79	361	135	394
BG20	Sacramento River	4/23/97	14	237	15	4	5	15	5	13	12	ND	2	8	ND	9	M	15
BG30	San Joaquin River	4/23/97	14	114	9	1	2	7	ND	7	6	ND	ND	5	ND	6	M	8
BF20	Grizzly Bay	4/22/97	14	287	17	5	8	15	3	16	18	3	6	15	ND	17	9	25
BD50	Napa River	4/22/97	14	342	21	6	11	19	7	23	21	4	7	16	1	18	10	29
BD40	Davis Point	4/21/97	14	387	25	7	11	20	8	28	22	5	10	23	3	24	13	38
BD30	Pinole Point	4/21/97	14	195	15	4	6	12	2	13	10	1	2	10	ND	13	7	19
BD20	San Pablo Bay	4/21/97	14	231	18	4	7	14	2	18	12	2	2	14	1	15	7	17
BD15	Petaluma River	4/21/97	14	603	31	8	20	33	11	40	32	7	15	37	5	37	16	60
BC60	Red Rock	4/14/97	14	193	14	4	7	14	4	13	13	ND	2	9	ND	9	5	14
BC20	Golden Gate	4/15/97	14	85	7	1	2	6	ND	5	4	ND	ND	3	ND	3	2	5
BC10	Yerba Buena Island	4/14/97	14	282	19	6	10	19	4	18	17	2	3	13	1	14	6	22
BB70	Alameda	4/15/97	14	214	23	4	7	15	3	13	11	1	3	10	1	12	6	15
BA40	Redwood Creek	4/16/97	14	515	36	8	17	32	7	31	29	2	11	29	4	31	14	51
BA30	Dumbarton Bridge	4/16/97	14	795	41	12	27	45	15	46	53	6	19	49	6	45	18	77
BA10	Coyote Creek	4/17/97	14	4547	189	72	128	214	49	263	250	50	144	340	41	283	125	455
C-3-0	San Jose	4/17/97	14	1736	106	26	41	87	25	87	81	15	43	94	14	98	37	137
BW10	Standish Dam	4/9/97	14	3635	M	55	160	207	47	274	276	61	124	143	59	340	120	441
BW15	Guadalupe River	4/7/97	14	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
BG20	Sacramento River	8/6/97	15	193	11	ND	2	11	2	28	20	2	3	22	ND	9	M	12
BG30	San Joaquin River	8/6/97	15	223	16	1	5	11	2	27	22	ND	4	19	ND	10	7	14
BF20	Grizzly Bay	8/5/97	15	259	18	3	6	14	4	21	15	2	6	10	ND	15	5	19
BD50	Napa River	8/5/97	15	662	M	16	21	52	15	69	46	7	23	46	5	49	15	68
BD40	Davis Point	8/4/97	15	585	M	9	16	30	12	48	41	7	18	46	4	43	14	64
BD30	Pinole Point	8/4/97	15	395	22	5	11	17	6	34	25	4	11	22	2	24	8	34
BD20	San Pablo Bay	8/4/97	15	971	M	13	40	56	21	80	72	11	30	76	8	73	20	107
BD15	Petaluma River	8/4/97	15	1564	52	22	42	74	33	87	97	20	46	116	12	106	36	150
BC60	Red Rock	7/30/97	15	327	17	4	9	16	5	29	19	2	2	25	2	20	6	29
BC20	Golden Gate	7/31/97	15	87	10	2	3	7	ND	4	5	ND	ND	3	ND	4	1	7
BC10	Yerba Buena Island	7/30/97	15	311	21	5	9	18	5	19	17	2	8	17	2	20	7	27
BB70	Alameda	7/30/97	15	366	23	6	11	21	6	21	19	3	11	24	3	25	9	37
BA40	Redwood Creek	7/29/97	15	507	32	7	17	30	8	30	33	6	14	34	2	33	11	53
BA30	Dumbarton Bridge	7/28/97	15	833	42	12	24	44	19	44	54	11	24	56	4	51	13	83
BA10	Coyote Creek	7/29/97	15	855	47	15	27	51	16	50	52	10	25	56	4	60	20	79
C-3-0	San Jose	7/29/97	15	3044	M	M	M	M	84	241	259	50	141	318	35	317	100	389
BW10	Standish Dam	8/1/97	15	1839	M	18	17	79	15	202	36	18	79	115	26	163	75	146
BW15	Guadalupe River	8/1/97	15	3677	M	63	124	236	79	234	121	39	142	320	41	333	108	394

Table 7. Total (dissolved + particulate) PCB concentrations in water samples, 1997 (continued).
M = matrix interference, NA = not analyzed, ND = not detected. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 156	PCB 158	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	PCB 201	PCB 203	Hexachlorobenzene
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	119	ND	ND	3	1	ND	5	ND	2	2	ND	ND	ND	29
BG30	San Joaquin River	1/29/97	13	117	ND	ND	3	1	ND	4	ND	2	1	ND	ND	2	35
BF20	Grizzly Bay	1/28/97	13	80	2	ND	2	ND	ND	2	ND	ND	ND	ND	2	1	21
BD50	Napa River	1/28/97	13	269	2	ND	6	5	3	14	2	9	6	ND	1	2	27
BD40	Davis Point	1/27/97	13	131	ND	ND	3	2	ND	6	ND	3	2	ND	ND	1	36
BD30	Pinole Point	1/27/97	13	280	2	2	7	5	3	14	2	10	4	1	1	2	72
BD20	San Pablo Bay	1/27/97	13	143	ND	ND	3	2	1	6	1	3	2	ND	ND	ND	35
BD15	Petaluma River	1/27/97	13	472	5	3	8	5	5	19	4	14	6	2	2	2	89
BC60	Red Rock	1/23/97	13	143	ND	ND	2	2	1	4	ND	3	1	ND	ND	ND	8
BC20	Golden Gate	1/24/97	13	77	ND	ND	ND	ND	6	2	ND	1	ND	ND	ND	ND	11
BC10	Yerba Buena Island	1/23/97	13	203	ND	1	3	2	2	8	1	5	2	ND	ND	1	13
BB70	Alameda	1/23/97	13	321	3	2	6	3	4	14	3	11	3	ND	1	1	11
BA40	Redwood Creek	1/22/97	13	3069	10	5	27	24	21	58	17	57	15	4	9	8	25
BA30	Dumbarton Bridge	1/21/97	13	1158	7	8	25	19	23	63	16	48	17	5	5	8	20
BA10	Coyote Creek	1/22/97	13	986	7	8	20	16	20	54	13	40	14	4	5	9	21
C-3-0	San Jose	1/22/97	13	2484	29	48	96	78	52	197	2	134	48	12	27	36	49
BW10	Standish Dam	2/7/97	13	5143	59	31	287	301	155	697	145	394	152	48	29	101	35
BW15	Guadalupe River	2/7/97	13	3663	36	27	175	157	82	371	3	208	98	30	24	58	38
BG20	Sacramento River	4/23/97	14	237	ND	ND	3	2	1	4	1	3	1	ND	ND	ND	21
BG30	San Joaquin River	4/23/97	14	114	ND	ND	2	ND	ND	4	ND	3	ND	ND	ND	ND	24
BF20	Grizzly Bay	4/22/97	14	287	2	ND	5	3	3	13	2	10	3	ND	ND	1	20
BD50	Napa River	4/22/97	14	342	1	2	6	4	3	14	3	9	4	ND	ND	2	22
BD40	Davis Point	4/21/97	14	387	2	3	9	6	5	20	5	15	5	1	ND	3	16
BD30	Pinole Point	4/21/97	14	195	ND	ND	4	2	2	8	2	7	2	ND	ND	ND	11
BD20	San Pablo Bay	4/21/97	14	231	ND	ND	4	3	2	10	2	7	2	ND	ND	ND	37
BD15	Petaluma River	4/21/97	14	603	4	5	14	9	9	30	7	25	9	2	3	4	16
BC60	Red Rock	4/14/97	14	193	ND	ND	3	2	1	6	1	5	1	ND	ND	ND	18
BC20	Golden Gate	4/15/97	14	85	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	20
BC10	Yerba Buena Island	4/14/97	14	282	ND	1	5	3	2	11	3	7	2	ND	1	1	20
BB70	Alameda	4/15/97	14	214	ND	ND	ND	2	2	6	2	5	ND	ND	1	ND	9
BA40	Redwood Creek	4/16/97	14	515	ND	2	9	6	6	19	5	19	5	ND	1	ND	21
BA30	Dumbarton Bridge	4/16/97	14	795	3	3	13	8	9	29	8	28	8	2	2	3	16
BA10	Coyote Creek	4/17/97	14	4547	21	36	123	83	90	275	54	205	90	11	8	40	24
C-3-0	San Jose	4/17/97	14	1736	8	11	30	26	24	70	20	58	22	5	6	9	37
BW10	Standish Dam	4/9/97	14	3635	25	43	83	113	92	328	66	207	100	10	3	50	112
BW15	Guadalupe River	4/7/97	14	M	M	M	M	M	M	M	M	M	M	M	M	M	M
BG20	Sacramento River	8/6/97	15	193	ND	3	2	ND	2	5	ND	4	1	ND	ND	ND	18
BG30	San Joaquin River	8/6/97	15	223	ND	3	3	2	2	5	ND	5	2	ND	ND	ND	30
BF20	Grizzly Bay	8/5/97	15	259	ND	ND	3	2	2	9	2	8	2	ND	ND	ND	12
BD50	Napa River	8/5/97	15	662	5	2	13	9	9	29	8	27	9	3	2	5	20
BD40	Davis Point	8/4/97	15	585	4	4	13	9	9	30	8	25	10	2	2	5	26
BD30	Pinole Point	8/4/97	15	395	2	2	7	4	4	15	4	13	5	ND	ND	2	14
BD20	San Pablo Bay	8/4/97	15	971	7	10	24	16	16	51	13	44	17	4	4	9	39
BD15	Petaluma River	8/4/97	15	1564	6	13	38	23	27	80	21	74	25	6	4	14	34
BC60	Red Rock	7/30/97	15	327	2	3	7	5	6	15	3	11	6	ND	2	3	12
BC20	Golden Gate	7/31/97	15	87	ND	ND	ND	ND	ND	2	ND	2	ND	ND	ND	ND	8
BC10	Yerba Buena Island	7/30/97	15	311	1	2	6	4	4	13	3	10	4	ND	ND	2	9
BB70	Alameda	7/30/97	15	366	2	2	8	6	5	19	4	14	5	ND	1	2	9
BA40	Redwood Creek	7/29/97	15	507	3	2	9	6	8	21	5	24	7	1	2	3	7
BA30	Dumbarton Bridge	7/28/97	15	833	5	6	15	9	12	33	9	35	10	2	5	5	13
BA10	Coyote Creek	7/29/97	15	855	4	7	14	10	14	32	10	36	10	2	4	10	5
C-3-0	San Jose	7/29/97	15	3044	26	37	101	68	73	217	20	70	63	10	8	35	98
BW10	Standish Dam	8/1/97	15	1839	7	2	67	66	40	160	36	87	44	4	9	30	34
BW15	Guadalupe River	8/1/97	15	3677	23	37	114	77	75	238	53	63	70	8	7	41	22

Table 8. Dissolved pesticide concentrations in water samples, 1997. B = blank contamination >10% of measured concentration, M = matrix intereference, NA = not analyzed, ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Chlorpyrifos	Diazinon	Sum of DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Sum of Chlordanes (SFEI)	alpha-Chlordane	gamma-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	330	37000	362	44	2	M	87	160	69	155	20	12	3	13	7	26	74
BG30	San Joaquin River	1/29/97	13	590	31000	360	44	4	M	85	190	37	190	26	23	4	16	ND	38	83
BF20	Grizzly Bay	1/28/97	13	460	Q	496	51	10	M	110	230	95	181	22	16	5	22	ND	26	90
BD50	Napa River	1/28/97	13	260	17000	653	38	5	M	110	370	130	349	76	69	15	45	ND	86	58
BD40	Davis Point	1/27/97	13	560	25000	451	35	13	M	110	200	93	221	42	30	6	23	ND	38	82
BD30	Pinole Point	1/27/97	13	480	39000	440	30	11	M	130	170	99	273	52	46	9	28	ND	59	79
BD20	San Pablo Bay	1/27/97	13	440	14000	417	42	30	M	120	150	75	217	47	14	7	27	ND	36	86
BD15	Petaluma River	1/27/97	13	290	7700	536	45	20	M	120	320	31	349	67	42	12	21	16	170	21
BC60	Red Rock	1/23/97	13	200	5300	272	ND	4	M	160	91	17	113	22	16	4	9	ND	9	53
BC20	Golden Gate	1/24/97	13	35	1300	152	17	3	M	98	26	8	68	15	7	1	3	12	7	23
BC10	Yerba Buena Island	1/23/97	13	190	4500	400	8	12	M	270	90	20	147	31	24	4	12	ND	16	60
BB70	Alameda	1/23/97	13	260	5300	140	5	2	M	90	42	1	147	32	19	3	10	ND	47	36
BA40	Redwood Creek	1/22/97	13	180	4400	246	19	7	M	89	130	1	145	29	23	11	16	ND	27	39
BA30	Dumbarton Bridge	1/21/97	13	240	9000	151	ND	9	7	62	62	11	230	57	37	6	21	ND	67	42
BA10	Coyote Creek	1/22/97	13	450	6800	200	22	31	M	58	78	11	153	45	22	5	16	ND	25	40
C-3-0	San Jose	1/22/97	13	35	20000	611	19	14	20	280	190	88	370	110	82	6	38	ND	66	68
BW10	Standish Dam	2/7/97	13	160	1300	1469	130	43	M	700	510	86	467	150	140	16	67	ND	41	53
BW15	Guadalupe River	2/7/97	13	350	3400	668	46	14	M	400	130	78	648	210	180	31	89	ND	97	41
BG20	Sacramento River	4/23/97	14	900	1800	488	82	24	M	210	170	2	179	31	18	ND	B	ND	10	120
BG30	San Joaquin River	4/23/97	14	290	1400	294	37	3	8	110	120	16	124	15	9	2	18	ND	6	74
BF20	Grizzly Bay	4/22/97	14	200	1700	338	55	3	8	160	100	12	115	19	13	ND	10	ND	2	71
BD50	Napa River	4/22/97	14	110	3000	304	44	5	5	170	64	17	152	29	18	8	26	ND	8	63
BD40	Davis Point	4/21/97	14	120	1600	240	37	5	5	130	52	11	65	17	8	4	3	ND	3	30
BD30	Pinole Point	4/21/97	14	110	1400	237	35	4	M	130	58	10	95	12	16	6	27	ND	ND	34
BD20	San Pablo Bay	4/21/97	14	78	ND	273	44	3	M	150	76	ND	169	19	13	7	B	ND	36	94
BD15	Petaluma River	4/21/97	14	62	1600	252	34	3	20	130	65	ND	119	26	18	ND	19	ND	3	53
BC60	Red Rock	4/14/97	14	72	1500	170	30	4	7	90	40	ND	59	14	8	ND	B	ND	3	35
BC20	Golden Gate	4/15/97	14	25	530	123	32	1	ND	72	18	ND	26	4	3	ND	B	ND	1	18
BC10	Yerba Buena Island	4/14/97	14	66	1300	238	48	3	M	130	43	14	119	18	14	8	18	ND	32	29
BB70	Alameda	4/15/97	14	70	1500	132	30	ND	M	69	33	ND	47	ND	ND	ND	5	ND	10	32
BA40	Redwood Creek	4/16/97	14	230	3700	397	67	4	17	170	99	40	237	62	49	18	10	ND	10	88
BA30	Dumbarton Bridge	4/16/97	14	86	3100	159	29	2	M	81	47	ND	107	26	20	ND	3	ND	6	52
BA10	Coyote Creek	4/17/97	14	250	3900	451	47	20	14	230	97	43	247	67	51	23	6	ND	6	95
C-3-0	San Jose	4/17/97	14	610	6500	759	130	20	29	340	190	50	298	70	44	15	7	ND	32	130
BW10	Standish Dam	4/9/97	14	1100	5500	1054	130	41	M	550	260	73	820	190	200	53	70	ND	17	290
BW15	Guadalupe River	4/7/97	14	1200	8500	1157	160	ND	M	500	460	37	1288	260	180	59	270	120	49	350
BG20	Sacramento River	8/6/97	15	320	2000	147	15	11	M	73	44	4	83	7	4	ND	B	ND	14	58
BG30	San Joaquin River	8/6/97	15	140	1700	99	7	ND	ND	58	34	ND	84	7	11	ND	B	ND	15	51
BF20	Grizzly Bay	8/5/97	15	230	540	305	23	9	M	200	73	ND	111	7	ND	4	B	ND	24	76
BD50	Napa River	8/5/97	15	86	5100	307	25	7	ND	190	85	ND	122	15	8	6	B	26	10	57
BD40	Davis Point	8/4/97	15	110	1900	142	14	3	ND	87	38	ND	88	12	9	ND	B	ND	15	52
BD30	Pinole Point	8/4/97	15	44	1800	141	13	4	M	85	34	6	82	8	8	3	B	ND	17	45
BD20	San Pablo Bay	8/4/97	15	62	370	311	19	9	ND	180	82	21	98	9	6	4	15	ND	14	50
BD15	Petaluma River	8/4/97	15	27	1300	299	26	11	ND	190	72	ND	162	19	9	14	24	ND	10	86
BC60	Red Rock	7/30/97	15	ND	490	40	ND	5	ND	4	31	ND	74	11	5	6	13	ND	20	20
BC20	Golden Gate	7/31/97	15	ND	ND	87	7	7	M	46	15	12	20	ND	ND	4	B	ND	13	4
BC10	Yerba Buena Island	7/30/97	15	220	640	137	9	11	M	84	33	ND	137	30	20	6	25	ND	34	22
BB70	Alameda	7/30/97	15	80	1000	145	18	8	M	79	40	ND	117	23	14	8	21	ND	28	23
BA40	Redwood Creek	7/29/97	15	65	750	109	11	4	ND	57	37	ND	94	11	6	ND	21	ND	18	38
BA30	Dumbarton Bridge	7/28/97	15	Q	Q	29	Q	3	Q	ND	26	Q	Q	Q	Q	Q	8	Q	Q	Q
BA10	Coyote Creek	7/29/97	15	NA	3100	55	NA	5	NA	ND	50	NA	7	NA	NA	NA	7	NA	NA	NA
C-3-0	San Jose	7/29/97	15	510	11000	424	26	28	M	240	130	ND	440	52	32	9	17	ND	200	130
BW10	Standish Dam	8/1/97	15	930	ND	2324	460	130	M	1100	610	24	1067	310	200	20	240	ND	57	240
BW15	Guadalupe River	8/1/97	15	390	9900	664	62	22	ND	330	250	ND	313	62	51	9	77	ND	17	97

Table 8. Dissolved pesticide concentrations in water samples, 1997 (continued).
B = blank contamination >10% of measured concentration, M = matrix intereference, NA = not analyzed, ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of HCHs (SFEI)	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH	Aldrin	Dieldrin	Endrin	Mirex
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	321	170	17	14	120	NA	240	ND	ND
BG30	San Joaquin River	1/29/97	13	341	170	37	14	120	NA	220	ND	ND
BF20	Grizzly Bay	1/28/97	13	299	150	19	ND	130	NA	250	ND	ND
BD50	Napa River	1/28/97	13	301	150	31	ND	120	NA	190	ND	ND
BD40	Davis Point	1/27/97	13	338	160	18	ND	160	NA	260	ND	ND
BD30	Pinole Point	1/27/97	13	328	140	28	ND	160	NA	270	ND	ND
BD20	San Pablo Bay	1/27/97	13	310	140	30	ND	140	NA	220	ND	ND
BD15	Petaluma River	1/27/97	13	517	260	40	37	180	NA	140	ND	ND
BC60	Red Rock	1/23/97	13	322	160	31	1	130	NA	150	ND	ND
BC20	Golden Gate	1/24/97	13	695	390	180	5	120	NA	60	ND	ND
BC10	Yerba Buena Island	1/23/97	13	408	190	71	7	140	NA	180	ND	ND
BB70	Alameda	1/23/97	13	523	190	83	ND	250	NA	170	ND	ND
BA40	Redwood Creek	1/22/97	13	397	130	47	ND	220	NA	150	ND	ND
BA30	Dumbarton Bridge	1/21/97	13	671	100	51	ND	520	NA	120	ND	ND
BA10	Coyote Creek	1/22/97	13	598	150	73	5	370	NA	120	ND	ND
C-3-0	San Jose	1/22/97	13	1370	190	69	11	1100	NA	190	ND	ND
BW10	Standish Dam	2/7/97	13	104	54	13	ND	37	NA	240	52	ND
BW15	Guadalupe River	2/7/97	13	162	60	29	ND	73	NA	210	ND	ND
BG20	Sacramento River	4/23/97	14	1078	220	18	ND	840	NA	320	ND	ND
BG30	San Joaquin River	4/23/97	14	369	100	29	ND	240	NA	120	ND	ND
BF20	Grizzly Bay	4/22/97	14	392	130	42	ND	220	NA	110	ND	ND
BD50	Napa River	4/22/97	14	495	210	75	ND	210	NA	120	ND	ND
BD40	Davis Point	4/21/97	14	426	180	66	ND	180	NA	95	ND	ND
BD30	Pinole Point	4/21/97	14	485	210	95	ND	180	NA	83	ND	ND
BD20	San Pablo Bay	4/21/97	14	630	230	220	ND	180	NA	82	ND	ND
BD15	Petaluma River	4/21/97	14	490	220	100	ND	170	NA	83	ND	ND
BC60	Red Rock	4/14/97	14	406	200	76	ND	130	NA	83	ND	ND
BC20	Golden Gate	4/15/97	14	511	260	170	ND	81	NA	37	ND	ND
BC10	Yerba Buena Island	4/14/97	14	490	250	100	ND	140	NA	78	ND	ND
BB70	Alameda	4/15/97	14	302	22	120	ND	160	NA	62	ND	ND
BA40	Redwood Creek	4/16/97	14	1280	180	100	ND	1000	NA	120	ND	ND
BA30	Dumbarton Bridge	4/16/97	14	810	190	110	ND	510	NA	88	ND	ND
BA10	Coyote Creek	4/17/97	14	1546	210	110	26	1200	NA	140	ND	ND
C-3-0	San Jose	4/17/97	14	2413	150	110	53	2100	NA	150	ND	ND
BW10	Standish Dam	4/9/97	14	4130	290	93	47	3700	NA	240	ND	ND
BW15	Guadalupe River	4/7/97	14	4270	380	650	140	3100	NA	440	ND	ND
BG20	Sacramento River	8/6/97	15	312	63	59	ND	190	NA	110	ND	ND
BG30	San Joaquin River	8/6/97	15	303	65	48	ND	190	NA	77	ND	ND
BF20	Grizzly Bay	8/5/97	15	308	78	10	ND	220	NA	110	ND	ND
BD50	Napa River	8/5/97	15	394	140	84	ND	170	NA	72	ND	ND
BD40	Davis Point	8/4/97	15	440	130	120	ND	190	NA	38	ND	ND
BD30	Pinole Point	8/4/97	15	360	130	100	ND	130	NA	42	ND	ND
BD20	San Pablo Bay	8/4/97	15	520	180	220	ND	120	NA	44	ND	ND
BD15	Petaluma River	8/4/97	15	410	140	130	ND	140	NA	46	ND	ND
BC60	Red Rock	7/30/97	15	80	13	61	ND	6	NA	41	ND	ND
BC20	Golden Gate	7/31/97	15	397	220	120	ND	57	NA	17	ND	ND
BC10	Yerba Buena Island	7/30/97	15	400	170	130	ND	100	NA	64	ND	ND
BB70	Alameda	7/30/97	15	470	180	180	ND	110	NA	49	ND	ND
BA40	Redwood Creek	7/29/97	15	319	110	79	ND	130	NA	37	ND	ND
BA30	Dumbarton Bridge	7/28/97	15	Q	Q	Q	Q	Q	NA	Q	Q	ND
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	ND
C-3-0	San Jose	7/29/97	15	2490	140	150	ND	2200	NA	73	ND	ND
BW10	Standish Dam	8/1/97	15	180	75	42	ND	63	NA	460	ND	ND
BW15	Guadalupe River	8/1/97	15	447	59	38	ND	350	NA	180	ND	ND

Table 9. Total (dissolved + particulate) pesticide concentrations in water samples, 1997.
B = blank contamination >10% of measured concentration, M = matrix intereference, NA = not analyzed, ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Chlorpyrifos	Diazinon	Sum of DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Sum of Chlordanes (SFEI)	alpha-Chlordane	gamma-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane
				pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L	pg/L
BG20	Sacramento River	1/29/97	13	358	37690	1769	104	49	M	347	920	349	256	24	17	3	26	7	29	151
BG30	San Joaquin River	1/29/97	13	604	31320	1049	62	16	M	124	570	277	249	34	30	7	26	ND	39	113
BF20	Grizzly Bay	1/28/97	13	481	Q	1659	86	48	M	310	840	375	254	26	21	5	30	ND	29	143
BD50	Napa River	1/28/97	13	294	17380	2753	77	36	M	490	1570	580	540	109	97	27	89	ND	93	125
BD40	Davis Point	1/27/97	13	560	25290	1595	68	34	M	250	750	493	305	55	37	9	36	ND	45	123
BD30	Pinole Point	1/27/97	13	525	39270	2293	94	40	M	440	990	729	478	96	89	20	70	ND	65	139
BD20	San Pablo Bay	1/27/97	13	453	14130	1087	60	42	M	220	420	345	282	57	21	11	38	ND	43	112
BD15	Petaluma River	1/27/97	13	303	7850	1141	73	37	M	360	530	141	471	92	63	20	55	16	176	49
BC60	Red Rock	1/23/97	13	203	5335	528	14	11	M	229	181	93	123	26	18	6	11	ND	9	53
BC20	Golden Gate	1/24/97	13	35	1300	218	26	6	M	102	51	32	84	27	7	1	3	12	9	25
BC10	Yerba Buena Island	1/23/97	13	194	4522	546	20	17	M	313	133	63	155	35	27	4	14	ND	16	60
BB70	Alameda	1/23/97	13	271	5326	285	21	7	M	133	99	25	160	39	19	3	14	ND	47	38
BA40	Redwood Creek	1/22/97	13	197	4480	684	46	9	M	249	320	60	252	48	45	22	31	ND	41	65
BA30	Dumbarton Bridge	1/21/97	13	290	9170	1079	42	30	32	332	442	201	414	114	98	19	65	ND	67	50
BA10	Coyote Creek	1/22/97	13	482	6910	824	57	50	M	258	338	121	252	75	57	5	44	ND	27	43
C-3-0	San Jose	1/22/97	13	195	20710	3519	149	52	70	1010	1690	548	836	173	242	67	148	ND	78	128
BW10	Standish Dam	2/7/97	13	370	1760	10419	990	233	M	3100	4010	2086	2309	680	770	146	447	ND	73	193
BW15	Guadalupe River	2/7/97	13	449	4500	3649	236	105	M	1350	1230	728	1455	500	410	114	239	ND	109	83
BG20	Sacramento River	4/23/97	14	913	1800	884	112	33	M	241	440	57	302	31	18	ND	B	ND	97	156
BG30	San Joaquin River	4/23/97	14	290	1400	499	41	9	M	175	240	34	172	15	9	2	21	ND	32	93
BF20	Grizzly Bay	4/22/97	14	221	1700	826	80	12	20	330	350	33	181	19	13	ND	14	ND	4	131
BD50	Napa River	4/22/97	14	114	3000	716	62	13	23	300	244	74	219	34	18	8	31	ND	15	113
BD40	Davis Point	4/21/97	14	138	1600	533	M	17	M	156	332	28	168	17	8	4	13	ND	51	75
BD30	Pinole Point	4/21/97	14	117	1400	441	48	12	M	208	148	25	116	29	16	6	31	ND	ND	34
BD20	San Pablo Bay	4/21/97	14	82	ND	478	52	8	M	214	172	32	195	19	13	7	B	ND	36	120
BD15	Petaluma River	4/21/97	14	85	1600	749	M	14	M	150	325	260	262	26	18	ND	64	ND	18	136
BC60	Red Rock	4/14/97	14	77	1500	294	45	7	7	144	91	ND	73	14	8	ND	B	ND	3	49
BC20	Golden Gate	4/15/97	14	25	530	252	32	1	ND	72	27	120	26	4	3	ND	B	ND	1	18
BC10	Yerba Buena Island	4/14/97	14	66	1300	439	64	7	M	197	105	66	144	27	14	8	21	ND	32	43
BB70	Alameda	4/15/97	14	70	1500	162	30	ND	M	69	63	ND	51	ND	ND	ND	9	ND	10	32
BA40	Redwood Creek	4/16/97	14	230	3700	460	67	7	17	170	159	40	289	62	55	18	34	ND	26	94
BA30	Dumbarton Bridge	4/16/97	14	102	3100	328	52	5	M	84	187	ND	163	40	46	ND	19	ND	6	52
BA10	Coyote Creek	4/17/97	14	M	4138	2171	112	65	14	340	1597	43	249	115	111	23	Q	M	M	M
C-3-0	San Jose	4/17/97	14	701	6500	1279	154	20	29	480	520	76	498	137	58	15	35	ND	58	195
BW10	Standish Dam	4/9/97	14	M	5890	3413	M	41	M	649	2560	163	734	M	M	53	280	M	43	358
BW15	Guadalupe River	4/7/97	14	M	9400	1387	M	ND	M	740	M	647	1748	260	180	59	480	M	259	510
BG20	Sacramento River	8/6/97	15	950	3000	647	47	49	M	233	304	14	180	11	9	ND	B	ND	17	144
BG30	San Joaquin River	8/6/97	15	500	2520	416	38	16	ND	158	204	ND	182	7	11	ND	B	ND	28	136
BF20	Grizzly Bay	8/5/97	15	240	540	536	30	29	M	272	193	12	148	7	ND	4	B	ND	24	113
BD50	Napa River	8/5/97	15	102	5100	552	49	7	7	380	97	13	210	20	14	6	B	26	10	135
BD40	Davis Point	8/4/97	15	185	1915	583	73	9	14	420	52	15	204	23	16	ND	B	ND	17	147
BD30	Pinole Point	8/4/97	15	102	2530	584	39	40	M	235	254	17	157	13	14	3	B	ND	20	106
BD20	San Pablo Bay	8/4/97	15	77	370	630	61	9	ND	450	90	21	198	9	9	4	23	ND	14	139
BD15	Petaluma River	8/4/97	15	46	1300	1099	M	47	M	260	682	110	330	22	9	14	43	ND	15	226
BC60	Red Rock	7/30/97	15	3	490	252	10	19	ND	86	111	26	95	11	5	6	13	ND	20	41
BC20	Golden Gate	7/31/97	15	ND	ND	100	7	7	M	46	28	12	20	ND	ND	4	B	ND	13	4
BC10	Yerba Buena Island	7/30/97	15	231	640	260	15	17	M	144	84	ND	161	30	20	6	29	ND	34	41
BB70	Alameda	7/30/97	15	80	1000	264	25	13	M	138	88	ND	136	27	14	8	23	ND	28	36
BA40	Redwood Creek	7/29/97	15	68	750	238	16	14	2	105	101	ND	118	12	6	ND	25	ND	18	57
BA30	Dumbarton Bridge	7/28/97	15	Q	Q	150	Q	22	Q	4	124	Q	Q	Q	Q	Q	16	Q	Q	Q
BA10	Coyote Creek	7/29/97	15	NA	3100	223	NA	26	M	17	180	NA	16	NA	NA	NA	16	NA	NA	NA
C-3-0	San Jose	7/29/97	15	578	11000	510	104	28	M	326	NA	52	618	57	46	9	59	ND	206	240
BW10	Standish Dam	8/1/97	15	M	ND	3840	460	270	M	1176	1910	24	400	M	M	M	400	M	M	M
BW15	Guadalupe River	8/1/97	15	438	9900	418	M	22	M	354	NA	42	505	62	66	9	148	ND	24	197

Table 9. Total (dissolved + particulate) pesticide concentrations in water samples, 1997 (continued).
B = blank contamination >10% of measured concentration, M = matrix intereference, NA = not analyzed, ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 2 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of HCHs (SFEI) pg/L	alpha-HCH pg/L	beta-HCH pg/L	delta-HCH pg/L	gamma-HCH pg/L	Aldrin pg/L	Dieldrin pg/L	Endrin pg/L	Mirex pg/L
BG20	Sacramento River	1/29/97	13	325	174	17	14	120	NA	275	ND	ND
BG30	San Joaquin River	1/29/97	13	353	172	42	14	125	NA	246	ND	ND
BF20	Grizzly Bay	1/28/97	13	299	150	19	ND	130	NA	280	4	ND
BD50	Napa River	1/28/97	13	301	150	31	ND	120	NA	218	12	ND
BD40	Davis Point	1/27/97	13	342	162	18	ND	162	NA	294	10	ND
BD30	Pinole Point	1/27/97	13	331	140	28	ND	163	NA	333	ND	ND
BD20	San Pablo Bay	1/27/97	13	310	140	30	ND	140	NA	237	ND	ND
BD15	Petaluma River	1/27/97	13	517	260	40	37	180	NA	157	ND	ND
BC60	Red Rock	1/23/97	13	322	160	31	1	130	NA	155	ND	ND
BC20	Golden Gate	1/24/97	13	695	390	180	5	120	NA	61	ND	ND
BC10	Yerba Buena Island	1/23/97	13	408	190	71	7	140	NA	184	ND	ND
BB70	Alameda	1/23/97	13	523	190	83	ND	250	NA	178	ND	ND
BA40	Redwood Creek	1/22/97	13	407	140	47	ND	220	NA	169	ND	1
BA30	Dumbarton Bridge	1/21/97	13	717	100	89	ND	528	NA	141	ND	ND
BA10	Coyote Creek	1/22/97	13	598	150	73	5	370	NA	134	ND	ND
C-3-0	San Jose	1/22/97	13	1370	190	69	11	1100	NA	252	ND	ND
BW10	Standish Dam	2/7/97	13	104	54	13	ND	37	NA	420	52	5
BW15	Guadalupe River	2/7/97	13	165	63	29	ND	73	NA	268	ND	ND
BG20	Sacramento River	4/23/97	14	1078	220	18	ND	840	NA	320	ND	ND
BG30	San Joaquin River	4/23/97	14	369	100	29	ND	240	NA	120	ND	ND
BF20	Grizzly Bay	4/22/97	14	392	130	42	ND	220	NA	117	ND	ND
BD50	Napa River	4/22/97	14	495	210	75	ND	210	NA	120	ND	ND
BD40	Davis Point	4/21/97	14	426	180	66	ND	180	NA	95	ND	ND
BD30	Pinole Point	4/21/97	14	485	210	95	ND	180	NA	91	ND	ND
BD20	San Pablo Bay	4/21/97	14	638	230	228	ND	180	NA	90	ND	ND
BD15	Petaluma River	4/21/97	14	490	220	100	ND	170	NA	83	ND	ND
BC60	Red Rock	4/14/97	14	406	200	76	ND	130	NA	83	ND	ND
BC20	Golden Gate	4/15/97	14	528	264	183	ND	81	NA	37	ND	ND
BC10	Yerba Buena Island	4/14/97	14	501	250	111	ND	140	NA	78	ND	ND
BB70	Alameda	4/15/97	14	302	22	120	ND	160	NA	67	ND	ND
BA40	Redwood Creek	4/16/97	14	1280	180	100	ND	1000	NA	130	ND	ND
BA30	Dumbarton Bridge	4/16/97	14	810	190	110	ND	510	NA	120	ND	ND
BA10	Coyote Creek	4/17/97	14	M	M	M	M	M	NA	140	ND	3
C-3-0	San Jose	4/17/97	14	2504	229	110	53	2112	NA	165	ND	ND
BW10	Standish Dam	4/9/97	14	M	M	M	M	M	NA	326	ND	2
BW15	Guadalupe River	4/7/97	14	M	M	M	M	M	NA	476	ND	M
BG20	Sacramento River	8/6/97	15	356	74	59	ND	223	NA	380	ND	ND
BG30	San Joaquin River	8/6/97	15	328	68	48	ND	212	NA	327	ND	ND
BF20	Grizzly Bay	8/5/97	15	321	82	16	ND	224	NA	117	ND	ND
BD50	Napa River	8/5/97	15	402	144	84	ND	173	NA	85	ND	ND
BD40	Davis Point	8/4/97	15	524	163	126	ND	235	NA	118	ND	ND
BD30	Pinole Point	8/4/97	15	416	148	105	ND	163	NA	113	ND	ND
BD20	San Pablo Bay	8/4/97	15	520	180	220	ND	120	NA	57	ND	ND
BD15	Petaluma River	8/4/97	15	416	146	130	ND	140	NA	61	ND	ND
BC60	Red Rock	7/30/97	15	80	13	61	ND	6	NA	52	ND	ND
BC20	Golden Gate	7/31/97	15	397	220	120	ND	57	NA	26	ND	ND
BC10	Yerba Buena Island	7/30/97	15	484	223	130	ND	131	NA	75	ND	ND
BB70	Alameda	7/30/97	15	470	180	180	ND	110	NA	53	ND	ND
BA40	Redwood Creek	7/29/97	15	337	116	91	ND	130	NA	37	ND	ND
BA30	Dumbarton Bridge	7/28/97	15	Q	Q	Q	Q	Q	NA	Q	Q	ND
BA10	Coyote Creek	7/29/97	15	NA	NA	NA	NA	NA	NA	NA	NA	ND
C-3-0	San Jose	7/29/97	15	2508	143	150	ND	2215	NA	102	ND	ND
BW10	Standish Dam	8/1/97	15	M	M	M	M	M	NA	460	ND	ND
BW15	Guadalupe River	8/1/97	15	451	63	38	ND	350	NA	205	ND	5

Table 10. Aquatic bioassay results, 1997. For reference toxicant and QA information refer to Table 5 in *Appendix B*.

Station Code	Station	Date	Cruise	% Normal Development Mean	Development (Control) Mean	Mean % Survival	Mean % Survival (Control)
				Mytilus edulis		*Mysidopsis bahia*	
BG20	Sacramento River	1/29/97	13	91	92	23 *	80
BG30	San Joaquin River	1/29/97	13	92	92	0 *	80
BF20	Grizzly Bay	1/28/97	13	90 *	93	78 *	95
BD50	Napa River	1/28/97	13	93	93	73 *	95
BD30	Pinole Point	1/27/97	13	94 *	98	88	95
BD15	Petaluma River	1/27/97	13	97	98	95	95
BA40	Redwood Creek	1/22/97	13	94 *	98	95	95
BA10	Coyote Creek	1/22/97	13	98	98	85	95
C-3-0	San Jose	1/22/97	13	97	98	88	95
C-1-3	Sunnyvale	1/22/97	13	95 *	98	45 *	95
BG20	Sacramento River	8/6/97	15	94	94	93	100
BG30	San Joaquin River	8/6/97	15	96	94	100	100
BF20	Grizzly Bay	8/5/97	15	96	96	95	100
BD50	Napa River	8/5/97	15	96	96	100	100
BD30	Pinole Point	8/4/97	15	95	96	85	90
BD15	Petaluma River	8/4/97	15	97	96	88	90
BA40	Redwood Creek	7/29/97	15	90	91	33 *	100
BA10	Coyote Creek	7/29/97	15	86	91	0 *	100
C-3-0	San Jose	7/29/97	15	87	91	0 *	100
C-1-3	Sunnyvale	7/29/97	15	85	91	0 *	100

* Significantly different from the control at alpha = 0.05

Table 11. General characteristics of sediment samples, 1997. . = no data, ND = not detected.

Station Code	Station	Date	Cruise	% Clay (<4µm)	% Silt (4µm-63µm)	% Sand (63µm-2mm)	% Gravel+Shell (>2mm)	Depth	Ammonia	Hydrogen Sulfide	pH	TOC	Total Sulfide
				%	%	%	%	m	mg/L	mg/L	pH	%	mg/L
BG20	Sacramento River	1/30/97	13	7	6	87	0	9	0.2	ND	6.8	0.3	ND
BG30	San Joaquin River	1/30/97	13	37	35	28	0	8	1.6	ND	6.7	0.8	ND
BF40	Honker Bay	1/30/97	13	56	41	3	0	2	0.3	ND	7.1	1.6	ND
BF21	Grizzly Bay	1/30/97	13	58	41	1	0	2	0.3	ND	7.2	1.4	ND
BF10	Pacheco Creek	1/30/97	13	7	6	87	0	6	0.6	ND	7.2	0.7	ND
BD50	Napa River	1/31/97	13	68	28	4	0	5	3.0	ND	7.0	1.7	ND
BD41	Davis Point	1/31/97	13	6	4	90	0	7	1.0	ND	7.1	0.3	ND
BD31	Pinole Point	1/31/97	13	60	29	10	0	7	1.4	ND	7.6	0.9	ND
BD22	San Pablo Bay	1/31/97	13	51	35	14	0	2	1.6	ND	8.3	1.3	ND
BD15	Petaluma River	1/31/97	13	66	34	0	0	4	1.8	ND	7.6	1.5	ND
BC60	Red Rock	2/3/97	13	9	4	80	7	12	0.7	ND	7.5	0.1	ND
BC41	Point Isabel	2/3/97	13	49	40	11	0	3	1.4	ND	7.3	1.2	ND
BC32	Richardson Bay	2/3/97	13	54	36	9	0	3	2.3	ND	7.2	0.9	ND
BC21	Horseshoe Bay	2/3/97	13	26	22	52	0	5	0.2	ND	7.5	0.7	ND
BC11	Yerba Buena Island	2/3/97	13	44	25	27	4	5	0.1	ND	7.8	1.0	ND
BB70	Alameda	2/3/97	13	59	31	10	0	9	0.3	ND	7.5	1.2	ND
BB30	Oyster Point	2/5/97	13	49	29	21	2	10	0.0	ND	7.5	1.3	ND
BB15	San Bruno Shoal	2/4/97	13	40	18	27	15	14	0.3	ND	7.1	0.8	ND
BA41	Redwood Creek	2/4/97	13	69	28	2	1	5	0.0	ND	8.2	1.2	ND
BA30	Dumbarton Bridge	2/4/97	13	62	29	8	1	8	0.0	ND	7.9	1.4	ND
BA21	South Bay	2/4/97	13	68	29	1	1	5	0.1	ND	7.8	1.4	ND
BA10	Coyote Creek	2/4/97	13	76	23	1	0	7	0.1	ND	7.2	0.8	ND
C-3-0	San Jose	2/5/97	13	17	8	75	0	5	0.0	ND	8.1	1.1	ND
C-1-3	Sunnyvale	2/5/97	13	20	9	72	0	4	0.1	ND	7.4	1.5	ND
BW10	Standish Dam	2/7/97	13	25	49	26	0	0	0.2	ND	7.5	1.8	ND
BW15	Guadalupe River	2/7/97	13	65	24	10	0	0	0.3	ND	7.7	.	ND
BG20	Sacramento River	8/7/97	15	4	3	93	0	8	0.3	0.10	7.4	0.1	0.5
BG30	San Joaquin River	8/7/97	15	9	7	84	0	5	1.3	0.19	7.5	0.6	1.1
BF40	Honker Bay	8/7/97	15	56	37	7	0	3	2.6	0.06	7.1	1.3	0.2
BF21	Grizzly Bay	8/7/97	15	62	37	1	0	3	1.9	0.06	6.9	1.4	0.1
BF10	Pacheco Creek	8/7/97	15	29	9	61	0	4	1.5	0.07	7.7	0.5	0.6
BD50	Napa River	8/8/97	15	48	25	8	19	4	2.2	0.20	7.1	1.9	0.6
BD41	Davis Point	8/8/97	15	5	3	92	0	6.5	0.7	0.06	7.6	0.1	0.4
BD31	Pinole Point	8/8/97	15	36	18	45	0	6.5	2.6	0.10	7.0	1.0	0.3
BD22	San Pablo Bay	8/8/97	15	52	35	13	0	3	0.2	0.05	7.8	1.1	0.6
BD15	Petaluma River	8/8/97	15	66	29	4	0	4	2.0	0.01	7.5	1.5	0.1
BC60	Red Rock	8/11/97	15	31	9	59	1	11	0.3	0.01	8.7	0.6	0.8
BC41	Point Isabel	8/11/97	15	53	39	8	0	1.5	0.2	0.00	8.1	1.1	0.1
BC32	Richardson Bay	8/11/97	15	49	31	20	0	1	0.5	0.04	7.6	1.0	0.2
BC21	Horseshoe Bay	8/11/97	15	20	13	66	0	12	1.8	0.03	7.5	0.7	0.2
BC11	Yerba Buena Island	8/11/97	15	28	10	58	4	6	0.2	0.01	8.4	0.9	0.2
BB70	Alameda	8/12/97	15	45	20	36	0	10	0.2	0.01	8.0	1.1	0.1
BB30	Oyster Point	8/12/97	15	41	18	39	2	9	0.2	0.01	8.0	0.8	0.2
BB15	San Bruno Shoal	8/12/97	15	35	13	46	6	12	0.3	0.02	7.7	1.1	0.2
BA41	Redwood Creek	8/12/97	15	52	25	16	8	2.5	0.7	0.03	7.6	1.2	0.2
BA30	Dumbarton Bridge	8/13/97	15	55	40	4	1	7	3.3	0.02	7.6	1.1	0.1
BA21	South Bay	8/12/97	15	59	32	7	2	5.5	1.7	0.01	7.8	1.4	0.1
BA10	Coyote Creek	8/13/97	15	33	52	10	4	5	5.6	0.03	7.6	1.8	0.2
C-3-0	San Jose	8/13/97	15	25	51	24	0	3	7.7	0.01	8.0	1.4	0.1
C-1-3	Sunnyvale	8/13/97	15	44	52	4	0	2.5	4.1	0.02	7.8	1.6	0.2
BW10	Standish Dam	8/6/97	15	58	29	13	0	0	3.6	0.18	7.2	1.5	0.6
BW15	Guadalupe River	8/6/97	15	79	20	1	0	0	0.3	0.04	7.6	1.8	0.3

Table 12. Concentrations of trace elements for sediment samples, 1997. . = no data, b = blank contamination <10% of measured concentration, B = blank contamination >10% of measured concentration. ND = not detected, For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Se	Zn
				ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
BG20	Sacramento River	1/30/97	13	ND	13700 b	5.4	0.16	76	B	25600 b	0.04	490	86	8.8	0.06	74.8
BG30	San Joaquin River	1/30/97	13	0.14	34300 b	12.7	0.39	102	54 b	35400 b	0.53	595	75	27.0	0.54	111.0
BF40	Honker Bay	1/30/97	13	0.24	36400 b	8.7	0.34	118	64 b	44100 b	0.26	1010	120	15.0	0.30	126.0
BF21	Grizzly Bay	1/30/97	13	0.19	37400 b	8.6	0.28	122	58 b	46100 b	0.29	1080	117	18.0	0.28	132.0
BF10	Pacheco Creek	1/30/97	13	0.07	13000 b	4.7	0.10	64	B	25000 b	0.05	403	71	5.9	0.06	60.5
BD50	Napa River	1/31/97	13	0.39	45000 b	9.1	0.24	127	62 b	47500 b	0.39	738	115	23.0	0.30	144.0
BD41	Davis Point	1/31/97	13	0.05	16500 b	3.6	0.08	78	B	26400 b	0.04	330	77	5.7	0.04	67.2
BD31	Pinole Point	1/31/97	13	0.23	43800 b	9.1	0.35	128	68 b	49100 b	0.23	923	133	13.0	0.31	138.0
BD22	San Pablo Bay	1/31/97	13	0.26	36100 b	10.8	0.23	108	50 b	39300 b	0.36	463	93	19.0	0.30	120.0
BD15	Petaluma River	1/31/97	13	0.18	44600 b	7.1	0.27	138	58 b	48700 b	0.48	1100	141	16.0	0.28	132.0
BC60	Red Rock	2/3/97	13	ND	12800 b	5.7	0.05	59	B	29800 b	0.05	495	65	8.7	0.07	62.6
BC41	Point Isabel	2/3/97	13	0.17	31000 b	6.7	0.13	106	45 b	38700 b	0.28	340	91	17.0	0.28	118.0
BC32	Richardson Bay	2/3/97	13	0.15	36400 b	8.4	0.19	116	50 b	42500 b	0.25	524	104	21.0	0.22	121.0
BC21	Horseshoe Bay	2/3/97	13	0.14	24500 b	5.3	0.14	88	B	31000 b	0.15	310	74	33.0	0.15	85.9
BC11	Yerba Buena Island	2/3/97	13	0.31	30300	5.3	0.23	93	32	29800	0.23	279	75	19.0	0.21	93.4
BB70	Alameda	2/3/97	13	0.18	39700 b	8.1	0.18	126	52 b	45600 b	0.27	620	116	13.0	0.25	127.0
BB30	Oyster Point	2/5/97	13	0.20	34300	5.5	0.13	106	34	34600	0.23	355	87	18.0	0.31	100.0
BB15	San Bruno Shoal	2/4/97	13	0.26	31300	6.0	0.16	94	32	31600	0.24	381	82	17.0	0.23	94.2
BA41	Redwood Creek	2/4/97	13	0.29	40600	6.4	0.15	121	39	40500	0.32	579	101	26.0	0.22	122.0
BA30	Dumbarton Bridge	2/4/97	13	0.31	40200	6.0	0.19	118	39	38900	0.33	658	98	26.0	0.36	119.0
BA21	South Bay	2/4/97	13	0.31	43400	6.1	0.21	130	40	41900	0.51	1010	113	28.0	0.33	130.0
BA10	Coyote Creek	2/4/97	13	0.44	48600	7.4	0.61	163	52	46500	0.78	751	190	35.0	0.44	396.0
C-3-0	San Jose	2/5/97	13	0.45	21000	4.0	0.47	107	22	26100	0.18	2040	95	23.0	0.18	102.0
C-1-3	Sunnyvale	2/5/97	13	0.16	22400	2.5	0.16	87	22	24200	0.16	479	64	15.0	0.13	81.7
BW10	Standish Dam	2/7/97	13	0.16	18500	5.9	0.26	79	32	29000	0.14	542	122	25.0	0.29	89.1
BW15	Guadalupe River	2/7/97	13	0.61	36100	6.7	0.42	131	50	43900	1.08	1230	131	44.0	0.47	168.0
BG20	Sacramento River	8/7/97	15	B	19736	6.7	0.18	110	14	27895	0.03	543	87	7.4	0.05	74.2
BG30	San Joaquin River	8/7/97	15	B	24058	5.8	0.12	128	14	32174	0.02	420	87	4.8	0.08	61.3
BF40	Honker Bay	8/7/97	15	B	57174	12.2	0.33	144	58	49565	0.29	822	119	21.3	0.34	144.0
BF21	Grizzly Bay	8/7/97	15	B	58723	13.0	0.30	146	60	49787	0.29	1102	126	21.3	0.32	138.0
BF10	Pacheco Creek	8/7/97	15	B	25735	7.7	0.13	103	22	32794	0.09	463	79	10.1	0.15	80.3
BD50	Napa River	8/8/97	15	B	61951	12.1	0.39	146	64	50732	0.31	727	129	24.4	0.41	148.0
BD41	Davis Point	8/8/97	15	B	18421	6.2	0.09	101	10	29079	0.08	345	76	9.1	0.07	66.6
BD31	Pinole Point	8/8/97	15	B	40600	9.9	0.20	114	40	38800	0.19	732	98	16.8	0.24	107.0
BD22	San Pablo Bay	8/8/97	15	B	51250	12.5	0.23	126	51	41250	0.32	602	99	22.9	0.33	120.0
BD15	Petaluma River	8/8/97	15	B	59250	10.4	0.30	146	59	48500	0.30	968	119	24.8	0.30	145.0
BC60	Red Rock	8/11/97	15	B	34754	12.2	0.21	106	29	38033	0.10	751	93	12.6	0.17	86.9
BC41	Point Isabel	8/11/97	15	B	47234	10.4	0.19	132	42	41915	0.25	389	99	23.4	0.31	123.0
BC32	Richardson Bay	8/11/97	15	B	45217	14.0	0.22	121	43	40870	0.22	385	97	18.9	0.29	109.0
BC21	Horseshoe Bay	8/11/97	15	B	26721	8.1	0.28	86	20	28525	0.11	380	70	12.4	0.18	71.1
BC11	Yerba Buena Island	8/11/97	15	B	43913	8.5	0.20	119	40	36304	0.20	522	87	32.6	0.25	109.0
BB70	Alameda	8/12/97	15	B	46792	8.1	0.21	148	39 b	39811	0.24	434	93	22.6	0.26	117.0
BB30	Oyster Point	8/12/97	15	B	39000	7.9	0.22	112	30 b	33400	0.14	452	85	14.0	0.28	89.6
BB15	San Bruno Shoal	8/12/97	15	B	33704	6.4	0.17	91	30 b	29074	0.19	418	73	18.5	0.21	86.7
BA41	Redwood Creek	8/12/97	15	B	52195	8.8	0.20	138	45	43902	0.27	515	106	26.8	0.33	131.0
BA30	Dumbarton Bridge	8/13/97	15	B	47391	8.0	0.17	131	43	41304	0.27	667	102	23.9	0.24	122.0
BA21	South Bay	8/12/97	15	B	51957	7.7	0.20	137	43	43913	0.28	687	111	26.1	0.40	130.0
BA10	Coyote Creek	8/13/97	15	B	54615	7.6	0.23	147	44	47179	0.39	1274	117	28.2	0.40	149.0
C-3-0	San Jose	8/13/97	15	1.30 b	50800	7.0	1.00	200	57	41600	0.41	624	133	.	0.49	184.0
C-1-3	Sunnyvale	8/13/97	15	B	63000	7.6	0.27	168	48 b	53333	0.36	1530	132	33.3	0.35	179.0
BW10	Standish Dam	8/6/97	15	0.40	43091	7.8	0.33	238	43 b	39818	0.34	689	181	30.9	0.48	148.0
BW15	Guadalupe River	8/6/97	15	0.53	57907	11.1	0.26	162	53 b	55349	0.50	1684	132	37.2	0.45	176.0

Table 13. PAH concentrations in sediment samples, 1997. B = blank contamination >10% of measured concentration, b = blank contamination <10% of measured concentration, HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs, ND = not detected. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of LPAHs (SFEI)	Biphenyl	Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	2,6-Dimethylnaphthalene	2,3,5-Trimethylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Dibenzothiophene	Fluorene	Phenanthrene	1-Methylphenanthrene
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	358	28	ND	B	ND	ND	ND	ND	ND	ND	6	2	ND	19 b	2
BG30	San Joaquin River	1/30/97	13	1293	79	ND	B	ND	ND	ND	ND	2	5	14	2	5	39 b	11
BF40	Honker Bay	1/30/97	13	612	40	ND	B	ND	ND	ND	ND	3	2	5	ND	ND	24 b	5
BF21	Grizzly Bay	1/30/97	13	679	57	ND	B	ND	ND	ND	ND	2	3	9	2	5	28 b	8
BF10	Pacheco Creek	1/30/97	13	127	15	ND	B	ND	ND	ND	ND	2	ND	3	ND	2	8 b	ND
BD50	Napa River	1/31/97	13	1120	146	5	19 b	6	10	6	5	7	4	12	4	10	46 b	11
BD41	Davis Point	1/31/97	13	13	ND	ND	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	ND
BD31	Pinole Point	1/31/97	13	490	152	7	B	10	10	5	ND	35	ND	12	ND	24	49 b	ND
BD22	San Pablo Bay	1/31/97	13	7406	873	11	68 b	10	14	7	22	27	39	163	22	39	397 b	54
BD15	Petaluma River	1/31/97	13	659	65	ND	B	ND	ND	ND	ND	4	4	19	ND	5	33 b	ND
BC60	Red Rock	2/3/97	13	40	ND	ND	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	ND
BC41	Point Isabel	2/3/97	13	1683	203	7	B	ND	ND	8	ND	11	13	45	7	11	84 b	17
BC32	Richardson Bay	2/3/97	13	1780	208	6	B	6	9	5	ND	9	10	55	7	10	78 b	16
BC21	Horseshoe Bay	2/3/97	13	4258	1091	9	B	15	15	19	14	34	68	200	39	78	479 b	122
BC11	Yerba Buena Island	2/3/97	13	914	112	ND	B	7	6	4	ND	5	6	14	3	6	50 b	12
BB70	Alameda	2/3/97	13	1329	166	5	17 b	6	7	5	ND	7	9	21	5	9	61 b	15
BB30	Oyster Point	2/5/97	13	3125	529	7	32 b	9	11	9	7	14	25	104	14	25	237 b	35
BB15	San Bruno Shoal	2/4/97	13	1629	223	2	19 b	6	7	5	ND	8	12	39	8	12	84 b	20
BA41	Redwood Creek	2/4/97	13	1740	194	3	21 b	6	8	6	ND	6	12	29	5	7	75 b	16
BA30	Dumbarton Bridge	2/4/97	13	2353	297	7	30 b	9	8	5	6	11	18	35	10	14	121 b	22
BA21	South Bay	2/4/97	13	1642	188	5	25 b	8	9	7	7	7	11	17	5	10	65 b	12
BA10	Coyote Creek	2/4/97	13	1021	148	7	22 b	10	17	5	6	4	4	9	5	6	44 b	8
C-3-0	San Jose	2/5/97	13	502	76	2	B	6	9	6	9	3	3	5	2	4	21 b	6
C-1-3	Sunnyvale	2/5/97	13	590	78	3	B	5	8	2	4	3	3	7	3	6	30 b	5
BW10	Standish Dam	2/7/97	13	558	91	5	B	7	11	6	4	3	1	7	3	4	33 b	7
BW15	Guadalupe River	2/7/97	13	1737	208	7	23 b	10	14	6	13	7	7	13	8	12	73 b	14
BG20	Sacramento River	8/7/97	15	2	ND	ND	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	ND
BG30	San Joaquin River	8/7/97	15	52	1	ND	B	ND	ND	ND	ND	1	ND	ND	ND	ND	B	ND
BF40	Honker Bay	8/7/97	15	583	77	4	B	6	6	4	ND	3	2	7	3	6	31 b	5
BF21	Grizzly Bay	8/7/97	15	54	3	ND	B	3	ND	ND	ND	ND	ND	ND	ND	ND	B	ND
BF10	Pacheco Creek	8/7/97	15	240	27	2	B	2	3	ND	ND	4	1	5	1	5	B	3
BD50	Napa River	8/8/97	15	856	116	7	B	8	14	7	ND	4	4	13	4	7	42 b	6
BD41	Davis Point	8/8/97	15	155	8	ND	B	2	2	ND	ND	ND	1	2	ND	ND	B	2
BD31	Pinole Point	8/8/97	15	885	74	3	B	5	7	2	ND	3	4	9	2	3	29 b	7
BD22	San Pablo Bay	8/8/97	15	3430	372	7	41 b	10	13	4	7	11	22	45	12	13	169 b	19
BD15	Petaluma River	8/8/97	15	790	118	6	22 b	7	10	5	ND	4	4	8	3	4	37 b	7
BC60	Red Rock	8/11/97	15	250	39	3	B	4	4	2	ND	5	1	3	ND	ND	15 b	3
BC41	Point Isabel	8/11/97	15	2370	295	5	33 b	11	11	7	6	7	16	38	8	9	116 b	27
BC32	Richardson Bay	8/11/97	15	2174	261	7	B	10	12	ND	ND	17	13	41	8	11	123 b	18
BC21	Horseshoe Bay	8/11/97	15	854	139	4	B	5	7	5	ND	5	8	22	5	6	65 b	9
BC11	Yerba Buena Island	8/11/97	15	1279	159	6	B	5	9	ND	ND	4	10	25	5	7	75 b	12
BB70	Alameda	8/12/97	15	3338	587	7	37 b	9	15	13	21	7	18	92	15	23	249 b	80
BB30	Oyster Point	8/12/97	15	809	108	5	B	7	8	ND	ND	5	6	14	4	4	45 b	9
BB15	San Bruno Shoal	8/12/97	15	1754	263	6	35 b	10	12	7	ND	9	12	35	8	10	100 b	19
BA41	Redwood Creek	8/12/97	15	2052	268	7	36 b	8	12	ND	10	6	16	33	8	9	100 b	23
BA30	Dumbarton Bridge	8/13/97	15	2833	338	7	33 b	8	13	ND	ND	9	22	46	12	12	147 b	29
BA21	South Bay	8/12/97	15	2028	271	8	37 b	12	16	ND	9	7	15	31	9	11	100 b	17
BA10	Coyote Creek	8/13/97	15	1676	193	9	32 b	10	15	ND	ND	6	10	18	7	7	67 b	12
C-3-0	San Jose	8/13/97	15	1738	219	10	33 b	11	19	ND	18	6	5	17	8	9	66 b	17
BW10	Standish Dam	8/6/97	15	1100	106	7	B	8	12	ND	ND	5	3	8	5	6	40 b	12
BW15	Guadalupe River	8/6/97	15	1856	592	22	38 b	68	84	45	89	7	5	15	51	24	104 b	40

Table 13. PAH concentrations in sediment samples, 1997 (continued). B = blank contamination >10% of measured concentration, b = blank contamination <10% of measured concentration, HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs, ND = not detected. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PAHs (SFEI)	Sum of HPAHs (SFEI)	Benz(a)anthracene	Chrysene	Fluoranthene	Pyrene	Benzo(a)pyrene	Benzo(e)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Dibenz(a,h)anthracene	Perylene	Benzo(ghi)perylene	Indeno(1,2,3-cd)pyrene
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	358	330	17	20	45	57	22	33	31	10	3	17	40	34
BG30	San Joaquin River	1/30/97	13	1293	1214	71	71	137	160	80	118	128	45	14	151	124	116
BF40	Honker Bay	1/30/97	13	612	572	23	38	58	74	40	48	62	19	7	68	74	61
BF21	Grizzly Bay	1/30/97	13	679	621	28	39	62	83	43	52	66	24	7	81	73	64
BF10	Pacheco Creek	1/30/97	13	127	112	6	9	18	17	8	9	13	5	ND	10	9	9
BD50	Napa River	1/31/97	13	1120	974	43	50	97	145	71	88	104	34	14	91	128	108
BD41	Davis Point	1/31/97	13	13	13	1	ND	B	B	1	1	2	ND	ND	4	2	1
BD31	Pinole Point	1/31/97	13	490	339	24	38	36 b	44 b	20	25	34	14	5	31	37	31
BD22	San Pablo Bay	1/31/97	13	7406	6533	388	335	635	945	496	798	810	213	86	207	820	800
BD15	Petaluma River	1/31/97	13	659	594	31	36	54 b	78 b	43	57	78	26	9	30	79	74
BC60	Red Rock	2/3/97	13	40	40	2	3	B	B	4	5	6	2	ND	5	7	6
BC41	Point Isabel	2/3/97	13	1683	1480	96	89	155 b	211 b	101	157	188	62	20	50	176	174
BC32	Richardson Bay	2/3/97	13	1780	1572	114	112	166 b	209 b	107	160	210	66	21	52	176	178
BC21	Horseshoe Bay	2/3/97	13	4258	3167	318	241	404 b	551 b	187	328	394	110	53	65	248	268
BC11	Yerba Buena Island	2/3/97	13	914	802	46	48	79	100	60	90	95	33	11	37	102	102
BB70	Alameda	2/3/97	13	1329	1163	67	67	124	161	84	132	141	46	16	51	136	137
BB30	Oyster Point	2/5/97	13	3125	2597	199	168	304	402 b	187	310	332	98	29	91	226	250
BB15	San Bruno Shoal	2/4/97	13	1629	1406	96	93	152	206	97	155	164	58	18	51	159	157
BA41	Redwood Creek	2/4/97	13	1740	1545	89	98	156	211	115	165	193	60	20	59	185	194
BA30	Dumbarton Bridge	2/4/97	13	2353	2056	119	125	218	284	143	223	254	75	27	75	250	263
BA21	South Bay	2/4/97	13	1642	1455	82	84	139	184	112	159	177	52	20	58	192	196
BA10	Coyote Creek	2/4/97	13	1021	873	39	56	97	106	72	77	115	38	14	53	105	101
C-3-0	San Jose	2/5/97	13	502	425	26	28	52	70 b	32	42	58	19	5	20	35	40
C-1-3	Sunnyvale	2/5/97	13	590	512	24	37	53	63 b	42	48	79	27	8	24	50	58
BW10	Standish Dam	2/7/97	13	558	467	28	45	55	60 b	39	34	67	21	8	34	37	41
BW15	Guadalupe River	2/7/97	13	1737	1528	84	105	180	217 b	120	140	226	63	19	76	140	159
BG20	Sacramento River	8/7/97	15	2	2	ND	ND	ND	ND	ND	ND	1	ND	ND	2	ND	ND
BG30	San Joaquin River	8/7/97	15	52	50	1	1	3	3	1	1	2	1	ND	35	3	ND
BF40	Honker Bay	8/7/97	15	583	506	23	34	48	61	37	44	58	19	ND	65	63	56
BF21	Grizzly Bay	8/7/97	15	54	52	2	3	7	8	4	4	4	ND	ND	7	7	5
BF10	Pacheco Creek	8/7/97	15	240	213	22	24	20	22	14	20	25	11	ND	17	20	18
BD50	Napa River	8/8/97	15	856	741	46	74	75	93	51	65	84	28	10	58	83	76
BD41	Davis Point	8/8/97	15	155	147	6	8	15	20	10	12	16	4	2	19	18	16
BD31	Pinole Point	8/8/97	15	885	811	48	56	94	118	58	80	95	36	11	49	85	81
BD22	San Pablo Bay	8/8/97	15	3430	3058	174	156	299	437	223	356	356	106	43	117	396	395
BD15	Petaluma River	8/8/97	15	790	671	26	32	64	88	52	68	76	27	9	53	94	83
BC60	Red Rock	8/11/97	15	250	211	8	12	22	28	15	20	22	7	3	18	30	27
BC41	Point Isabel	8/11/97	15	2370	2075	134	125	218	296	145	238	235	81	31	79	248	245
BC32	Richardson Bay	8/11/97	15	2174	1913	106 b	119	220	282	136	214	213	77	25	73	227	221
BC21	Horseshoe Bay	8/11/97	15	854	715	43 b	47	92	118	46	73	77	26	10	30	78	76
BC11	Yerba Buena Island	8/11/97	15	1279	1121	60 b	72	126	163	79	123	132	44	15	48	134	125
BB70	Alameda	8/12/97	15	3338	2751	237 b	218	290	441	181	313	323	99	47	91	260	251
BB30	Oyster Point	8/12/97	15	809	702	33 b	44	72	103	50	76	80	27	9	36	90	81
BB15	San Bruno Shoal	8/12/97	15	1754	1491	90 b	93	151	204	106	164	179	57	22	56	188	182
BA41	Redwood Creek	8/12/97	15	2052	1784	96 b	108	178	241	131	202	217	76	26	69	223	217
BA30	Dumbarton Bridge	8/13/97	15	2833	2495	146 b	152	263	348	179	279	305	95	37	88	300	303
BA21	South Bay	8/12/97	15	2028	1757	89 b	102	170	243	132	182	218	72	26	72	230	222
BA10	Coyote Creek	8/13/97	15	1676	1483	59 b	78	136	188	116	152	198	59	21	66	208	202
C-3-0	San Jose	8/13/97	15	1738	1519	78 b	90	212	255	108	138	189	67	19	61	147	156
BW10	Standish Dam	8/6/97	15	1100	994	40 b	57	111	122	78	86	144	44	15	50	120	127
BW15	Guadalupe River	8/6/97	15	1856	1265	44 b	60	119	161	100	119	174	60	17	69	166	176

Table 14. PCB concentrations in sediment samples, 1997. ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 008	PCB 018	PCB 028	PCB 031	PCB 033	PCB 044	PCB 049	PCB 052	PCB 056	PCB 060
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	1/30/97	13	1.0	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND
BF21	Grizzly Bay	1/30/97	13	1.6	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND
BF10	Pacheco Creek	1/30/97	13	2.2	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND
BD50	Napa River	1/31/97	13	5.9	ND	ND	0.3	ND	ND	0.5	ND	ND	ND	ND
BD41	Davis Point	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	1.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	1/31/97	13	3.7	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	1/31/97	13	4.6	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND
BC60	Red Rock	2/3/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	2/3/97	13	14.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC32	Richardson Bay	2/3/97	13	5.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	2/3/97	13	3.0	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	2/3/97	13	8.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BB70	Alameda	2/3/97	13	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BB30	Oyster Point	2/5/97	13	6.3	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND
BB15	San Bruno Shoal	2/4/97	13	4.5	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND
BA41	Redwood Creek	2/4/97	13	5.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	2/4/97	13	8.2	ND	ND	0.2	ND	ND	ND	ND	0.3	ND	ND
BA21	South Bay	2/4/97	13	10.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	2/4/97	13	40.1	ND	ND	0.8	0.7	ND	0.7	ND	1.4	ND	ND
C-3-0	San Jose	2/5/97	13	81.2	ND	1.4	2.6	ND	0.5	2.5	2.4	3.9	1.3	0.8
C-1-3	Sunnyvale	2/5/97	13	10.0	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND
BW10	Standish Dam	2/7/97	13	44.6	ND	ND	ND	0.3	ND	0.4	ND	0.8	ND	ND
BW15	Guadalupe River	2/7/97	13	42.2	ND	ND	0.7	0.7	ND	0.6	ND	1.4	ND	ND
BG20	Sacramento River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF21	Grizzly Bay	8/7/97	15	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF10	Pacheco Creek	8/7/97	15	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	8/8/97	15	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD41	Davis Point	8/8/97	15	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	4.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	8/8/97	15	4.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	8/8/97	15	5.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC60	Red Rock	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	8/11/97	15	11.1	ND	ND	ND	ND	ND	ND	ND	0.8	ND	ND
BC32	Richardson Bay	8/11/97	15	2.3	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND
BC21	Horseshoe Bay	8/11/97	15	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	8/11/97	15	28.5	ND	ND	ND	ND	ND	ND	0.7	ND	ND	0.4
BB70	Alameda	8/12/97	15	27.6	ND	ND	ND	ND	ND	0.6	0.4	1.3	ND	ND
BB30	Oyster Point	8/12/97	15	4.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	8/12/97	15	5.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BA41	Redwood Creek	8/12/97	15	9.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	8/13/97	15	48.6	ND	ND	0.4	ND	ND	1.0	0.6	2.4	ND	ND
BA21	South Bay	8/12/97	15	10.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	8/13/97	15	12.6	ND	ND	ND	ND	ND	ND	ND	0.5	0.3	ND
C-3-0	San Jose	8/13/97	15	119.4	ND	3.0	5.0	ND	1.5	3.7	4.5	5.5	2.2	1.2
BW10	Standish Dam	8/6/97	15	33.3	ND	ND	1.2	ND	ND	0.4	ND	ND	0.4	0.5
BW15	Guadalupe River	8/6/97	15	22.6	ND	1.9	ND	ND	ND	ND	0.5	ND	ND	ND

Table 14. PCB concentrations in sediment samples, 1997 (continued). ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 066	PCB 070	PCB 074	PCB 087	PCB 095	PCB 097	PCB 099	PCB 101	PCB 105	PCB 110
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	1/30/97	13	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
BF21	Grizzly Bay	1/30/97	13	1.6	ND	ND	ND	ND	ND	ND	ND	0.2	ND	0.3
BF10	Pacheco Creek	1/30/97	13	2.2	0.1	ND	ND	ND	0.3	ND	ND	0.3	ND	ND
BD50	Napa River	1/31/97	13	5.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6
BD41	Davis Point	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	1.9	ND	ND	ND	ND	ND	ND	ND	0.2	ND	0.8
BD22	San Pablo Bay	1/31/97	13	3.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
BD15	Petaluma River	1/31/97	13	4.6	0.2	ND	ND	ND	0.8	ND	ND	ND	ND	1.7
BC60	Red Rock	2/3/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	0.7	ND	ND
BC41	Point Isabel	2/3/97	13	14.0	0.4	0.3	ND	0.8	1.0	ND	0.8	0.8	0.5	1.2
BC32	Richardson Bay	2/3/97	13	5.1	0.2	0.2	ND	ND	0.9	ND	ND	0.5	ND	0.5
BC21	Horseshoe Bay	2/3/97	13	3.0	ND	ND	ND	ND	ND	ND	ND	0.4	ND	0.3
BC11	Yerba Buena Island	2/3/97	13	8.6	0.2	ND	ND	ND	0.3	ND	ND	0.5	ND	0.4
BB70	Alameda	2/3/97	13	1.1	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND
BB30	Oyster Point	2/5/97	13	6.3	ND	ND	ND	ND	ND	ND	ND	0.5	ND	0.6
BB15	San Bruno Shoal	2/4/97	13	4.5	ND	0.2	ND	ND	ND	ND	ND	0.2	ND	0.3
BA41	Redwood Creek	2/4/97	13	5.2	ND	ND	ND	ND	ND	ND	ND	0.5	ND	0.7
BA30	Dumbarton Bridge	2/4/97	13	8.2	0.3	0.3	ND	ND	0.4	0.2	0.3	0.6	0.4	0.5
BA21	South Bay	2/4/97	13	10.8	0.4	ND	ND	ND	0.5	0.3	0.4	0.8	0.4	0.9
BA10	Coyote Creek	2/4/97	13	40.1	0.9	1.3	0.4	0.8	1.7	0.6	0.8	2.3	0.8	2.5
C-3-0	San Jose	2/5/97	13	81.2	2.8	4.2	1.6	2.7	3.5	1.7	2.0	5.6	1.9	5.9
C-1-3	Sunnyvale	2/5/97	13	10.0	0.3	ND	ND	0.4	0.5	ND	ND	0.6	ND	1.6
BW10	Standish Dam	2/7/97	13	44.6	0.4	0.7	ND	0.4	1.8	0.7	ND	2.1	ND	2.1
BW15	Guadalupe River	2/7/97	13	42.2	1.0	1.3	0.4	0.6	1.8	0.8	ND	2.5	0.8	2.9
BG20	Sacramento River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
BF21	Grizzly Bay	8/7/97	15	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
BF10	Pacheco Creek	8/7/97	15	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	8/8/97	15	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
BD41	Davis Point	8/8/97	15	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	4.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
BD22	San Pablo Bay	8/8/97	15	4.0	0.2	ND	ND	ND	1.6	ND	ND	ND	ND	ND
BD15	Petaluma River	8/8/97	15	5.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.8
BC60	Red Rock	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	8/11/97	15	11.1	0.4	ND	ND	ND	0.6	0.3	ND	ND	0.7	0.7
BC32	Richardson Bay	8/11/97	15	2.3	ND	ND	ND	ND	ND	ND	ND	0.4	ND	0.3
BC21	Horseshoe Bay	8/11/97	15	2.0	ND	ND	ND	ND	ND	ND	ND	0.2	ND	0.2
BC11	Yerba Buena Island	8/11/97	15	28.5	0.7	0.8	ND	0.5	1.3	0.5	1.0	2.1	ND	1.6
BB70	Alameda	8/12/97	15	27.6	0.5	1.1	0.3	1.0	1.8	0.8	1.0	2.7	0.7	2.6
BB30	Oyster Point	8/12/97	15	4.0	ND	ND	ND	ND	ND	ND	ND	0.5	ND	0.3
BB15	San Bruno Shoal	8/12/97	15	5.2	0.2	0.2	ND	ND	0.5	ND	0.3	ND	ND	0.4
BA41	Redwood Creek	8/12/97	15	9.1	ND	0.4	ND	ND	ND	ND	0.5	0.9	ND	0.7
BA30	Dumbarton Bridge	8/13/97	15	48.6	0.8	1.8	ND	2.5	3.5	1.5	1.7	5.1	1.8	5.3
BA21	South Bay	8/12/97	15	10.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6
BA10	Coyote Creek	8/13/97	15	12.6	0.7	ND	ND	ND	0.6	ND	ND	1.1	ND	0.7
C-3-0	San Jose	8/13/97	15	119.4	5.2	6.3	2.1	2.3	5.1	2.3	3.7	7.1	2.0	7.7
BW10	Standish Dam	8/6/97	15	33.3	0.8	1.0	ND	0.5	1.3	0.4	ND	2.5	ND	4.3
BW15	Guadalupe River	8/6/97	15	22.6	0.8	0.9	ND	1.4	2.9	ND	ND	ND	ND	2.5

Table 14. PCB concentrations in sediment samples, 1997 (continued). ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 118	PCB 128	PCB 132	PCB 138	PCB 141	PCB 149	PCB 151	PCB 153	PCB 156	PCB 158
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	0.7	0.2	0.3	ND	ND	ND	ND	ND	ND	0.2	ND
BF40	Honker Bay	1/30/97	13	1.0	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND
BF21	Grizzly Bay	1/30/97	13	1.6	ND	0.1	ND	0.2	ND	ND	ND	ND	ND	ND
BF10	Pacheco Creek	1/30/97	13	2.2	ND	ND	ND	ND	ND	0.5	ND	0.3	ND	ND
BD50	Napa River	1/31/97	13	5.9	0.8	ND	ND	0.7	ND	0.7	ND	0.8	ND	ND
BD41	Davis Point	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	1.9	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	1/31/97	13	3.7	ND	ND	ND	0.5	ND	0.3	ND	0.7	ND	ND
BD15	Petaluma River	1/31/97	13	4.6	ND	ND	ND	0.4	ND	0.2	ND	0.4	ND	ND
BC60	Red Rock	2/3/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	2/3/97	13	14.0	1.1	0.4	0.4	1.2	ND	1.0	ND	1.3	ND	ND
BC32	Richardson Bay	2/3/97	13	5.1	0.6	0.2	ND	0.6	0.2	0.4	ND	0.8	ND	ND
BC21	Horseshoe Bay	2/3/97	13	3.0	ND	0.1	ND	0.5	ND	ND	ND	0.6	ND	ND
BC11	Yerba Buena Island	2/3/97	13	8.6	0.4	1.3	ND	0.7	0.2	0.5	ND	0.9	ND	ND
BB70	Alameda	2/3/97	13	1.1	ND	ND	ND	0.3	ND	ND	ND	0.5	ND	ND
BB30	Oyster Point	2/5/97	13	6.3	0.5	ND	ND	0.9	0.2	0.7	ND	0.9	ND	ND
BB15	San Bruno Shoal	2/4/97	13	4.5	0.4	0.1	ND	0.7	ND	0.4	ND	0.7	ND	ND
BA41	Redwood Creek	2/4/97	13	5.2	0.6	0.2	ND	0.8	ND	0.6	ND	1.0	ND	ND
BA30	Dumbarton Bridge	2/4/97	13	8.2	0.8	0.2	0.3	0.9	0.2	0.6	ND	0.9	ND	ND
BA21	South Bay	2/4/97	13	10.8	1.2	0.2	0.5	1.2	ND	1.1	ND	1.3	ND	ND
BA10	Coyote Creek	2/4/97	13	40.1	1.6	0.6	1.5	3.7	0.9	3.1	ND	4.0	0.3	0.3
C-3-0	San Jose	2/5/97	13	81.2	4.9	1.0	2.0	6.3	1.0	4.5	Q	5.2	0.5	0.8
C-1-3	Sunnyvale	2/5/97	13	10.0	0.7	0.2	ND	1.0	ND	1.1	ND	1.3	ND	ND
BW10	Standish Dam	2/7/97	13	44.6	1.0	0.5	1.9	4.7	1.2	4.7	Q	5.1	0.2	0.5
BW15	Guadalupe River	2/7/97	13	42.2	2.3	0.5	1.4	3.9	0.7	3.6	ND	4.4	ND	0.4
BG20	Sacramento River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	1.4	ND	ND	ND	ND	ND	0.3	ND	0.4	ND	ND
BF21	Grizzly Bay	8/7/97	15	1.7	ND	ND	0.8	ND	ND	ND	ND	0.6	ND	ND
BF10	Pacheco Creek	8/7/97	15	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	8/8/97	15	3.3	ND	ND	ND	1.2	ND	ND	ND	0.7	ND	ND
BD41	Davis Point	8/8/97	15	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	4.8	0.4	ND	ND	0.8	ND	0.6	ND	0.9	ND	ND
BD22	San Pablo Bay	8/8/97	15	4.0	ND	ND	ND	1.1	ND	ND	ND	1.1	ND	ND
BD15	Petaluma River	8/8/97	15	5.7	0.8	ND	ND	1.4	ND	0.4	ND	1.2	ND	ND
BC60	Red Rock	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	8/11/97	15	11.1	1.0	ND	0.7	1.3	ND	1.0	ND	1.4	ND	ND
BC32	Richardson Bay	8/11/97	15	2.3	ND	ND	ND	0.7	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	8/11/97	15	2.0	ND	ND	ND	0.4	ND	ND	ND	0.5	ND	ND
BC11	Yerba Buena Island	8/11/97	15	28.5	1.5	0.5	0.7	2.8	0.6	2.7	ND	3.2	ND	ND
BB70	Alameda	8/12/97	15	27.6	2.2	0.6	0.7	2.4	0.5	1.7	ND	2.2	0.3	ND
BB30	Oyster Point	8/12/97	15	4.0	0.4	ND	ND	0.6	0.1	0.5	ND	0.7	ND	ND
BB15	San Bruno Shoal	8/12/97	15	5.2	0.3	ND	ND	0.8	0.2	0.6	ND	0.7	ND	ND
BA41	Redwood Creek	8/12/97	15	9.1	1.1	ND	ND	1.2	ND	1.0	ND	1.6	ND	ND
BA30	Dumbarton Bridge	8/13/97	15	48.6	4.0	ND	2.1	5.0	1.0	3.3	ND	ND	0.6	0.6
BA21	South Bay	8/12/97	15	10.3	1.4	ND	1.2	1.7	ND	0.8	ND	1.6	ND	ND
BA10	Coyote Creek	8/13/97	15	12.6	0.9	ND	ND	1.7	ND	1.4	ND	1.9	ND	ND
C-3-0	San Jose	8/13/97	15	119.4	6.2	1.4	2.6	7.4	1.4	6.3	Q	7.3	0.7	0.7
BW10	Standish Dam	8/6/97	15	33.3	1.6	0.7	0.6	4.0	1.0	2.3	Q	2.7	ND	ND
BW15	Guadalupe River	8/6/97	15	22.6	1.3	ND	0.6	2.9	ND	1.4	ND	2.4	ND	ND

Table 14. PCB concentrations in sediment samples, 1997 (continued). ND = not detected, Q = data point outside data quality objective. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of PCBs (SFEI)	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	PCB 201	PCB 203	Hexachlorobenzene
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	1/30/97	13	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
BF21	Grizzly Bay	1/30/97	13	1.6	ND	ND	ND	ND	0.2	0.4	ND	ND	ND	ND	0.3
BF10	Pacheco Creek	1/30/97	13	2.2	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND
BD50	Napa River	1/31/97	13	5.9	0.2	ND	ND	0.4	0.2	0.7	ND	ND	ND	ND	0.3
BD41	Davis Point	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	1.9	ND	ND	ND	ND	ND	0.7	ND	ND	ND	ND	ND
BD22	San Pablo Bay	1/31/97	13	3.7	0.2	ND	ND	0.4	0.1	0.9	ND	ND	ND	ND	0.1
BD15	Petaluma River	1/31/97	13	4.6	ND	ND	ND	0.2	ND	0.3	ND	ND	ND	ND	0.2
BC60	Red Rock	2/3/97	13	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	2/3/97	13	14.0	ND	0.6	0.4	0.9	0.4	0.8	ND	ND	ND	ND	0.2
BC32	Richardson Bay	2/3/97	13	5.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	2/3/97	13	3.0	0.1	ND	ND	0.4	0.1	0.3	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	2/3/97	13	8.6	0.3	0.2	ND	0.6	1.6	0.4	0.2	ND	ND	ND	ND
BB70	Alameda	2/3/97	13	1.1	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND
BB30	Oyster Point	2/5/97	13	6.3	ND	ND	ND	0.6	0.2	0.7	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	2/4/97	13	4.5	0.2	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND
BA41	Redwood Creek	2/4/97	13	5.2	ND	ND	ND	0.4	ND	0.6	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	2/4/97	13	8.2	0.2	ND	ND	0.4	ND	0.4	ND	ND	ND	ND	ND
BA21	South Bay	2/4/97	13	10.8	0.3	ND	ND	0.6	0.2	0.5	0.2	ND	ND	ND	ND
BA10	Coyote Creek	2/4/97	13	40.1	1.1	0.9	0.9	2.7	0.6	1.7	0.6	ND	ND	0.4	ND
C-3-0	San Jose	2/5/97	13	81.2	1.2	0.9	0.9	2.9	0.7	1.8	0.8	ND	ND	0.4	ND
C-1-3	Sunnyvale	2/5/97	13	10.0	0.2	0.2	ND	0.5	0.1	0.5	0.2	ND	ND	0.2	ND
BW10	Standish Dam	2/7/97	13	44.6	1.8	1.5	1.4	4.2	1.0	3.4	1.0	0.4	ND	0.6	0.2
BW15	Guadalupe River	2/7/97	13	42.2	1.1	0.8	0.9	2.6	0.6	1.9	0.8	0.3	ND	0.4	ND
BG20	Sacramento River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	1.4	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	0.4
BF21	Grizzly Bay	8/7/97	15	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
BF10	Pacheco Creek	8/7/97	15	0.9	ND	ND	ND	0.9	ND	ND	ND	ND	ND	ND	0.2
BD50	Napa River	8/8/97	15	3.3	ND	ND	ND	0.4	0.2	ND	ND	ND	ND	0.3	0.5
BD41	Davis Point	8/8/97	15	0.2	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	4.8	0.4	0.2	ND	0.8	ND	0.5	ND	ND	ND	ND	0.2
BD22	San Pablo Bay	8/8/97	15	4.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	8/8/97	15	5.7	ND	ND	ND	0.4	ND	0.8	ND	ND	ND	ND	ND
BC60	Red Rock	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
BC41	Point Isabel	8/11/97	15	11.1	0.4	ND	ND	0.8	0.2	0.6	0.2	ND	ND	ND	ND
BC32	Richardson Bay	8/11/97	15	2.3	ND	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	8/11/97	15	2.0	ND	ND	ND	0.3	ND	0.5	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	8/11/97	15	28.5	ND	0.7	0.8	2.4	0.6	1.5	0.6	ND	ND	0.4	ND
BB70	Alameda	8/12/97	15	27.6	0.4	ND	0.3	0.8	0.2	0.6	0.2	ND	ND	ND	ND
BB30	Oyster Point	8/12/97	15	4.0	0.2	ND	ND	0.4	ND	0.4	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	8/12/97	15	5.2	ND	ND	ND	0.5	0.1	0.4	ND	ND	ND	ND	ND
BA41	Redwood Creek	8/12/97	15	9.1	0.4	ND	ND	0.8	ND	0.7	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	8/13/97	15	48.6	0.8	ND	0.6	1.3	0.4	0.9	0.3	ND	ND	0.2	ND
BA21	South Bay	8/12/97	15	10.3	ND	ND	ND	0.6	ND	1.0	0.3	ND	ND	ND	ND
BA10	Coyote Creek	8/13/97	15	12.6	0.4	ND	0.5	0.8	0.3	0.9	0.2	ND	ND	ND	ND
C-3-0	San Jose	8/13/97	15	119.4	1.9	1.3	1.6	4.3	1.1	2.8	1.1	0.5	ND	0.7	ND
BW10	Standish Dam	8/6/97	15	33.3	1.0	0.7	0.9	2.1	0.5	1.4	0.5	ND	ND	0.5	ND
BW15	Guadalupe River	8/6/97	15	22.6	ND	ND	0.6	1.2	0.4	0.8	0.4	ND	ND	ND	ND

Table 15. Pesticide concentrations in sediment samples, 1997. ND = not detected. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Sum of DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Sum of Chlordanes	alpha-Chlordane	gamma-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	6.5	0.2	ND	ND	4.5	0.6	1.2	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	2.3	ND	ND	ND	ND	ND	2.3	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	1/30/97	13	8.8	ND	ND	ND	2.4	4.4	2.1	0.7	0.5	ND	ND	0.1	ND	ND	ND
BF21	Grizzly Bay	1/30/97	13	8.4	0.3	ND	ND	2.8	2.6	2.7	0.2	ND	ND	ND	0.2	ND	ND	ND
BF10	Pacheco Creek	1/30/97	13	2.3	ND	ND	ND	ND	0.4	1.9	0.2	ND	ND	ND	0.2	ND	ND	ND
BD50	Napa River	1/31/97	13	8.4	ND	ND	ND	3.0	2.2	3.2	ND	ND	ND	ND	ND	ND	ND	ND
BD41	Davis Point	1/31/97	13	1.6	ND	ND	ND	ND	0.3	1.3	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	13.0	ND	ND	ND	3.3	5.5	4.2	1.3	0.6	0.4	ND	0.4	ND	ND	ND
BD22	San Pablo Bay	1/31/97	13	8.3	ND	ND	0.7	1.7	1.4	4.5	ND	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	1/31/97	13	6.1	ND	ND	ND	1.9	2.0	2.2	0.4	ND	ND	ND	0.4	ND	ND	ND
BC60	Red Rock	2/3/97	13	2.7	ND	ND	ND	ND	0.6	2.1	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	2/3/97	13	9.4	M	ND	ND	4.1	2.0	3.3	0.8	0.8	ND	ND	ND	ND	ND	ND
BC32	Richardson Bay	2/3/97	13	7.0	ND	ND	ND	2.5	2.1	2.4	ND	ND	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	2/3/97	13	4.4	ND	ND	ND	1.7	0.8	1.9	ND	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	2/3/97	13	5.9	0.9	ND	ND	3.9	0.7	0.3	ND	ND	ND	ND	ND	ND	ND	ND
BB70	Alameda	2/3/97	13	2.8	ND	ND	ND	0.9	1.1	0.8	ND	ND	ND	ND	ND	ND	ND	ND
BB30	Oyster Point	2/5/97	13	3.5	ND	ND	ND	1.6	1.1	0.7	ND	ND	ND	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	2/4/97	13	2.7	ND	ND	ND	1.4	0.9	0.4	ND	ND	ND	ND	ND	ND	ND	ND
BA41	Redwood Creek	2/4/97	13	2.6	ND	ND	ND	1.2	1.0	0.5	ND	ND	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	2/4/97	13	2.7	ND	ND	ND	1.2	1.1	0.4	0.8	0.4	0.2	ND	0.2	ND	ND	ND
BA21	South Bay	2/4/97	13	5.0	ND	ND	ND	1.9	2.6	0.6	1.6	0.7	0.4	ND	0.4	ND	ND	ND
BA10	Coyote Creek	2/4/97	13	27.0	ND	ND	0.9	8.8	13.0	4.3	4.0	ND	2.1	ND	1.9	ND	ND	ND
C-3-0	San Jose	2/5/97	13	16.6	ND	ND	0.2	4.7	10.6	1.1	1.3	1.3	ND	ND	ND	ND	ND	ND
C-1-3	Sunnyvale	2/5/97	13	9.3	ND	ND	0.5	2.6	4.1	2.2	3.8	1.6	1.2	ND	0.9	ND	ND	ND
BW10	Standish Dam	2/7/97	13	76.0	7.8	ND	ND	17.8	33.0	17.4	19.7	8.0	6.6	ND	4.9	ND	ND	0.2
BW15	Guadalupe River	2/7/97	13	26.8	3.2	ND	0.5	10.0	10.0	3.1	9.2	3.7	3.0	ND	2.5	ND	ND	ND
BG20	Sacramento River	8/7/97	15	0.7	ND	ND	ND	0.3	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	0.7	ND	ND	ND	ND	0.3	0.4	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	4.9	ND	ND	ND	1.7	2.2	1.0	ND	ND	ND	ND	ND	ND	ND	ND
BF21	Grizzly Bay	8/7/97	15	12.1	ND	ND	ND	2.9	3.3	5.9	0.9	0.5	ND	ND	ND	ND	0.3	ND
BF10	Pacheco Creek	8/7/97	15	1.9	ND	ND	ND	0.8	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	8/8/97	15	10.6	ND	ND	ND	3.3	4.0	3.4	0.9	0.6	ND	ND	0.2	ND	ND	ND
BD41	Davis Point	8/8/97	15	1.1	ND	ND	ND	0.3	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	8.2	ND	ND	ND	2.7	2.0	3.5	ND	ND	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	8/8/97	15	9.8	ND	ND	ND	2.5	2.1	5.1	ND	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	8/8/97	15	13.8	ND	ND	ND	3.2	3.5	7.2	0.5	0.5	ND	ND	ND	ND	ND	ND
BC60	Red Rock	8/11/97	15	3.0	ND	ND	ND	1.0	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	8/11/97	15	6.0	ND	ND	ND	3.3	2.1	0.6	ND	ND	ND	ND	ND	ND	ND	ND
BC32	Richardson Bay	8/11/97	15	4.0	ND	ND	ND	1.9	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	8/11/97	15	2.6	ND	ND	ND	1.1	1.1	0.3	ND	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	8/11/97	15	5.4	ND	ND	ND	3.3	2.1	ND	0.8	0.8	ND	ND	ND	ND	ND	ND
BB70	Alameda	8/12/97	15	4.2	ND	ND	ND	1.8	1.8	0.7	0.5	0.5	ND	ND	ND	ND	ND	ND
BB30	Oyster Point	8/12/97	15	1.1	ND	ND	ND	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	8/12/97	15	5.6	ND	ND	ND	1.6	0.8	3.2	ND	ND	ND	ND	ND	ND	ND	ND
BA41	Redwood Creek	8/12/97	15	5.1	ND	ND	ND	2.2	2.1	0.8	0.9	0.6	0.3	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	8/13/97	15	4.6	ND	ND	ND	1.9	2.0	0.7	ND	ND	ND	ND	ND	ND	ND	ND
BA21	South Bay	8/12/97	15	14.8	ND	ND	ND	2.1	2.6	10.1	ND	ND	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	8/13/97	15	7.6	ND	ND	ND	4.0	3.6	ND	2.1	0.8	0.6	ND	0.7	ND	ND	ND
C-3-0	San Jose	8/13/97	15	23.7	ND	ND	0.3	5.2	17.1	1.2	4.4	3.2	1.3	ND	ND	ND	ND	ND
BW10	Standish Dam	8/6/97	15	44.4	3.0	ND	0.6	8.5	12.7	19.6	7.9	3.3	2.3	ND	1.8	ND	ND	0.4
BW15	Guadalupe River	8/6/97	15	16.8	0.6	ND	ND	ND	3.8	12.4	2.0	0.8	0.7	ND	ND	ND	0.4	ND

Table 15. Pesticide concentrations in sediment samples, 1997 (continued). ND = not detected. For MDLs refer to Table 3 in *Appendix B*.

Station Code	Station	Date	Cruise	Aldrin	Dieldrin	Endrin	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH	Mirex
				µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BF21	Grizzly Bay	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BF10	Pacheco Creek	1/30/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BD41	Davis Point	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	1/31/97	13	ND	0.7	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	1/31/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BC60	Red Rock	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BC32	Richardson Bay	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	0.3
BB70	Alameda	2/3/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BB30	Oyster Point	2/5/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	2/4/97	13	ND	ND	ND	ND	0.2	ND	ND	0.4
BA41	Redwood Creek	2/4/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	2/4/97	13	ND	ND	ND	ND	0.3	ND	ND	ND
BA21	South Bay	2/4/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	2/4/97	13	ND	ND	ND	ND	ND	ND	ND	ND
C-3-0	San Jose	2/5/97	13	ND	ND	ND	ND	ND	ND	ND	0.2
C-1-3	Sunnyvale	2/5/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BW10	Standish Dam	2/7/97	13	ND	ND	ND	ND	ND	ND	ND	ND
BW15	Guadalupe River	2/7/97	13	ND	ND	ND	ND	1.3	ND	ND	ND
BG20	Sacramento River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BF40	Honker Bay	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BF21	Grizzly Bay	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BF10	Pacheco Creek	8/7/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BD50	Napa River	8/8/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BD41	Davis Point	8/8/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BD31	Pinole Point	8/8/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BD22	San Pablo Bay	8/8/97	15	ND	0.8	ND	ND	ND	ND	ND	1.1
BD15	Petaluma River	8/8/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BC60	Red Rock	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BC41	Point Isabel	8/11/97	15	ND	ND	ND	ND	1.4	ND	ND	ND
BC32	Richardson Bay	8/11/97	15	ND	ND	ND	ND	1.1	ND	ND	ND
BC21	Horseshoe Bay	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BC11	Yerba Buena Island	8/11/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BB70	Alameda	8/12/97	15	ND	ND	ND	ND	ND	ND	ND	0.4
BB30	Oyster Point	8/12/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BB15	San Bruno Shoal	8/12/97	15	ND	ND	ND	ND	ND	ND	ND	0.5
BA41	Redwood Creek	8/12/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	8/13/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BA21	South Bay	8/12/97	15	ND	ND	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	8/13/97	15	ND	ND	ND	ND	ND	ND	ND	ND
C-3-0	San Jose	8/13/97	15	ND	ND	ND	ND	ND	ND	0.3	ND
BW10	Standish Dam	8/6/97	15	ND	0.9	ND	0.3	ND	ND	ND	ND
BW15	Guadalupe River	8/6/97	15	ND	ND	ND	ND	ND	ND	ND	ND

Table 16. Sediment bioassay data for 1997 RMP cruises. For physical/chemical measurements of test solutions and QA information refer to Table 6 in *Appendix B*.

Station Code	Station	Date	Cruise	Mean % Normal Development	SD—% Normal Development	Mean % Survival	SD—% Survival
				Mytilus edulis		*Eohaustorius estuarius*	
BG20	Sacramento River	1/30/97	13	21 *	5	94	5
BG30	San Joaquin River	1/30/97	13	0 *	0	91	7
BF21	Grizzly Bay	1/30/97	13	0 *	0	50 *	8
BD50	Napa River	1/31/97	13	50 *	4	71	10
BD41	Davis Point	1/31/97	13	67 *	7	95	4
BC60	Red Rock	2/3/97	13	84	4	94	7
BC21	Horseshoe Bay	2/3/97	13	83	5	80	11
BC11	Yerba Buena Island	2/3/97	13	87	7	76	16
BB70	Alameda	2/3/97	13	79	11	79	13
BB15	San Bruno Shoal	2/4/97	13	80 *	3	81	11
BA41	Redwood Creek	2/4/97	13	87	8	21 *	20
BA30	Dumbarton Bridge	2/4/97	13	94	8	45 *	25
BA21	South Bay	2/4/97	13	86	6	55 *	15
BA10	Coyote Creek	2/4/97	13	0 *	0	73 *	6
C-3-0	San Jose	2/5/97	13	80 *	5	66	42
–	Control	–	13	94	7	98	3
BG20	Sacramento River	8/7/97	15	0 *	0	91	10
BG30	San Joaquin River	8/7/97	15	0 *	0	91	7
BF21	Grizzly Bay	8/7/97	15	0 *	0	87 *	6
BD50	Napa River	8/8/97	15	0 *	0	80 *	9
BD41	Davis Point	8/8/97	15	90	6	94	5
BC60	Red Rock	8/8/97	15	93	11	92	7
BC21	Horseshoe Bay	8/11/97	15	83	5	91	5
BC11	Yerba Buena Island	8/11/97	15	90	6	55 *	15
BB70	Alameda	8/12/97	15	89	5	75 *	13
BB15	San Bruno Shoal	8/12/97	15	93	12	89	7
BA41	Redwood Creek	8/12/97	15	90	4	56	40
BA21	South Bay	8/12/97	15	87	5	56	40
BA10	Coyote Creek	8/13/97	15	0 *	0	90 *	8
C-3-0	San Jose	8/13/97	15	89	3	60	44
–	Control	–	15	90	6	99	2

* Sample mean was significantly different than control mean based on separate variance t-test (1-tailed, alpha = 0.01).

Table 17. Bivalve condition index and survival, 1997. NA = not analyzed, NS = not sampled. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading.

Station Code	Station	Date	Cruise	Species	Condition Index Mean	Condition Index Standard Error	% Survival per Species
BG20	Sacramento River	5/9/97	13	CFLU	0.089	0.003	93
BG30	San Joaquin River	5/9/97	13	CFLU	0.070	0.003	98
BF20	Grizzly Bay	5/9/97	13	CFLU	0.079	0.003	99
BD50	Napa River	5/8/97	13	CGIG	NA	NA	49
BD40	Davis Point	NS	13	–	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	0.197	0.008	85
BD20	San Pablo Bay	5/9/97	13	CGIG	0.176	0.007	92
BD15	Petaluma River	5/8/97	13	CFLU	0.111	0.006	97
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	0
BC21	Horseshoe Bay	5/9/97	13	MCAL	0.161	0.005	60
BC10	Yerba Buena Island	5/7/97	13	MCAL	NA	NA	9
BB71	Alameda	5/7/97	13	MCAL	0.192	0.005	97
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	0
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	0
BA10	Coyote Creek	5/7/97	13	CGIG	0.159	0.007	72
T-0	Putah Creek	1/27/97	13	CFLU	0.097	0.002	100
T-0	Tomales Bay	1/27/97	13	CGIG	0.093	0.004	100
T-0	Bodega Head	1/27/97	13	MCAL	0.106	0.003	100
BG20	Sacramento River	9/26/97	15	CFLU	0.042	0.005	85
BG30	San Joaquin River	9/26/97	15	CFLU	0.033	0.002	88
BF20	Grizzly Bay	9/23/97	15	CFLU	0.048	0.004	70
BD50	Napa River	9/23/97	15	CGIG	0.038	0.002	70
BD40	Davis Point	9/23/97	15	CGIG	NA	NA	9
BD30	Pinole Point	9/25/97	15	MCAL	0.065	0.002	97
BD20	San Pablo Bay	9/25/97	15	CGIG	0.082	0.005	66
BD15	Petaluma River	9/25/97	15	CGIG	0.045	0.002	64
BC61	Red Rock	9/25/97	15	MCAL	0.075	0.002	98
BC21	Horseshoe Bay	9/25/97	15	MCAL	0.130	0.004	91
BC10	Yerba Buena Island	9/24/97	15	MCAL	0.104	0.003	98
BB71	Alameda	9/24/97	15	MCAL	0.086	0.002	100
BA40	Redwood Creek	9/24/97	15	MCAL	0.073	0.001	99
BA30	Dumbarton Bridge	9/24/97	15	MCAL	0.070	0.002	97
BA10	Coyote Creek	9/24/97	15	CGIG	0.052	0.003	83
T-0	Putah Creek	6/23/97	15	CFLU	0.055	0.005	100
T-0	Tomales Bay	6/24/97	15	CGIG	0.123	0.004	100
T-0	Bodega Head	6/23/97	15	MCAL	0.075	0.002	100

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 18. Trace element concentrations in bivalve tissues, 1997. NA = not analyzed, ND = not detected, NS = not sampled. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For method detection limits see Table 4 in *Appendix B*.

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	DBT	MBT	TBT	TTBT
					%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	µg/kg Sn*	µg/kg Sn*	µg/kg Sn*	µg/kg Sn*
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	ND	9.1	1.1	33.6	82	0.168	5.6	0.9	2.9	166	ND	ND	ND	ND
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	ND	12.0	1.3	53.9	103	0.227	7.7	1.0	2.6	233	ND	ND	11	19
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	0.10	9.0	1.0	43.6	97	0.219	7.1	1.0	3.3	218	ND	ND	47	ND
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	3.49	9.5	12.2	1.9	277	0.212	2.0	0.6	3.6	858	ND	ND	48	7
BD40	Davis Point	NS	13	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	1.88	6.9	5.3	0.9	139	0.106	0.9	0.4	3.5	483	ND	ND	24	4
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	2.00	8.7	6.1	0.7	133	0.102	0.7	0.4	3.6	497	ND	ND	26	ND
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	0.17	8.8	2.5	69.7	128	0.142	13.7	1.2	2.4	365	ND	ND	ND	8
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	ND	10.1	4.7	5.7	13	0.177	6.3	1.9	4.5	199	ND	ND	33	ND
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	54	ND
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	ND	8.4	2.8	3.7	9	0.107	3.9	1.3	2.6	140	ND	ND	36	ND
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	3.53	8.4	5.9	1.7	164	0.141	1.5	0.7	4.0	672	ND	ND	86	ND
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	0.04	6.7	0.5	42.8	80	0.203	4.2	0.6	2.6	164	ND	ND	ND	30
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	1.61	7.5	9.3	1.3	78	0.346	1.4	0.2	1.5	582	ND	ND	ND	ND
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	0.06	8.7	6.0	3.6	8	0.201	3.7	1.3	2.1	200	ND	ND	5	6
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	0.21	19.6	2.2	17.2	261	0.272	5.3	1.0	4.3	165	24	201	54	ND
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	0.27	24.4	2.6	18.9	255	0.286	6.2	1.1	4.3	187	62	360	68	ND
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	0.34	15.9	1.5	12.1	180	0.228	3.5	0.9	3.4	127	52	234	62	ND
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	6.58	10.4	15.0	1.6	465	0.526	2.7	0.8	5.4	1578	ND	ND	54	ND
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	4.29	8.1	6.4	0.9	246	0.289	1.0	0.4	7.3	658	ND	ND	41	ND
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	ND	14.6	7.2	4.8	13	0.268	6.2	3.1	2.2	341	ND	ND	24	ND
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	7.49	6.7	10.4	2.0	437	0.258	2.3	0.9	8.1	958	ND	ND	28	ND
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	5.78	7.0	15.9	2.4	311	0.462	3.3	1.2	5.5	1234	ND	ND	6	ND
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	ND	14.1	5.8	3.9	11	0.309	5.4	2.8	4.7	264	ND	ND	41	ND
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	0.09	10.2	5.5	2.7	11	0.189	3.8	2.9	4.5	211	ND	ND	34	ND
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	0.17	7.4	4.2	2.1	11	0.220	3.7	2.4	4.1	238	12	ND	111	ND
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	0.19	11.5	5.1	2.5	10	0.243	3.9	2.5	3.3	249	8	ND	56	ND
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	0.14	15.1	6.2	3.5	9	0.302	5.2	2.6	2.5	275	ND	ND	14	ND
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	0.07	7.4	7.1	3.2	8	0.228	6.5	2.8	2.5	292	ND	ND	5	ND
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	16.70	7.8	12.3	0.8	428	0.574	1.5	0.7	5.5	1341	ND	ND	ND	ND
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	0.18	12.0	1.6	16.1	151	0.180	2.0	0.6	2.6	162	ND	201	ND	ND
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	1.62	8.3	11.3	0.6	113	0.308	0.9	0.6	1.8	958	ND	ND	ND	ND
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	0.05	10.2	4.8	1.0	5	0.139	1.5	1.2	2.3	160	ND	ND	2	ND

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas* , MCAL—*Mytilus californianus* * Tins are reported in terms of total tins.

Table 19. PAH concentrations in bivalve tissues, 1997. HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs, NA = not analyzed, ND = not detected, NS = not sampled, Q = data point outside data quality objective, r = surrogate interference. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For MDLs refer to Table 4 in *Appendix B.*

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Sum of PAHs (SFEI)	Sum of LPAHs (SFEI)	Biphenyl	Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	2,6-Dimethylnaphthalene	2,3,5-Trimethylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Dibenzothiophene	Fluorene	Phenanthrene	1-Methylphenanthrene
					%	%	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	164	46	ND	12	ND	10	ND	ND	ND	ND	ND	ND	ND	24	ND
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	150	43	ND	14	ND	10	ND	ND	ND	ND	ND	ND	ND	20	ND
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	242	52	ND	19	ND	7	ND	ND	ND	ND	ND	ND	ND	26	ND
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	382	50	ND	11	ND	6	3	ND	ND	ND	ND	ND	ND	29	ND
BD40	Davis Point	NS	13	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	284	49	ND	12	ND	5	ND	ND	ND	ND	ND	2	6	24	ND
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	185	25	ND	6	ND	3	ND	ND	ND	ND	ND	ND	ND	16	ND
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	263	79	ND	33	7	13	3	ND	ND	ND	ND	ND	ND	24	ND
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	89	33	ND	8	5	5	ND	ND	ND	ND	ND	ND	ND	16	ND
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	90	30	ND	7	ND	7	ND	ND	ND	ND	ND	ND	ND	16	ND
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	51	19	ND	5	ND	4	ND	ND	ND	ND	ND	ND	ND	10	ND
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	447	32	ND	7	ND	3	ND	ND	ND	ND	ND	ND	ND	21	ND
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	187	162	7	32	10	24	7	9	ND	ND	ND	ND	18	55	ND
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	88	34	ND	12	ND	6	ND	ND	ND	ND	ND	ND	ND	16	ND
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	45	42	ND	16	5	12	ND	ND	ND	ND	ND	ND	ND	10	ND
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	433 r	154 r	Q	29 r	17 r	31 r	9 r	Q	Q	Q	18 r	Q	6 r	32 r	12 r
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	80	39	ND	12	5	10	2	ND	ND	ND	ND	ND	ND	8	ND
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	689	453	ND	172	77	134	22	ND	ND	ND	ND	ND	ND	37	11
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	373	81	ND	26	11	21	4	ND	ND	ND	ND	ND	ND	19	ND
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	260	106	ND	46	12	24	5	ND	ND	ND	ND	ND	ND	18	ND
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	108	59	ND	22	7	13	3	ND	ND	ND	ND	ND	ND	14	ND
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	336	40	ND	14	4	8	2	ND	ND	ND	ND	ND	ND	12	ND
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	247	24	ND	9	ND	7	ND	ND	ND	ND	ND	ND	ND	8	ND
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	221	79	2	23	9	16	6	ND	ND	ND	ND	ND	ND	24	ND
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	315	180	4	43	15	30	7	3	5	ND	10	ND	6	47	10
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	234	75	ND	7	ND	7	2	ND	5	ND	8	ND	4	42	ND
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	252	114	4	35	11	20	4	ND	4	ND	8	ND	4	25	ND
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	89	27	ND	9	ND	7	ND	ND	ND	ND	ND	ND	ND	11	ND
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	173	86	3	31	9	19	4	ND	ND	ND	ND	ND	ND	19	ND
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	343	30	ND	10	ND	7	ND	ND	ND	ND	ND	ND	ND	13	ND
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	81	71	ND	23	8	13	4	ND	ND	ND	ND	ND	ND	22	ND
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	76	41	ND	10	8	8	ND	ND	9	ND	ND	ND	ND	8	ND
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	28	23	ND	8	3	7	ND	ND	ND	ND	ND	ND	ND	5	ND

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 19. PAH concentrations in bivalve tissues, 1997 (continued). HPAH = high molecular weight PAHs, LPAH = low molecular weight PAHs, NA = not analyzed, ND = not detected, NS = not sampled, Q = data point ouside data quality objective, r = surrogate interference. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For MDLs refer to Table 4 in *Appendix B.*

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Sum of PAHs (SFEI)	Sum of HPAHs (SFEI)	Benz(a)anthracene	Chrysene	Fluoranthene	Pyrene	Benzo(a)pyrene	Benzo(e)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Dibenz(a,h)anthracene	Perylene	Benzo(ghi)perylene	Indeno(1,2,3-cd)pyrene
					%	%	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	164	118	11	12	55	40	ND	ND	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	150	107	11	13	43	39	ND	ND	ND	ND	ND	ND	ND	ND
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	242	190	16	16	73	73	ND	12	ND	ND	ND	ND	ND	ND
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	382	333	18	25	105	102	ND	31	25	ND	ND	ND	7	18
BD40	Davis Point	NS	13	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	284	235	9	10	84	93	ND	18	17	ND	ND	ND	4	ND
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	185	160	6	15	41	45	ND	16	14	ND	ND	ND	4	18
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	263	184	12	11	63	60	ND	16	14	ND	ND	ND	8	ND
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	89	56	7	10	11	15	ND	ND	8	ND	ND	ND	5	ND
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	90	60	21	ND	22	10	ND	ND	7	ND	ND	ND	ND	ND
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	51	32	ND	ND	11	9	ND	ND	ND	ND	ND	ND	5	7
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	447	415	32	44	68	91	15	61	59	16	ND	ND	19	10
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	187	25	ND	ND	19	7	ND	ND	ND	ND	ND	ND	ND	ND
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	88	55	ND	ND	31	24	ND	ND	ND	ND	ND	ND	ND	ND
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	45	3	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	433 q	279 r	9 r	20 r	88 r	118 r	5 r	15 r	14 r	5 r	Q	6 r	Q	Q
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	80	41	5	ND	15	21	ND	ND	ND	ND	ND	ND	ND	ND
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	689	235	16	22	82	73	ND	25	18	ND	ND	ND	ND	ND
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	373	293	17	21	75	72	ND	28	35	14	ND	19	12	ND
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	260	155	12	ND	56	46	ND	17	23	ND	ND	ND	ND	ND
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	108	49	5	9	15	8	ND	ND	7	ND	ND	ND	5	ND
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	336	296	17	20	55	45	16	38	50	21	ND	18	11	6
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	247	223	8	7	35	51	16	28	32	12	ND	14	12	8
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	221	142	13	19	33	19	9	7	17	9	ND	ND	10	7
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	315	135	10	11	47	22	10	5	10	7	ND	ND	7	5
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	234	160	15	13	69	24	ND	7	13	6	ND	ND	8	6
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	252	138	8	12	28	22	11	8	15	8	7	ND	11	7
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	89	62	5	5	15	11	ND	6	10	ND	ND	ND	6	5
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	173	87	7	10	19	16	ND	8	12	ND	ND	ND	8	7
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	343	313	11	15	51	68	21	43	48	18	ND	ND	26	12
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	81	10	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	76	35	ND	6	13	13	ND	3	ND	ND	ND	ND	ND	ND
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	28	5	ND	ND	3	2	ND	ND	ND	ND	ND	ND	ND	ND

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 20. PCB concentrations in bivalve tissues, 1997. . = no data, NA = not analyzed, ND = not detected, NS = not sampled. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For MDLs refer to Table 4 in *Appendix B.*

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Sum of PCBs (SFEI)	PCB 008	PCB 018	PCB 028	PCB 031	PCB 033	PCB 044	PCB 049	PCB 052	PCB 056/060	PCB 060	PCB 066	PCB 070	PCB 074	PCB 087	PCB 095	PCB 097	PCB 099	PCB 101	PCB 105	PCB 110
					%	%	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	64	2.9	4.7	.	.	.	4.6	3.0	4.0	1.4	.	1.4	1.7	0.7	1.3	4.9	2.9	2.9	.	1.0	4.8
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	63	2.3	3.9	.	.	.	5.0	3.2	3.1	ND	.	2.0	1.1	ND	1.1	4.8	3.3	3.4	.	ND	4.5
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	96	3.9	9.4	.	.	.	5.8	3.4	4.9	1.4	.	2.0	2.6	1.9	1.8	7.9	3.9	5.4	.	1.4	8.2
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	275	2.7	6.6	.	.	.	13.7	18.8	22.2	11.8	.	13.6	23.1	12.6	10.1	16.8	9.2	16.6	.	6.9	25.6
BD40	Davis Point	NS	13	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	62	1.0	1.0	.	.	.	2.1	2.6	3.3	0.8	.	1.1	1.7	0.9	1.7	4.6	1.7	4.2	.	0.9	6.2
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	53	1.1	1.2	.	.	.	1.6	1.5	2.3	0.9	.	1.3	1.3	0.9	1.6	3.9	1.8	3.7	.	0.8	5.2
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	95	2.3	2.5	.	.	.	4.0	2.4	4.0	1.4	.	1.8	2.3	1.0	1.4	7.4	4.5	6.3	.	1.9	9.1
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	26	1.1	1.2	.	.	.	1.9	1.2	1.3	1.6	.	0.6	0.9	ND	1.0	1.7	0.7	1.6	.	ND	2.5
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	60	1.5	1.6	.	.	.	3.2	2.4	3.1	1.1	.	1.2	3.6	0.8	2.5	3.9	2.1	3.4	.	1.0	5.6
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	44	1.0	1.0	.	.	.	1.3	1.6	2.3	0.6	.	0.8	1.4	0.7	1.5	3.1	1.8	2.9	.	0.8	5.0
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	159	ND	2.1	.	.	.	3.6	4.8	6.8	2.6	.	2.8	5.1	2.3	5.2	12.0	5.1	12.3	.	2.4	16.7
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	35	6.0	5.2	.	.	.	3.4	1.3	2.0	ND	.	1.0	1.2	0.6	ND	3.2	ND	1.7	.	ND	2.4
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	8	ND	1.4	.	.	.	0.7	0.8	1.2	ND	.	ND	ND	ND	ND	ND	ND	0.7	.	ND	0.9
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	12	1.4	1.8	.	.	.	0.7	0.6	0.9	ND	.	ND	0.6	ND	ND	ND	ND	0.6	.	ND	0.8
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	93	2.7	.	.	.	.	5.5	1.8	2.8	1.0	.	1.0	1.4	0.9	1.4	8.0	4.7	4.1	.	1.6	6.5
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	38	1.8	.	.	.	.	2.0	1.1	1.4	0.4	.	0.4	0.6	0.4	ND	2.4	1.5	1.4	.	0.8	2.0
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	132	12.2	.	.	.	.	10.2	4.1	6.6	1.7	.	2.1	1.9	1.5	2.2	8.0	6.5	5.9	.	2.6	8.6
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	37	2.9	.	.	.	.	1.3	1.5	1.8	0.4	.	ND	0.8	0.6	0.8	1.8	1.2	2.3	.	ND	3.4
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	47	6.1	.	.	.	.	1.9	2.1	2.6	0.8	.	0.7	1.0	0.9	ND	1.6	1.2	2.4	.	1.0	3.1
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	41	2.6	.	.	.	.	1.1	1.2	1.5	0.7	.	1.0	1.1	0.8	1.1	2.1	1.6	2.7	.	0.6	3.9
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	97	3.3	.	.	.	.	1.7	2.3	2.8	1.4	.	2.1	2.6	1.7	2.4	6.3	3.2	8.0	.	1.6	9.6
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	37	4.4	.	.	.	.	1.4	1.8	2.2	0.4	.	0.5	0.6	0.6	0.6	1.2	1.0	2.0	.	ND	2.5
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	78	5.3	.	.	.	.	2.1	2.6	3.0	1.8	.	1.9	2.9	1.8	2.1	4.7	3.2	5.4	.	1.3	6.9
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	95	5.0	.	.	.	.	4.1	3.5	6.4	2.0	.	3.0	5.4	1.9	3.8	7.2	3.6	5.3	.	1.7	8.8
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	73	1.2	.	.	.	.	1.8	2.5	3.2	1.1	.	1.4	1.6	1.3	2.4	4.2	2.5	5.5	.	2.0	7.5
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	104	5.0	.	.	.	.	2.3	3.6	3.8	0.9	.	1.6	1.7	1.1	2.7	4.7	3.0	6.8	.	1.9	8.4
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	43	1.2	.	.	.	.	0.7	1.1	1.2	0.4	.	0.7	0.7	0.5	0.9	1.5	1.2	3.4	.	1.1	3.6
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	69	3.6	.	.	.	.	1.8	2.6	2.8	0.8	.	1.0	1.3	0.8	1.7	2.3	2.2	4.9	.	1.6	5.4
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	59	1.8	.	.	.	.	1.1	1.5	1.9	0.7	.	0.9	1.3	0.8	1.4	2.8	1.7	4.7	.	1.1	5.4
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	86	7.4	.	.	.	.	8.1	2.8	4.7	1.4	.	1.5	1.8	1.1	1.5	7.4	5.2	4.1	.	1.6	5.7
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	10	ND	.	ND	ND	ND	ND	ND	1.3	.	ND	ND	ND	ND	.	ND	B	1.6	ND	ND	0.5
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	5	1.3	.	.	.	.	0.4	0.5	0.6	ND	.	ND	0.2	ND	ND	ND	ND	0.2	.	ND	0.3

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 20. PCB concentrations in bivalve tissues, 1997 (continued). . = no data, NA = not analyzed, ND = not detected, NS = not sampled. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For MDLs refer to Table 4 in *Appendix B*.d under station name heading. For method detection limits, refer to Table 4 in *Appendix B*.

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Sum of PCBs (SFEI)	PCB 118	PCB 128	PCB 132	PCB 138	PCB 141	PCB 149	PCB 151	PCB 153	PCB 156	PCB 158	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	PCB 201	PCB 203	Hexachlorobenzene
					%	%	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	64	5.2	ND	.	.	ND	6.9	2.6	.	ND	.	.	ND	1.0	1.8	1.0	2.9	ND	ND	ND	.	1.6
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	63	5.0	ND	.	.	ND	7.2	2.3	.	ND	.	.	1.5	1.7	2.8	1.3	3.6	ND	ND	ND	.	2.0
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	96	6.8	ND	.	.	ND	11.9	3.1	.	ND	.	.	ND	ND	3.1	2.4	5.2	ND	ND	ND	.	1.7
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	275	19.3	2.8	.	.	0.9	19.7	5.7	.	1.2	.	.	ND	2.5	2.8	2.8	6.8	ND	ND	ND	.	ND
BD40	Davis Point	NS	13	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	62	2.9	1.0	.	.	1.0	10.1	3.0	.	ND	.	.	0.4	1.9	2.7	1.2	4.3	ND	ND	ND	.	ND
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	53	2.4	ND	.	.	0.8	8.9	3.1	.	ND	.	.	ND	2.2	1.9	1.1	4.1	ND	ND	ND	.	ND
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	95	6.2	1.9	.	.	ND	14.9	4.2	.	ND	.	.	1.3	3.2	2.6	2.3	6.2	ND	ND	ND	.	ND
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	26	1.2	ND	.	.	ND	3.0	0.9	.	ND	.	.	ND	ND	0.9	0.8	1.8	ND	ND	ND	.	ND
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	60	3.1	0.9	.	.	ND	7.3	3.1	.	ND	.	.	1.3	1.3	1.7	1.6	3.1	ND	ND	ND	.	ND
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	44	2.5	0.7	.	.	ND	6.4	3.0	.	ND	.	.	ND	1.7	ND	1.4	2.7	ND	ND	ND	.	ND
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	159	9.3	1.9	.	.	1.7	28.0	8.3	.	ND	.	.	1.2	4.4	5.0	3.4	11.9	ND	ND	ND	.	ND
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	35	4.4	ND	.	.	ND	2.5	ND	.	ND	.	.	ND	ND	ND	ND	ND	ND	ND	ND	.	ND
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	8	0.6	ND	.	.	ND	0.9	0.6	.	ND	.	.	ND	ND	ND	ND	ND	ND	ND	ND	.	ND
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	12	0.8	ND	.	.	ND	1.1	2.9	.	ND	.	.	ND	ND	ND	ND	ND	ND	ND	ND	.	ND
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	93	9.2	1.8	.	.	ND	12.0	2.7	.	0.9	.	.	0.9	3.6	7.4	2.8	8.4	ND	ND	ND	.	ND
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	38	3.3	1.0	.	.	ND	4.7	1.2	.	0.4	.	.	0.6	2.2	2.9	1.3	3.8	ND	ND	ND	.	ND
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	132	11.5	2.7	.	.	ND	13.0	3.2	.	1.2	.	.	1.8	3.8	7.6	3.2	8.2	ND	ND	1.6	.	1.5
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	37	1.9	0.7	.	.	ND	6.0	1.6	.	ND	.	.	ND	1.8	1.1	1.2	3.9	ND	ND	ND	.	ND
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	47	2.3	1.3	.	.	ND	6.9	1.8	.	ND	.	.	ND	2.0	1.3	1.5	4.7	ND	ND	ND	.	ND
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	41	2.4	1.1	.	.	ND	5.7	2.1	.	ND	.	.	ND	1.1	1.2	1.6	2.9	ND	ND	0.6	.	ND
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	97	5.5	2.1	.	.	0.9	17.5	5.2	.	0.6	.	.	ND	4.5	2.3	1.9	7.9	ND	ND	ND	.	ND
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	37	1.6	0.9	.	.	ND	5.4	1.6	.	ND	.	.	ND	2.0	1.4	1.0	4.2	ND	ND	ND	.	ND
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	78	4.6	1.3	.	.	ND	10.1	3.3	.	ND	.	.	ND	2.7	2.9	3.4	4.6	ND	ND	ND	.	ND
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	95	4.6	1.7	.	.	ND	8.6	2.7	.	1.7	.	.	1.0	2.0	2.3	2.8	4.3	1.0	ND	0.7	.	ND
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	73	6.1	1.6	.	.	0.3	10.6	2.8	.	1.0	.	.	0.3	2.2	2.5	2.5	5.0	ND	ND	0.4	.	ND
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	104	6.3	3.0	.	.	0.6	15.8	4.9	.	1.3	.	.	ND	4.9	5.1	5.0	9.0	ND	ND	0.7	.	ND
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	43	3.7	1.4	.	.	ND	6.7	1.8	.	0.6	.	.	ND	2.0	1.9	1.9	4.6	ND	ND	ND	.	ND
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	69	4.9	2.8	.	.	ND	9.5	3.5	.	ND	.	.	ND	3.0	3.1	2.6	7.0	ND	ND	ND	.	ND
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	59	4.3	1.2	.	.	ND	10.9	2.8	.	ND	.	.	ND	2.8	1.2	1.5	7.2	ND	ND	ND	.	ND
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	86	8.5	1.5	.	.	ND	7.3	1.6	.	0.7	.	.	ND	2.6	5.0	1.6	3.5	ND	ND	ND	.	ND
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	10	ND	ND	1.3	0.8	ND	0.8	ND	2.5	.	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	ND
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	5	0.3	0.2	.	.	ND	0.4	0.7	.	ND	.	.	ND	ND	ND	ND	0.3	ND	ND	ND	.	ND

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 21. Pesticide concentrations in bivalve tissues, 1997. NA = not analyzed, ND = not detected, NS = not sampled. Units expressed as dry weight. T-0 = time of bivalve deployment into the Estuary from the source indicated under station name heading. For MDLs refer to Table 4 in *Appendix B.*

Station Code	Station	Date	Cruise	Species	Lipid	Moisture	Sum of DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Sum of Chlordanes (SFEI)	alpha-Chlordane	gamma-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane	Aldrin	Dieldrin	Endrin	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH	Mirex
					%	%	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
BG20	Sacramento River	5/9/97	13	CFLU	8.7	90.1	395	17.4	9.4	17.3	44.9	262.3	43.8	32	7.1	5.8	3.8	8.7	4.3	1.2	1.1	2.1	16.7	11.8	ND	ND	ND	ND	ND
BG30	San Joaquin River	5/9/97	13	CFLU	7.3	92.0	407	10.8	6.9	17.2	34.4	286.3	51.6	33	7.2	6.3	2.9	9.6	6.2	1.2	ND	3.6	12.5	18.9	ND	ND	ND	0.8	ND
BF20	Grizzly Bay	5/9/97	13	CFLU	17.4	94.5	943	44.9	20.7	38.5	116.0	636.9	86.1	77	18.8	14.7	8.3	22.9	8.2	2.2	1.7	2.8	26.6	14.9	ND	ND	ND	1.4	ND
BD50	Napa River	5/8/97	13	CGIG	14.5	89.5	229	23.1	5.4	11.0	55.4	134.3	0.2	33	8.6	7.4	2.4	9.5	2.5	1.8	1.2	1.3	14.2	9.3	ND	0.4	ND	0.7	ND
BD40	Davis Point	NS	13	--	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD30	Pinole Point	5/8/97	13	CGIG	13.1	79.7	161	18.1	4.0	6.8	41.9	75.7	14.9	22	6.0	5.0	2.1	5.8	1.3	1.3	0.9	0.8	9.6	4.1	ND	0.6	ND	ND	ND
BD20	San Pablo Bay	5/8/97	13	CGIG	12.2	80.4	164	17.4	3.9	7.8	43.9	75.7	15.2	21	5.8	4.8	1.6	5.8	1.5	1.3	0.6	0.9	10.3	7.3	ND	0.6	ND	ND	ND
BD15	Petaluma River	5/8/97	13	CFLU	9.3	87.4	273	18.3	6.4	11.3	49.1	162.4	25.8	33	8.7	6.9	2.7	10.1	2.2	1.3	1.2	1.1	8.5	2.1	ND	0.3	ND	ND	ND
BC61	Red Rock	5/8/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC21	Horseshoe Bay	5/9/97	13	MCAL	8.0	83.6	63	8.6	1.6	2.7	15.8	28.1	6.2	10	3.5	2.4	0.4	2.2	0.7	1.0	ND	0.5	11.0	6.2	ND	1.1	ND	ND	ND
BC10	Yerba Buena Island	5/7/97	13	MCAL	9.1	83.2	102	13.8	1.7	4.1	30.5	44.0	7.8	16	5.2	3.9	0.9	3.5	0.7	1.5	0.4	0.5	16.3	2.2	ND	0.6	ND	ND	ND
BB71	Alameda	5/7/97	13	MCAL	9.9	80.1	92	11.4	2.1	3.8	26.1	41.5	7.0	16	5.1	3.8	0.9	3.6	0.9	1.4	0.4	0.9	15.8	3.7	ND	0.8	ND	ND	ND
BA40	Redwood Creek	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA30	Dumbarton Bridge	5/7/97	13	MCAL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BA10	Coyote Creek	5/7/97	13	CGIG	15.0	85.5	249	24.2	4.2	ND	63.0	132.2	25.9	82	25.9	20.8	2.4	24.7	2.7	3.0	2.2	0.9	17.5	5.6	ND	0.8	ND	2.4	ND
T-0	Putah Creek	1/26/97	13	CFLU	10.7	88.5	365	3.4	6.5	10.6	11.7	294.7	38.0	29	6.1	5.5	2.7	6.3	5.9	1.9	0.9	2.9	5.3	16.1	ND	1.1	ND	ND	ND
T-0	Tomales Bay	1/26/97	13	CGIG	7.6	89.1	48	2.1	1.5	4.5	5.7	15.8	18.8	12	3.9	1.8	ND	2.0	3.1	ND	1.3	2.2	4.8	13.0	ND	0.6	ND	0.3	ND
T-0	Bodega Head	1/26/97	13	MCAL	5.9	82.6	15	0.8	0.6	ND	3.0	8.7	1.8	7	2.5	0.8	0.5	0.6	0.5	1.3	0.5	0.5	6.4	ND	1.4	1.1	ND	0.5	ND
BG20	Sacramento River	9/26/97	15	CFLU	7.1	95.9	269	15.3	4.8	13.1	42.3	182.4	11.1	29	4.8	4.7	7.0	12.5	ND	ND	ND	ND	11.5	ND	ND	ND	ND	ND	ND
BG30	San Joaquin River	9/26/97	15	CFLU	4.1	96.3	142	8.0	2.0	5.2	20.6	101.0	5.2	16	3.2	2.4	3.0	7.0	ND	ND	ND	ND	6.2	ND	ND	ND	ND	ND	ND
BF20	Grizzly Bay	9/23/97	15	CFLU	6.2	94.5	386	17.3	9.8	13.6	49.8	279.0	16.6	31	4.9	4.9	7.8	13.2	ND	ND	ND	ND	7.6	ND	ND	ND	ND	ND	ND
BD50	Napa River	9/23/97	15	CGIG	1.8	96.1	40	ND	ND	ND	15.1	24.4	ND	6	2.0	ND	1.8	2.6	ND	ND	ND	ND	1.8	ND	ND	ND	ND	ND	ND
BD40	Davis Point	9/23/97	15	CGIG	2.4	93.4	36	ND	ND	1.7	14.6	19.3	0.7	6	1.8	ND	1.7	2.6	ND	ND	ND	ND	1.8	2.5	ND	ND	ND	ND	ND
BD30	Pinole Point	9/25/97	15	MCAL	2.8	92.6	35	ND	ND	1.5	15.7	16.1	1.2	10	3.2	2.5	1.6	2.3	ND	ND	ND	ND	12.7	ND	ND	ND	ND	ND	ND
BD20	San Pablo Bay	9/25/97	15	CGIG	7.3	91.0	80	ND	1.7	3.3	35.4	39.9	ND	15	3.3	3.1	4.2	4.8	ND	ND	ND	ND	4.0	ND	ND	ND	ND	ND	ND
BD15	Petaluma River	9/25/97	15	CGIG	2.5	93.0	39	6.2	ND	ND	12.5	20.7	ND	7	1.7	1.6	1.9	2.2	ND	ND	ND	ND	1.5	ND	ND	ND	ND	ND	ND
BC61	Red Rock	9/25/97	15	MCAL	4.6	88.4	44	6.2	ND	1.1	19.7	17.2	ND	11	3.2	3.1	2.4	2.6	ND	ND	ND	ND	13.3	ND	ND	ND	ND	ND	ND
BC21	Horseshoe Bay	9/25/97	15	MCAL	6.1	84.7	30	4.7	0.6	0.7	12.8	10.9	ND	6	2.6	ND	1.2	1.8	ND	ND	ND	ND	8.8	ND	ND	0.5	ND	ND	ND
BC10	Yerba Buena Island	9/24/97	15	MCAL	4.7	89.5	43	5.5	1.9	1.4	17.6	16.4	ND	12	4.3	3.6	2.6	2.0	ND	ND	ND	ND	12.3	ND	ND	ND	ND	0.5	ND
BB71	Alameda	9/24/97	15	MCAL	4.4	85.6	38	5.5	0.7	1.1	14.1	17.0	ND	9	2.9	ND	2.6	3.3	ND	0.6	ND	ND	10.1	ND	ND	ND	ND	ND	ND
BA40	Redwood Creek	9/24/97	15	MCAL	1.9	90.9	17	2.8	ND	ND	4.9	9.8	ND	12	3.6	3.1	2.4	3.4	ND	ND	ND	ND	10.7	ND	ND	ND	ND	ND	ND
BA30	Dumbarton Bridge	9/24/97	15	MCAL	2.6	92.0	24	4.1	ND	ND	7.6	12.1	ND	15	3.8	3.4	2.8	4.9	ND	ND	ND	ND	10.1	ND	ND	ND	ND	ND	ND
BA10	Coyote Creek	9/24/97	15	CGIG	1.4	93.8	30	4.5	ND	ND	8.6	17.2	ND	12	2.6	ND	2.7	6.9	ND	ND	ND	ND	1.5	ND	ND	ND	ND	ND	ND
T-0	Putah Creek	6/24/97	15	CFLU	9.4	86.6	623	14.8	17.8	25.7	51.8	477.0	36.0	43	6.6	6.0	10.5	20.0	ND	ND	ND	2.8	4.9	ND	ND	ND	0.5	ND	ND
T-0	Tomales Bay	6/23/97	15	CGIG	11.3	91.4	15	ND	ND	ND	2.2	11.0	1.8	4	0.8	0.7	1.1	1.2	ND	ND	ND	ND	0.8	ND	ND	1.2	ND	0.4	ND
T-0	Bodega Head	6/23/97	15	MCAL	4.3	84.3	5	ND	ND	ND	0.7	4.2	ND	2	ND	1.1	0.5	ND	ND	0.7	ND	ND	8.0	ND	ND	1.4	ND	0.5	ND

CFLU—*Corbicula fluminea*, CGIG—*Crassostrea gigas*, MCAL—*Mytilus californianus*

Table 22. Mercury concentrations in fish tissue, 1997.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	Avg Length (cm)	% Moisture	Hg (µg/g wet)
6/12/97	Berkeley	Halibut	Off	1	75	75	73	0.195
6/13/97	Berkeley	Halibut	Off	1	79	79	71	0.335
6/13/97	Berkeley	Halibut	Off	1	60	60	73	0.294
6/17/97	Berkeley	Halibut	Off	1	73	73	73	0.194
3/28/97	San Pablo Bay	Halibut	Off	1	92	92	72	0.389
6/24/97	San Pablo Bay	Halibut	Off	1	59	59	71	0.209
7/23/97	San Pablo Bay	Halibut	Off	1	77	77	76	0.470
6/3/97	South Bay Bridges	Halibut	Off	1	55	55	73	0.251
6/12/97	Berkeley	Jacksmelt	On+	5	24-28.5	25	71	0.062
6/12/97	Berkeley	Jacksmelt	On+	5	24-27	26	70	0.069
6/12/97	Berkeley	Jacksmelt	On+	5	22-30	26	71	0.074
6/30/97	Oakland	Jacksmelt	On+	5	25-30	27	68	0.134
6/30/97	Oakland	Jacksmelt	On+	5	23-29	26	68	0.131
7/2/97	Oakland	Jacksmelt	On+	5	27-29	28	65	0.255
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	20.5-28.5	25	73	0.090
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	21-30	25	70	0.101
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	21-27	25	68	0.068
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-28	27	71	0.095
7/9/97	San Pablo Bay	Jacksmelt	On+	5	25-29	27	72	0.094
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-30	28	72	0.094
6/13/97	Berkeley	Leopard Shark	Off	3	91-93	92	75	0.881
6/13/97	Berkeley	Leopard Shark	Off	3	92-102	98	75	0.877
6/20/97	San Pablo Bay	Leopard Shark	Off	3	99-100	100	74	0.744
6/20/97	San Pablo Bay	Leopard Shark	Off	3	91.5-94	93	74	0.884
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	114	72	1.138
6/2/97	South Bay Bridges	Leopard Shark	Off	3	93-97	95	69	1.050
6/2/97	South Bay Bridges	Leopard Shark	Off	3	108-135	118	73	0.869
6/2/97	South Bay Bridges	Leopard Shark	Off	3	94-99	96	74	0.801
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-14.5	12	66	0.072
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-12.5	12	65	0.109
6/13/97	Berkeley	Shiner Surf Perch	On+	20	10.5-14.5	12	69	0.098
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14.5	12	64	0.151
6/5/97	Oakland	Shiner Surf Perch	On+	20	10.5-14.5	12	64	0.154
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14	12	67	0.192
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	66	0.136
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	65	0.111
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	10.5-13	12	67	0.084
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-14	12	69	0.082
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	10-15	12	68	0.116
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-12.5	12	65	0.119
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	13	73	0.126
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	10.5-14.5	12	65	0.086
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	12	68	0.105

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 22. (continued).

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	Avg Length (cm)	% Moisture	Hg (µg/g wet)
6/13/97	Berkeley	Striped Bass	Off	3	50-52	51	70	0.263
6/18/97	Berkeley	Striped Bass	Off	2	63,75	69	69	0.352
7/8/97	Davis Point	Striped Bass	Off	1	60	60	73	0.448
7/8/97	Davis Point	Striped Bass	Off	1	53	53	74	0.347
7/8/97	Davis Point	Striped Bass	Off	1	51	51	74	0.435
7/8/97	Davis Point	Striped Bass	Off	1	56	56	75	0.823
7/8/97	Davis Point	Striped Bass	Off	1	48	48	75	0.507
7/8/97	Davis Point	Striped Bass	Off	1	50	50	76	0.581
7/8/97	Davis Point	Striped Bass	Off	1	68	68	74	0.495
7/8/97	Davis Point	Striped Bass	Off	1	63	63	76	0.530
7/8/97	Davis Point	Striped Bass	Off	1	58	58	74	0.895
7/8/97	Davis Point	Striped Bass	Off	1	55	55	75	0.462
6/20/97	San Pablo Bay	Striped Bass	Off	3	50-52	51	71	0.424
6/20/97	San Pablo Bay	Striped Bass	Off	3	61-66	64	73	0.581
6/2/97	South Bay Bridges	Striped Bass	Off	1	45	45	78	0.360
6/2/97	South Bay Bridges	Striped Bass	Off	1	50	50	75	0.405
6/2/97	South Bay Bridges	Striped Bass	Off	1	49	49	76	0.390
6/2/97	South Bay Bridges	Striped Bass	Off	1	54	54	75	0.659
6/2/97	South Bay Bridges	Striped Bass	Off	1	62	62	73	0.385
6/3/97	South Bay Bridges	Striped Bass	Off	1	52	52	73	0.684
6/3/97	South Bay Bridges	Striped Bass	Off	1	48	48	75	0.321
6/6/97	South Bay Bridges	Striped Bass	Off	1	69	69	74	0.448
6/27/97	Suisun Bay	Striped Bass	Off	3	50-52	51	76	0.530
10/8/97	San Pablo Bay	Sturgeon	Off	3	117-128	124	72	0.291
10/8/97	San Pablo Bay	Sturgeon	Off	3	140-145	142	76	0.223
3/12/97	South Bay Bridges	Sturgeon	Off	3	119-124	121	79	0.243
3/12/97	South Bay Bridges	Sturgeon	Off	2	135,149	142	82	0.354
6/13/97	Berkeley	White Croaker	On	5	24-28	27	66	0.255
6/13/97	Berkeley	White Croaker	On	5	20-30	24	67	0.185
6/13/97	Berkeley	White Croaker	On	5	21-29	24	70	0.212
6/13/97	Berkeley	White Croaker	On	5	20-29	23	70	0.176
6/11/97	Oakland	White Croaker	On	5	20-28	25	68	0.162
7/2/97	Oakland	White Croaker	On	5	21-30	26	75	0.220
7/2/97	Oakland	White Croaker	On	5	21-27	24	67	0.170
7/11/97	Oakland	White Croaker	On	5	23-30	27	74	0.177
7/1/97	S.F. Waterfront	White Croaker	On	5	22-29	25	66	0.190
7/1/97	S.F. Waterfront	White Croaker	On	5	20-30	25	66	0.310
7/10/97	S.F. Waterfront	White Croaker	On	5	20-30	23	68	0.175
6/23/97	San Pablo Bay	White Croaker	On	5	23-29	26	66	0.239
6/26/97	San Pablo Bay	White Croaker	On	5	23-29	26	66	0.167
7/9/97	San Pablo Bay	White Croaker	On	5	22-30	27	71	0.344

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 23. Selenium concentrations in fish tissue, 1997.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	% Moisture	Se (µg/g)
6/25/97	San Pablo Bay	Sturgeon	Off	1	120.5	78	0.98
10/8/97	San Pablo Bay	Sturgeon	Off	1	140	75	1.90
10/8/97	San Pablo Bay	Sturgeon	Off	1	145	75	0.81
10/8/97	San Pablo Bay	Sturgeon	Off	1	117	75	1.25
10/8/97	San Pablo Bay	Sturgeon	Off	1	141	75	0.82
10/8/97	San Pablo Bay	Sturgeon	Off	1	127	76	0.85
10/15/97	San Pablo Bay	Sturgeon	Off	1	128	77	3.71
3/12/97	South Bay Bridges	Sturgeon	Off	1	117	78	1.87
3/12/97	South Bay Bridges	Sturgeon	Off	1	135	74	1.17
3/12/97	South Bay Bridges	Sturgeon	Off	1	121	80	0.92
3/13/97	South Bay Bridges	Sturgeon	Off	1	119	78	0.70
3/13/97	South Bay Bridges	Sturgeon	Off	1	124	75	1.11
6/4/97	South Bay Bridges	Sturgeon	Off	1	149	80	0.53

Off—Skin off muscle

Table 24. PCB concentrations (ng/g wet) in fish tissue, 1997.
ND = not detected. Aroclor concentrations were estimated from the congener data.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	Avg Length (cm)	% Moisture	% Lipid	Total Aroclors (SFEI)	Aroclor 1248	Aroclor 1254	Aroclor 1260	Sum of PCB Congeners (SFEI)	PCB 005	PCB 008	PCB 018	PCB 027	PCB 028	PCB 029	PCB 031	PCB 033
6/12/97	Berkeley	Halibut	Off	1	75	75	74	0.4	13	ND	ND	13	12	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	79	79	76	0.5	14	ND	14	ND	12	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	60	60	74	0.3	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	73	75	0.3	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	92	77	0.3	ND	ND	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	59	73	0.4	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	77	77	0.2	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	55	74	0.5	59	ND	36	23	34	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	24-28.5	25	74	1.6	24	ND	24	ND	21	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	24-27	26	75	3.2	19	ND	19	ND	14	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	22-30	26	76	3.2	32	ND	32	ND	22	ND	ND	ND	ND	ND	ND	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	25-30	27	82	1.4	211	35	150	26	137	ND	ND	0.4	ND	1.2	ND	1.8	ND
6/30/97	Oakland	Jacksmelt	On+	5	23-29	26	78	1.9	157	ND	130	27	112	ND	ND	0.4	ND	0.6	ND	0.9	ND
7/2/97	Oakland	Jacksmelt	On+	5	27-29	28	69	3.4	327	44	230	53	211	ND	ND	0.6	ND	1.7	ND	2.1	0.4
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	20.5-28.5	25	75	1.8	21	ND	21	ND	20	ND	ND	ND	ND	ND	ND	ND	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	21-30	25	74	1.5	46	ND	20	26	33	ND	ND	ND	ND	ND	ND	ND	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	21-27	25	75	2.5	35	ND	18	17	24	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-28	27	75	1.5	58	ND	37	21	36	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	25-29	27	71	1.4	76	ND	55	21	46	ND	ND	ND	ND	ND	ND	0.3	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-30	28	74	2.4	44	ND	26	18	27	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	91-93	92	76	0.2	16	ND	16	ND	9	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	92-102	98	75	0.2	13	ND	13	ND	8	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	99-100	100	75	0.3	ND	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	91.5-94	93	76	0.3	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	114	78	0.3	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	93-97	95	76	0.2	23	ND	23	ND	12	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	108-135	118	77	0.6	45	ND	28	17	19	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	94-99	96	77	0.1	12	ND	12	ND	6	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-14.5	12	71	3.9	179	ND	130	49	110	ND	ND	ND	ND	0.3	ND	0.5	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-12.5	12	77	2.6	139	ND	88	51	91	ND	ND	ND	ND	0.3	ND	0.5	ND
6/13/97	Berkeley	Shiner Surf Perch	On+	20	10.5-14.5	12	77	2.1	139	ND	83	56	96	ND	ND	ND	ND	0.3	ND	0.5	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14.5	12	77	2.5	590	ND	480	110	423	ND	ND	0.3	ND	1.5	ND	1.4	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	10.5-14.5	12	77	2.9	820	ND	680	140	515	ND	ND	0.3	ND	1.4	ND	2.2	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14	12	78	1.9	801	31	600	170	486	ND	ND	ND	ND	1.3	ND	2.2	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	77	2.0	201	ND	140	61	131	ND	ND	ND	ND	0.4	ND	0.8	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	76	3.0	239	ND	180	59	152	ND	ND	ND	ND	0.4	ND	0.6	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	10.5-13	12	78	1.7	295	22	210	63	184	ND	ND	ND	ND	0.4	ND	1.9	ND
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-14	12	78	2.6	128	ND	99	29	77	ND	ND	ND	ND	ND	ND	0.4	ND
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	10-15	12	76	2.4	98	ND	74	24	58	ND	ND	ND	ND	ND	ND	0.3	ND
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-12.5	12	76	1.5	75	ND	51	24	45	ND	ND	ND	ND	ND	ND	0.3	ND
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	13	68	4.0	276	ND	180	96	172	ND	ND	ND	ND	0.3	ND	0.6	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	10.5-14.5	12	79	1.9	121	ND	73	48	81	ND	ND	ND	ND	0.3	ND	0.2	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	12	79	2.6	157	ND	110	47	111	ND	ND	ND	ND	0.4	ND	0.7	ND
6/13/97	Berkeley	Striped Bass	Off	3	50-52	51	73	4.1	48	ND	30	18	33	ND	ND	ND	ND	ND	ND	ND	ND
6/18/97	Berkeley	Striped Bass	Off	2	63,75	69	72	1.6	43	ND	25	18	28	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	50-53	51	77	0.5	47	ND	30	17	29	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	60-68	64	75	0.8	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	48-56	53	77	0.8	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	50-52	51	75	1.0	19	ND	19	ND	21	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	61-66	64	77	0.8	40	ND	25	15	23	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	3	49-52	50	78	0.5	34	ND	19	15	22	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	2	62,69	66	75	0.5	34	ND	18	16	22	ND	ND	ND	ND	ND	ND	ND	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	50-52	51	78	0.6	17	ND	17	ND	14	ND	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	117-128	124	74	1.3	33	ND	33	ND	33	ND	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	140-145	142	77	1.3	32	ND	32	ND	28	ND	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	3	119-124	121	79	0.6	ND	ND	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	135,149	142	75	1.5	46	ND	32	14	31	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	24-28	27	70	6.4	330	ND	200	130	220	ND	ND	ND	ND	0.6	ND	1.1	ND
6/13/97	Berkeley	White Croaker	On	5	20-30	24	72	7.4	260	ND	190	70	162	ND	ND	ND	ND	0.3	ND	0.7	ND
6/13/97	Berkeley	White Croaker	On	5	21-29	24	72	6.1	250	ND	180	70	164	ND	ND	ND	ND	0.6	ND	0.5	ND
6/13/97	Berkeley	White Croaker	On	5	20-29	23	68	5.4	203	ND	120	83	141	ND	ND	ND	ND	0.4	ND	0.4	ND
6/11/97	Oakland	White Croaker	On	5	20-28	25	70	7.5	559	49	370	140	364	ND	ND	0.6	ND	2.0	0.8	2.6	0.5
7/2/97	Oakland	White Croaker	On	5	21-30	26	68	7.3	867	57	570	240	589	ND	ND	0.8	ND	2.8	ND	2.8	0.5
7/2/97	Oakland	White Croaker	On	5	21-27	24	69	7.7	387	47	230	110	265	ND	ND	0.9	ND	1.7	ND	2.3	0.4
7/11/97	Oakland	White Croaker	On	5	23-30	27	72	6.8	512	62	310	140	338	ND	ND	1.0	ND	2.7	ND	2.9	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	22-29	25	70	7.3	433	33	290	110	268	ND	ND	0.4	ND	0.8	ND	2.5	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	20-30	25	70	7.6	371	51	190	130	253	ND	ND	0.4	ND	1.1	ND	4.5	0.3
7/10/97	S.F. Waterfront	White Croaker	On	5	20-30	23	73	5.2	232	ND	150	82	153	ND	ND	ND	ND	0.6	ND	0.5	ND
6/23/97	San Pablo Bay	White Croaker	On	5	23-29	26	69	9.3	281	ND	200	81	182	ND	ND	ND	ND	0.4	ND	0.8	ND
6/26/97	San Pablo Bay	White Croaker	On	5	23-29	26	66	6.4	161	ND	100	61	115	ND	ND	ND	ND	0.3	ND	0.7	ND
7/9/97	San Pablo Bay	White Croaker	On	5	22-30	27	73	3.3	200	ND	100	100	145	ND	ND	ND	ND	0.4	ND	0.4	ND
6/13/97	Berkeley	White Croaker	Off	5	24-28	NA	69	4.7	156	ND	98	58	108	ND	ND	ND	ND	ND	ND	ND	ND
6/11/97	Oakland	White Croaker	Off	5	20-28	NA	65	5.5	499	39	340	120	312	ND	ND	0.4	ND	1.6	ND	2.0	0.5
7/1/97	S.F. Waterfront	White Croaker	Off	5	22-29	25	72	5.3	237	ND	180	57	158	ND	ND	ND	ND	0.5	ND	1.5	ND
6/23/97	San Pablo Bay	White Croaker	Off	5	23-29	NA	67	4.7	150	ND	110	40	100	ND	ND	ND	ND	ND	ND	0.4	ND

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 24. PCB concentrations (ng/g wet) in fish tissue, 1997 (continued).
ND = not detected. Aroclor concentrations were estimated from the congener data.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Avg Length (cm)	% Lipid	Sum of PCB Congeners (SFEI)	PCB 044	PCB 049	PCB 052	PCB 056/60	PCB 066	PCB 070	PCB 074	PCB 087	PCB 095	PCB 097	PCB 099	PCB 101	PCB 105
6/12/97	Berkeley	Halibut	Off	1	75	0.4	12	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	0.5	0.9	ND
6/13/97	Berkeley	Halibut	Off	1	79	0.5	12	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	0.6	1.1	ND
6/13/97	Berkeley	Halibut	Off	1	60	0.3	7	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	0.4	0.6	ND
6/17/97	Berkeley	Halibut	Off	1	73	0.3	12	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	0.6	1.0	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	0.3	8	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	0.3	0.7	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	0.4	7	ND	ND	0.3	ND	ND	ND	ND	ND	0.3	ND	0.4	0.6	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	0.2	11	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	0.5	0.9	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	0.5	34	ND	ND	0.7	ND	ND	ND	ND	0.3	1.1	ND	1.4	2.4	0.4
6/12/97	Berkeley	Jacksmelt	On+	5	25	1.6	21	0.3	0.3	2.6	ND	0.6	0.4	0.3	0.5	0.9	0.3	1.0	1.7	0.4
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	14	ND	ND	0.4	0.5	0.3	ND	ND	0.3	0.6	ND	0.7	1.2	0.3
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	22	ND	ND	0.6	0.6	0.4	ND	ND	0.4	0.6	0.3	1.0	1.6	0.4
6/30/97	Oakland	Jacksmelt	On+	5	27	1.4	137	1.9	1.8	6.1	1.6	3.9	2.4	1.8	3.0	5.6	2.4	6.4	11.9	2.6
6/30/97	Oakland	Jacksmelt	On+	5	26	1.9	112	1.1	1.0	4.0	0.8	2.4	1.2	1.2	2.3	3.8	1.7	5.2	9.7	2.5
7/2/97	Oakland	Jacksmelt	On+	5	28	3.4	211	2.4	2.5	7.3	2.3	4.4	3.0	2.0	3.9	8.5	3.1	10.2	18.1	4.0
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.8	20	ND	ND	2.1	0.5	0.4	ND	ND	0.3	0.7	ND	1.0	1.3	0.3
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.5	33	ND	0.3	0.6	ND	0.3	0.3	ND	0.3	1.1	ND	1.1	2.1	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	25	2.5	24	ND	0.3	0.6	ND	0.4	0.3	ND	0.3	0.9	0.3	1.0	1.8	0.3
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.5	36	0.3	0.3	2.4	ND	0.5	0.3	0.2	0.5	1.3	0.4	1.6	2.3	0.5
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.4	46	0.3	0.3	0.9	0.5	0.9	0.7	0.4	0.7	1.4	0.5	2.0	3.1	0.7
7/9/97	San Pablo Bay	Jacksmelt	On+	5	28	2.4	27	ND	ND	1.7	0.6	0.3	ND	ND	0.5	0.9	0.3	1.1	1.7	0.3
6/13/97	Berkeley	Leopard Shark	Off	3	92	0.2	9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	98	0.2	8	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	100	0.3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	93	0.3	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	0.3	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	95	0.2	12	ND	ND	0.8	ND	0.3	ND	ND	ND	ND	ND	1.0	ND	0.2
6/2/97	South Bay Bridges	Leopard Shark	Off	3	118	0.6	19	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	1.4	ND	0.3
6/2/97	South Bay Bridges	Leopard Shark	Off	3	96	0.1	6	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	0.6	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	3.9	110	0.5	0.7	1.9	2.3	0.9	1.3	0.8	1.2	2.5	0.6	4.5	6.9	2.1
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	2.6	91	0.4	0.6	3.3	1.5	0.7	1.0	0.8	1.1	2.0	0.5	3.6	5.8	1.7
6/13/97	Berkeley	Shiner Surf Perch	On+	20	12	2.1	96	0.4	0.6	4.6	1.7	0.9	1.1	0.8	1.0	2.1	0.5	3.6	5.7	1.7
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.5	423	2.3	4.7	8.9	0.6	4.8	5.5	3.4	9.1	11.1	5.5	22.7	39.5	5.9
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.9	515	2.7	5.3	10.5	4.6	6.0	6.1	4.1	11.4	13.5	6.2	27.8	46.9	12.6
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	1.9	486	2.4	4.5	10.4	3.8	5.5	4.6	4.0	11.6	11.4	5.0	26.6	46.5	11.9
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	2.0	131	0.7	0.8	3.9	2.3	1.1	1.5	1.1	2.4	3.1	0.8	5.6	10.3	2.9
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	3.0	152	0.8	1.1	3.5	0.9	1.1	1.9	1.2	2.9	4.4	1.1	7.5	13.3	4.2
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	1.7	184	1.3	1.5	4.7	1.6	1.6	2.5	1.4	4.2	5.4	2.4	7.2	16.1	3.9
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.6	77	0.4	0.5	1.8	1.3	0.8	0.9	0.6	1.0	2.1	0.6	3.4	5.1	1.3
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.4	58	0.3	0.4	1.2	0.9	0.5	0.6	0.4	0.8	1.5	0.4	2.5	3.7	1.0
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	1.5	45	0.2	0.3	2.1	0.3	0.4	0.5	0.4	0.5	1.1	0.3	2.0	2.5	0.8
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	13	4.0	172	0.5	0.9	2.3	1.4	1.3	1.4	0.9	1.7	3.6	1.0	7.4	10.5	2.8
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	1.9	81	0.3	0.4	1.1	0.4	0.7	0.6	0.4	0.6	1.8	0.5	3.5	5.0	1.0
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	2.6	111	0.5	0.7	1.9	1.0	1.2	1.3	0.8	1.3	2.5	0.8	4.7	7.1	1.9
6/13/97	Berkeley	Striped Bass	Off	3	51	4.1	33	ND	0.3	1.1	ND	0.3	0.4	ND	0.4	1.6	0.3	1.4	2.4	ND
6/18/97	Berkeley	Striped Bass	Off	2	69	1.6	28	ND	0.3	1.0	ND	ND	ND	ND	0.3	1.3	ND	1.2	2.0	ND
7/8/97	Davis Point	Striped Bass	Off	3	51	0.5	29	ND	0.3	0.9	ND	0.3	ND	ND	0.4	1.2	0.2	1.1	1.8	0.4
7/8/97	Davis Point	Striped Bass	Off	3	64	0.8	7	ND	ND	ND	ND	ND	ND	ND	ND	0.5	ND	0.5	0.7	ND
7/8/97	Davis Point	Striped Bass	Off	3	53	0.8	11	ND	ND	0.5	ND	ND	ND	ND	ND	0.5	ND	0.5	1.0	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	51	1.0	21	ND	ND	1.2	ND	0.3	ND	ND	ND	0.7	ND	0.8	1.5	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	64	0.8	23	ND	ND	0.8	ND	ND	ND	ND	0.3	1.0	ND	1.0	1.6	0.2
6/2/97	South Bay Bridges	Striped Bass	Off	3	50	0.5	22	ND	ND	0.4	ND	ND	ND	ND	ND	0.6	ND	0.9	1.2	0.3
6/2/97	South Bay Bridges	Striped Bass	Off	2	66	0.5	22	ND	ND	0.6	ND	ND	ND	ND	ND	1.0	ND	0.9	1.6	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	51	0.6	14	ND	ND	0.7	ND	ND	ND	ND	ND	0.7	ND	0.6	0.9	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	124	1.3	33	ND	0.3	1.3	ND	ND	ND	ND	0.3	2.2	ND	1.4	2.2	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	142	1.3	28	ND	0.3	1.0	ND	ND	ND	ND	0.3	1.9	ND	1.1	1.8	0.3
3/12/97	South Bay Bridges	Sturgeon	Off	3	121	0.6	10	ND	ND	ND	ND	ND	ND	ND	ND	0.5	ND	0.5	0.6	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	142	1.5	31	ND	0.3	1.1	ND	0.3	ND	ND	0.4	1.9	ND	1.1	2.1	0.3
6/13/97	Berkeley	White Croaker	On	5	27	6.4	220	1.3	1.5	4.6	4.5	3.2	1.9	1.5	3.0	6.2	2.5	8.5	13.8	2.9
6/13/97	Berkeley	White Croaker	On	5	24	7.4	162	0.9	1.0	2.8	3.6	2.1	1.4	0.9	2.0	5.2	2.0	6.3	9.9	2.4
6/13/97	Berkeley	White Croaker	On	5	24	6.1	164	0.9	1.1	2.3	1.2	2.2	1.5	1.0	1.7	4.6	1.5	6.4	9.8	2.0
6/13/97	Berkeley	White Croaker	On	5	23	5.4	141	0.7	1.0	2.4	0.8	1.1	1.0	0.6	1.4	5.9	1.1	5.1	8.2	1.4
6/11/97	Oakland	White Croaker	On	5	25	7.5	364	3.8	3.8	7.7	3.9	6.1	4.5	2.8	6.1	13.0	5.8	15.0	25.0	7.0
7/2/97	Oakland	White Croaker	On	5	26	7.3	589	4.5	5.6	11.5	5.6	8.8	5.0	4.4	9.0	18.1	8.1	24.2	41.3	10.1
7/2/97	Oakland	White Croaker	On	5	24	7.7	265	2.8	3.0	7.6	2.7	5.9	3.1	2.7	5.0	9.0	3.7	10.5	19.1	4.7
7/11/97	Oakland	White Croaker	On	5	27	6.8	338	3.8	4.3	11.1	3.2	7.4	3.7	3.5	5.8	10.6	4.7	13.6	24.1	5.6
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.3	268	1.6	1.9	5.0	5.5	3.5	3.0	1.7	3.7	7.3	3.6	10.0	17.0	4.3
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.6	253	1.7	2.0	6.0	2.0	3.8	3.2	1.9	4.1	6.4	2.9	8.1	16.3	4.1
7/10/97	S.F. Waterfront	White Croaker	On	5	23	5.2	153	1.1	1.2	4.3	1.2	2.5	1.7	1.3	2.7	4.8	1.8	6.5	10.6	2.7
6/23/97	San Pablo Bay	White Croaker	On	5	26	9.3	182	1.0	1.1	3.3	4.0	2.3	1.6	0.9	2.2	5.6	1.8	6.9	10.6	2.5
6/26/97	San Pablo Bay	White Croaker	On	5	26	6.4	115	0.7	0.9	4.7	2.7	1.5	1.0	0.7	1.6	3.5	1.4	4.4	7.0	1.5
7/9/97	San Pablo Bay	White Croaker	On	5	27	3.3	145	0.9	1.0	2.1	0.7	1.7	1.0	0.9	1.3	3.6	1.2	5.3	7.8	1.7
6/13/97	Berkeley	White Croaker	Off	5	NA	4.7	108	0.7	0.8	6.4	0.8	1.6	0.8	0.8	1.5	2.7	1.2	4.1	6.5	1.6
6/11/97	Oakland	White Croaker	Off	5	NA	5.5	312	2.4	3.1	6.8	5.2	5.1	3.7	2.4	4.9	10.7	4.2	12.9	21.3	5.8
7/1/97	S.F. Waterfront	White Croaker	Off	5	25	5.3	158	0.9	1.1	3.1	3.7	2.1	1.8	1.0	2.2	4.8	1.9	6.1	10.3	2.6
6/23/97	San Pablo Bay	White Croaker	Off	5	NA	4.7	100	0.6	0.6	1.9	2.5	1.2	0.9	0.5	1.2	3.5	1.2	4.0	5.8	1.3

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 24. PCB concentrations (ng/g wet) in fish tissue, 1997 (continued).
ND = not detected. Aroclor concentrations were estimated from the congener data.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Avg Length (cm)	% Lipid	Sum of PCB Congeners (SFEI)	PCB 110	PCB 118	PCB 128	PCB 132	PCB 137	PCB 138	PCB 141	PCB 149	PCB 151	PCB 153	PCB 156	PCB 157	PCB 158
6/12/97	Berkeley	Halibut	Off	1	75	0.4	12	0.4	0.6	ND	ND	ND	1.7	ND	1.0	0.5	2.7	ND	ND	0.3
6/13/97	Berkeley	Halibut	Off	1	79	0.5	12	0.6	0.8	ND	ND	ND	2.2	ND	1.0	0.5	3.2	ND	ND	0.3
6/13/97	Berkeley	Halibut	Off	1	60	0.3	7	0.5	0.5	ND	ND	ND	1.4	ND	0.6	0.3	2.0	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	0.3	12	0.5	0.8	0.4	ND	ND	1.9	ND	0.9	0.4	2.6	ND	ND	0.3
3/28/97	San Pablo Bay	Halibut	Off	1	92	0.3	8	0.3	0.4	ND	ND	ND	1.1	ND	0.7	0.3	2.1	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	0.4	7	0.4	0.4	ND	ND	ND	1.1	ND	0.5	0.3	1.5	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	0.2	11	0.6	0.6	ND	ND	ND	1.5	ND	0.9	0.4	2.2	ND	ND	0.3
6/3/97	South Bay Bridges	Halibut	Off	1	55	0.5	34	1.5	2.1	0.7	0.4	ND	5.7	0.5	2.3	1.2	8.6	ND	ND	0.6
6/12/97	Berkeley	Jacksmelt	On+	5	25	1.6	21	1.2	1.4	0.4	0.4	ND	2.5	ND	1.4	0.6	3.6	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	14	0.8	1.0	0.3	0.3	ND	2.5	ND	1.2	0.4	3.2	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	22	1.0	1.7	0.4	0.4	ND	4.3	0.2	1.3	0.7	5.4	ND	ND	0.3
6/30/97	Oakland	Jacksmelt	On+	5	27	1.4	137	8.1	10.4	2.4	2.4	0.6	17.6	1.0	9.8	4.0	23.3	1.0	0.3	1.8
6/30/97	Oakland	Jacksmelt	On+	5	26	1.9	112	5.8	9.2	2.2	1.8	0.5	16.8	0.9	8.5	3.7	23.0	0.8	0.4	1.7
7/2/97	Oakland	Jacksmelt	On+	5	28	3.4	211	13.6	15.5	3.3	3.8	0.7	30.0	2.1	14.0	6.9	39.8	1.2	ND	3.1
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.8	20	0.9	1.3	0.3	0.3	ND	2.7	ND	1.3	0.5	4.3	ND	ND	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.5	33	1.2	1.3	0.4	0.7	ND	4.4	0.6	2.8	1.3	6.8	ND	ND	1.7
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	25	2.5	24	1.1	1.2	0.5	0.5	ND	2.9	0.4	1.9	0.8	4.1	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.5	36	1.8	1.9	0.8	0.7	ND	5.2	0.4	2.6	1.2	7.6	ND	ND	0.5
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.4	46	2.1	3.0	0.8	0.9	ND	8.5	0.4	2.7	1.5	10.3	0.3	ND	0.6
7/9/97	San Pablo Bay	Jacksmelt	On+	5	28	2.4	27	1.2	1.4	0.6	0.5	ND	3.8	0.3	1.8	0.9	5.8	ND	ND	0.4
6/13/97	Berkeley	Leopard Shark	Off	3	92	0.2	9	ND	0.7	0.3	ND	ND	2.6	ND	ND	ND	4.3	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	98	0.2	8	ND	0.8	ND	ND	ND	2.3	ND	ND	ND	4.0	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	100	0.3	3	ND	0.3	ND	ND	ND	1.0	ND	ND	ND	1.5	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	93	0.3	5	ND	0.5	ND	ND	ND	1.4	ND	ND	ND	2.5	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	0.3	4	ND	0.4	ND	ND	ND	1.0	ND	ND	ND	1.9	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	95	0.2	12	ND	1.2	0.3	ND	ND	3.2	ND	ND	ND	4.6	ND	ND	0.3
6/2/97	South Bay Bridges	Leopard Shark	Off	3	118	0.6	19	0.3	1.7	0.7	ND	ND	4.2	ND	ND	ND	7.4	0.3	ND	0.6
6/2/97	South Bay Bridges	Leopard Shark	Off	3	96	0.1	6	ND	0.6	ND	ND	ND	1.8	ND	ND	ND	2.9	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	3.9	110	4.5	6.7	1.8	1.4	0.4	20.9	1.6	4.6	4.0	22.1	1.3	ND	1.7
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	2.6	91	2.8	5.6	1.4	0.9	0.5	13.6	1.1	3.5	2.9	19.9	1.1	0.3	1.4
6/13/97	Berkeley	Shiner Surf Perch	On+	20	12	2.1	96	3.1	5.0	1.4	1.0	0.5	13.4	1.3	4.5	2.9	19.3	1.1	0.5	1.3
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.5	423	26.6	37.4	8.4	5.2	1.8	68.8	5.2	21.7	13.2	80.8	4.9	1.0	5.7
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.9	515	32.5	46.9	11.6	8.7	2.3	88.5	6.9	24.3	15.9	92.5	6.8	0.4	7.4
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	1.9	486	22.2	42.7	10.0	5.6	2.5	82.9	6.0	21.2	13.2	102.0	6.0	0.9	8.0
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	2.0	131	4.6	9.8	2.0	1.3	0.9	19.8	1.8	5.5	3.9	25.7	1.8	0.4	2.1
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	3.0	152	7.0	13.5	2.7	1.7	0.9	24.0	2.2	5.5	4.6	28.1	2.3	ND	2.5
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	1.7	184	12.1	13.0	2.6	3.1	0.9	30.6	3.2	8.0	5.2	32.8	2.4	ND	2.6
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.6	77	3.6	4.9	1.4	1.0	ND	14.9	1.1	3.3	2.7	14.1	0.7	ND	1.1
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.4	58	2.5	3.8	1.0	0.7	ND	11.8	0.6	2.3	2.0	12.0	0.6	ND	0.9
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	1.5	45	1.9	2.5	1.0	0.5	ND	7.1	0.5	2.2	1.6	10.3	0.6	ND	0.8
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	13	4.0	172	6.1	10.3	2.9	1.9	0.6	29.3	2.0	7.2	6.1	39.0	1.7	0.4	2.4
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	1.9	81	2.6	4.6	1.7	0.8	0.2	11.6	0.8	3.9	2.3	18.2	0.6	0.3	1.0
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	2.6	111	4.7	6.9	0.6	1.4	0.3	20.4	1.3	4.6	4.0	22.9	1.0	ND	1.5
6/13/97	Berkeley	Striped Bass	Off	3	51	4.1	33	1.4	2.1	0.9	ND	ND	5.0	0.6	2.6	1.1	7.6	ND	ND	0.5
6/18/97	Berkeley	Striped Bass	Off	2	69	1.6	28	1.2	1.7	0.6	ND	ND	4.3	0.5	2.2	0.9	6.4	ND	ND	0.4
7/8/97	Davis Point	Striped Bass	Off	3	51	0.5	29	1.5	1.6	0.6	0.5	ND	4.4	0.4	2.1	1.0	6.0	ND	ND	0.4
7/8/97	Davis Point	Striped Bass	Off	3	64	0.8	7	0.6	0.5	ND	ND	ND	1.3	ND	0.7	0.3	1.7	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	53	0.8	11	0.6	0.6	0.4	ND	ND	1.6	ND	1.1	0.4	2.5	ND	ND	0.3
6/20/97	San Pablo Bay	Striped Bass	Off	3	51	1.0	21	0.9	1.1	0.5	0.3	ND	2.9	0.2	1.6	0.7	4.3	ND	2.6	0.4
6/20/97	San Pablo Bay	Striped Bass	Off	3	64	0.8	23	1.2	1.4	0.5	0.4	ND	3.8	0.4	1.3	0.8	5.2	ND	ND	0.4
6/2/97	South Bay Bridges	Striped Bass	Off	3	50	0.5	22	0.9	1.2	0.6	0.3	ND	2.7	0.3	1.4	0.8	3.8	ND	2.6	0.2
6/2/97	South Bay Bridges	Striped Bass	Off	2	66	0.5	22	1.0	1.2	0.5	0.3	ND	3.2	0.3	1.8	0.8	4.7	ND	ND	0.3
6/27/97	Suisun Bay	Striped Bass	Off	3	51	0.6	14	0.8	0.9	0.2	0.3	ND	2.3	ND	1.1	0.5	3.3	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	124	1.3	33	1.5	1.0	ND	0.3	ND	6.2	0.3	3.5	1.6	8.0	ND	ND	0.6
10/8/97	San Pablo Bay	Sturgeon	Off	3	142	1.3	28	1.9	0.8	0.5	0.7	ND	5.0	0.3	2.7	1.3	5.8	ND	ND	0.4
3/12/97	South Bay Bridges	Sturgeon	Off	3	121	0.6	10	0.5	0.2	0.3	ND	ND	1.6	ND	1.1	0.4	2.2	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	142	1.5	31	1.8	0.9	0.5	0.7	ND	5.6	0.3	2.7	1.3	6.2	ND	ND	0.4
6/13/97	Berkeley	White Croaker	On	5	27	6.4	220	9.8	11.6	2.2	4.6	0.9	30.8	3.4	17.0	7.2	41.0	2.0	0.7	2.6
6/13/97	Berkeley	White Croaker	On	5	24	7.4	162	9.2	8.2	2.6	3.9	0.5	28.0	2.3	11.0	6.1	26.3	1.4	ND	2.0
6/13/97	Berkeley	White Croaker	On	5	24	6.1	164	8.7	8.7	2.8	3.3	0.4	26.2	2.2	11.8	5.9	28.9	1.0	0.4	1.9
6/13/97	Berkeley	White Croaker	On	5	23	5.4	141	6.3	7.2	1.5	2.6	0.4	21.1	2.6	10.9	4.6	25.9	1.1	1.0	1.9
6/11/97	Oakland	White Croaker	On	5	25	7.5	364	24.5	22.6	5.9	10.0	1.1	54.8	5.6	22.6	12.9	53.9	3.8	ND	4.2
7/2/97	Oakland	White Croaker	On	5	26	7.3	589	34.4	38.5	10.4	14.3	2.0	85.5	9.2	39.4	20.4	106.0	5.2	0.4	7.6
7/2/97	Oakland	White Croaker	On	5	24	7.7	265	13.8	15.6	4.8	5.4	1.1	33.0	4.0	20.5	7.7	41.8	2.2	0.7	3.1
7/11/97	Oakland	White Croaker	On	5	27	6.8	338	18.0	20.7	6.0	6.9	1.3	44.1	4.5	25.2	10.2	55.6	3.1	0.7	3.9
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.3	268	17.0	15.3	4.1	6.8	1.0	44.1	4.2	17.0	9.7	45.0	2.5	ND	3.9
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.6	253	12.2	12.8	4.1	4.4	1.0	30.7	4.0	18.8	6.2	40.0	2.2	0.4	3.0
7/10/97	S.F. Waterfront	White Croaker	On	5	23	5.2	153	7.7	8.8	3.0	3.0	0.7	19.0	2.5	11.6	4.8	24.1	1.6	0.6	1.9
6/23/97	San Pablo Bay	White Croaker	On	5	26	9.3	182	10.2	8.8	2.7	4.1	0.6	30.8	2.5	12.0	6.9	30.5	1.7	ND	2.2
6/26/97	San Pablo Bay	White Croaker	On	5	26	6.4	115	5.2	5.8	2.3	2.4	0.5	14.5	1.6	8.8	3.6	19.1	1.1	ND	1.3
7/9/97	San Pablo Bay	White Croaker	On	5	27	3.3	145	5.8	7.0	3.3	2.4	0.5	17.5	2.0	10.2	4.7	24.4	0.9	0.5	1.7
6/13/97	Berkeley	White Croaker	Off	5	NA	4.7	108	4.6	5.4	2.2	2.0	0.4	14.1	1.6	8.1	3.4	18.6	0.9	0.3	1.3
6/11/97	Oakland	White Croaker	Off	5	NA	5.5	312	21.1	19.1	5.6	8.1	1.0	47.7	4.7	20.9	11.0	47.7	2.7	ND	4.3
7/1/97	S.F. Waterfront	White Croaker	Off	5	25	5.3	158	10.3	8.9	2.5	3.9	0.5	26.9	2.4	10.1	5.6	25.1	1.3	ND	2.2
6/23/97	San Pablo Bay	White Croaker	Off	5	NA	4.7	100	5.5	4.9	1.6	2.1	ND	16.5	1.4	7.0	3.6	16.7	0.9	ND	1.1

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 24. PCB concentrations (ng/g wet) in fish tissue, 1997 (continued).
ND = not detected. Aroclor concentrations were estimated from the congener data.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Avg Length (cm)	% Lipid	Sum of PCB Congeners (SFEI)	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 189	PCB 194	PCB 195	PCB 201	PCB 203	PCB 206	PCB 209
6/12/97	Berkeley	Halibut	Off	1	75	0.4	12	0.4	0.3	0.4	1.5	0.5	1.5	ND	0.3	ND	0.4	0.4	ND	ND
6/13/97	Berkeley	Halibut	Off	1	79	0.5	12	0.4	ND	0.4	1.3	0.5	1.5	ND	ND	ND	0.3	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	60	0.3	7	0.3	ND	0.3	1.0	0.3	1.0	ND	ND	ND	ND	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	0.3	12	0.5	ND	0.5	1.6	0.5	1.5	ND	ND	ND	0.3	0.3	ND	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	0.3	8	0.3	ND	0.3	1.2	0.4	1.3	ND	ND	ND	0.3	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	0.4	7	0.3	ND	0.3	0.9	0.3	0.9	ND	ND	ND	ND	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	0.2	11	0.4	ND	0.5	1.4	0.5	1.7	ND	0.2	ND	0.3	0.3	ND	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	0.5	34	1.0	0.4	1.2	3.2	1.3	4.2	ND	0.5	ND	0.7	0.7	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	25	1.6	21	0.4	ND	0.4	1.1	0.4	1.0	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	14	0.3	ND	0.4	0.9	0.4	1.2	ND	ND	ND	0.2	0.3	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	22	0.3	0.3	0.7	1.4	0.6	1.9	ND	ND	ND	0.4	0.4	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	27	1.4	137	1.3	0.8	3.8	4.9	2.8	6.7	ND	0.5	0.2	0.7	0.8	0.2	ND
6/30/97	Oakland	Jacksmelt	On+	5	26	1.9	112	1.5	0.8	2.4	5.1	2.9	6.7	ND	0.6	ND	0.8	0.7	ND	ND
7/2/97	Oakland	Jacksmelt	On+	5	28	3.4	211	2.4	1.7	3.9	9.8	5.3	12.0	ND	1.1	0.4	1.6	1.6	0.6	ND
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.8	20	0.5	0.3	0.5	1.5	0.6	1.4	ND	0.3	ND	0.4	0.3	ND	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.5	33	0.9	1.0	1.1	3.3	1.4	3.5	ND	0.5	ND	0.7	0.7	ND	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	25	2.5	24	0.7	0.6	0.7	2.2	0.8	2.0	ND	0.4	ND	0.5	0.4	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.5	36	0.8	0.5	1.0	2.6	1.1	3.1	ND	0.4	ND	0.7	0.5	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.4	46	0.9	0.5	1.2	2.8	1.3	4.0	ND	0.5	ND	0.8	0.6	0.3	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	28	2.4	27	0.7	0.4	0.9	2.0	0.9	2.4	ND	0.3	ND	0.6	0.4	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	92	0.2	9	0.5	ND	ND	1.8	0.6	0.9	ND	0.3	ND	ND	0.3	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	98	0.2	8	0.4	ND	ND	1.7	0.5	0.9	ND	0.3	ND	ND	0.3	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	100	0.3	3	ND	ND	ND	0.6	ND	0.4	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	93	0.3	5	0.3	ND	ND	1.1	0.4	0.8	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	0.3	4	0.2	ND	ND	0.9	0.3	0.5	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	95	0.2	12	0.5	ND	ND	1.7	0.6	1.5	ND	0.3	ND	0.2	0.3	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	118	0.6	19	0.8	ND	0.3	2.8	1.1	2.7	ND	0.4	ND	0.4	0.5	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	96	0.1	6	0.3	ND	ND	1.0	0.4	1.0	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	3.9	110	3.1	0.7	3.1	10.5	3.5	8.9	ND	1.2	ND	1.6	1.3	0.4	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	2.6	91	2.9	0.5	2.7	9.5	3.2	8.2	0.2	1.3	0.3	1.4	1.4	0.3	ND
6/13/97	Berkeley	Shiner Surf Perch	On+	20	12	2.1	96	3.1	0.8	3.1	10.6	3.4	8.2	ND	1.4	0.4	1.6	1.5	0.4	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.5	423	8.2	1.9	7.9	30.4	10.5	25.0	0.3	2.7	1.0	2.7	4.1	0.7	0.2
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.9	515	9.5	2.2	8.3	31.3	10.9	24.3	0.5	3.4	1.3	3.2	4.7	1.3	0.4
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	1.9	486	10.7	1.5	9.2	34.0	11.6	27.7	0.7	4.6	1.8	3.8	5.9	1.3	0.7
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	2.0	131	3.8	0.6	3.5	11.6	4.1	9.5	0.3	1.5	0.4	1.6	1.7	0.3	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	3.0	152	3.9	0.6	3.6	12.0	4.2	10.7	ND	1.4	0.4	1.5	1.7	0.5	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	1.7	184	4.3	0.9	3.5	14.3	4.7	10.0	0.2	1.6	0.5	1.7	1.9	0.5	ND
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.6	77	1.8	0.4	2.1	6.5	2.4	5.8	ND	0.7	ND	0.9	0.9	0.3	ND
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.4	58	1.4	ND	1.6	5.3	2.0	4.9	ND	0.6	ND	0.7	0.8	0.3	ND
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	1.5	45	1.4	ND	1.5	4.2	1.7	4.5	ND	0.6	ND	0.6	0.7	ND	ND
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	13	4.0	172	5.2	1.0	6.1	17.4	6.4	18.6	ND	2.3	0.6	2.8	2.7	0.8	0.3
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	1.9	81	2.6	0.6	3.2	8.7	3.5	10.1	ND	1.2	0.4	1.4	1.5	0.4	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	2.6	111	2.9	0.6	3.7	10.1	4.0	11.3	ND	1.2	0.4	1.5	1.5	0.4	ND
6/13/97	Berkeley	Striped Bass	Off	3	51	4.1	33	0.8	0.6	0.9	3.1	1.1	3.2	ND	0.4	ND	0.6	0.5	ND	ND
6/18/97	Berkeley	Striped Bass	Off	2	69	1.6	28	0.7	0.5	0.8	2.7	1.0	2.8	ND	0.4	ND	0.5	0.5	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	51	0.5	29	0.7	0.5	0.8	2.5	0.9	2.9	ND	0.4	ND	0.5	0.5	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	64	0.8	7	0.3	ND	ND	0.8	0.3	0.7	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	53	0.8	11	0.3	ND	0.4	1.1	0.4	1.3	ND	ND	ND	0.3	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	51	1.0	21	0.4	0.3	0.5	1.5	0.6	1.8	ND	ND	ND	0.3	0.3	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	64	0.8	23	0.6	0.3	0.7	2.2	0.8	2.4	ND	0.3	ND	0.5	0.4	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	3	50	0.5	22	0.7	0.3	0.8	2.1	0.7	2.4	ND	0.3	ND	0.4	0.4	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	2	66	0.5	22	0.6	0.4	0.8	2.2	0.8	2.5	ND	0.3	ND	0.5	0.5	ND	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	51	0.6	14	0.4	0.2	0.4	1.4	0.5	1.6	ND	0.2	ND	0.3	0.3	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	124	1.3	33	0.4	0.4	1.1	2.0	1.2	3.6	ND	0.3	ND	0.4	0.3	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	142	1.3	28	0.4	0.3	1.1	1.4	0.9	2.8	ND	ND	ND	0.2	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	3	121	0.6	10	0.3	ND	0.6	1.2	0.5	1.5	ND	ND	ND	0.3	0.2	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	142	1.5	31	0.6	0.4	1.2	2.1	1.0	3.1	ND	0.4	ND	0.4	0.4	ND	ND
6/13/97	Berkeley	White Croaker	On	5	27	6.4	220	5.8	4.3	6.2	19.7	6.4	18.3	ND	ND	0.8	3.8	3.4	1.0	0.6
6/13/97	Berkeley	White Croaker	On	5	24	7.4	162	3.4	2.8	4.3	11.9	4.1	11.3	ND	1.6	0.4	2.4	1.8	0.7	0.4
6/13/97	Berkeley	White Croaker	On	5	24	6.1	164	3.8	3.3	4.8	15.0	4.8	15.0	ND	1.6	0.5	2.5	2.0	0.5	0.4
6/13/97	Berkeley	White Croaker	On	5	23	5.4	141	3.8	3.2	4.1	13.1	4.2	11.8	ND	1.9	0.5	2.7	2.4	0.8	0.4
6/11/97	Oakland	White Croaker	On	5	25	7.5	364	6.8	5.9	7.2	22.6	7.8	20.1	0.3	3.2	1.0	4.4	3.9	1.5	0.5
7/2/97	Oakland	White Croaker	On	5	26	7.3	589	13.0	9.2	12.6	46.0	14.5	39.1	0.6	5.7	1.9	6.8	6.8	2.3	1.0
7/2/97	Oakland	White Croaker	On	5	24	7.7	265	5.7	4.2	6.4	18.6	6.4	16.2	0.3	2.4	0.8	2.9	3.1	0.7	0.4
7/11/97	Oakland	White Croaker	On	5	27	6.8	338	6.8	4.9	7.4	22.5	7.8	21.4	0.4	3.5	1.1	4.0	4.1	1.1	0.6
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.3	268	5.9	4.4	6.0	20.1	6.5	17.4	ND	2.4	0.7	3.4	3.0	0.9	0.3
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.6	253	7.4	4.1	12.8	23.9	7.3	17.4	0.4	3.1	1.0	3.2	3.7	0.6	0.3
7/10/97	S.F. Waterfront	White Croaker	On	5	23	5.2	153	3.8	2.8	3.8	12.3	4.1	9.8	ND	1.8	0.5	2.3	2.3	0.6	0.3
6/23/97	San Pablo Bay	White Croaker	On	5	26	9.3	182	3.9	3.0	5.1	14.2	4.9	14.7	ND	1.8	0.4	2.8	2.1	1.1	0.3
6/26/97	San Pablo Bay	White Croaker	On	5	26	6.4	115	2.7	1.9	3.1	9.0	3.1	9.2	ND	1.4	0.4	1.9	1.7	0.6	0.4
7/9/97	San Pablo Bay	White Croaker	On	5	27	3.3	145	4.2	3.2	5.2	14.8	5.2	15.3	ND	2.4	0.7	3.2	3.2	1.1	0.5
6/13/97	Berkeley	White Croaker	Off	5	NA	4.7	108	2.8	2.1	3.1	9.6	3.1	8.6	ND	1.4	0.3	1.8	1.6	0.4	ND
6/11/97	Oakland	White Croaker	Off	5	NA	5.5	312	5.9	4.7	6.4	20.2	6.5	17.5	ND	2.6	0.7	3.4	3.4	1.4	ND
7/1/97	S.F. Waterfront	White Croaker	Off	5	25	5.3	158	3.3	2.5	3.5	11.6	3.7	9.4	ND	1.3	0.3	1.9	1.7	0.6	ND
6/23/97	San Pablo Bay	White Croaker	Off	5	NA	4.7	100	2.1	1.6	3.0	7.9	2.7	8.4	ND	0.9	ND	1.5	1.1	0.5	ND

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 25. Pesticide concentrations (ng/g wet) in fish tissue, 1997. ND = not detected.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	Avg Length (cm)	% Moisture	% Lipid	Total DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDMS	p,p'-DDMU	p,p'-DDT	p,p'-Dichlorobenzophenone
6/12/97	Berkeley	Halibut	Off	1	75	75	74	0.4	6.9	ND	ND	ND	1.5	5.4	ND	1.6	ND	ND
6/13/97	Berkeley	Halibut	Off	1	79	79	76	0.5	6.7	ND	ND	ND	1.3	5.3	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	60	60	74	0.3	4.8	ND	ND	ND	1.1	3.7	ND	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	73	75	0.3	6.5	ND	ND	ND	1.3	5.1	ND	5.1	ND	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	92	77	0.3	6.5	ND	ND	ND	1.1	5.4	ND	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	59	73	0.4	6.2	ND	ND	ND	1.0	5.2	ND	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	77	77	0.2	10.4	ND	ND	ND	2.2	8.1	ND	1.2	ND	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	55	74	0.5	14.1	ND	ND	ND	2.5	11.6	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	24-28.5	25	74	1.6	41.0	ND	ND	ND	4.9	34.3	ND	5.9	1.8	ND
6/12/97	Berkeley	Jacksmelt	On+	5	24-27	26	75	3.2	28.1	ND	ND	ND	1.1	27.0	ND	3.9	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	22-30	26	76	3.2	33.0	ND	ND	ND	2.6	29.2	ND	2.5	1.2	ND
6/30/97	Oakland	Jacksmelt	On+	5	25-30	27	82	1.4	35.5	ND	ND	ND	5.1	29.0	ND	3.8	1.4	ND
6/30/97	Oakland	Jacksmelt	On+	5	23-29	26	78	1.9	40.5	ND	ND	ND	4.5	33.7	ND	3.3	2.3	ND
7/2/97	Oakland	Jacksmelt	On+	5	27-29	28	69	3.4	48.3	ND	ND	ND	10.4	36.0	ND	7.1	1.9	ND
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	20.5-28.5	25	75	1.8	34.2	ND	ND	ND	1.5	31.4	ND	4.3	1.4	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	21-30	25	74	1.5	11.7	ND	ND	ND	3.1	8.6	ND	1.6	ND	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	21-27	25	75	2.5	33.9	ND	ND	ND	3.3	27.3	ND	4.9	3.3	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-28	27	75	1.5	33.2	ND	ND	ND	4.5	27.6	ND	3.3	1.1	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	25-29	27	71	1.4	34.9	ND	ND	ND	5.1	29.8	ND	3.5	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	26-30	28	74	2.4	25.6	ND	ND	ND	3.8	21.8	ND	6.1	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	91-93	92	76	0.2	5.8	ND	ND	ND	1.0	4.8	ND	1.7	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	92-102	98	75	0.2	5.0	ND	ND	ND	ND	5.0	ND	1.3	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	99-100	100	75	0.3	3.4	ND	ND	ND	ND	3.4	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	91.5-94	93	76	0.3	4.6	ND	ND	ND	ND	4.6	ND	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	114	78	0.3	5.7	ND	ND	ND	ND	5.7	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	93-97	95	76	0.2	7.5	ND	ND	ND	1.1	6.4	ND	1.9	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	108-135	118	77	0.6	11.2	ND	ND	ND	1.3	9.9	ND	1.9	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	94-99	96	77	0.1	4.1	ND	ND	ND	ND	4.1	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-14.5	12	71	3.9	69.3	3.7	1.0	ND	13.6	51.0	ND	8.4	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	11-12.5	12	77	2.6	63.9	1.6	0.9	1.0	9.1	49.0	ND	5.5	2.3	ND
6/13/97	Berkeley	Shiner Surf Perch	On+	20	10.5-14.5	12	77	2.1	44.1	ND	0.8	1.0	2.0	40.3	ND	1.9	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14.5	12	77	2.5	95.4	3.9	ND	1.1	31.8	53.6	7.0	20.3	5.0	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	10.5-14.5	12	77	2.9	95.5	3.7	ND	1.6	29.0	58.6	6.5	17.1	2.6	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	11-14	12	78	1.9	90.8	2.9	ND	1.9	21.0	60.8	ND	12.1	4.2	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	77	2.0	41.0	1.4	ND	ND	7.1	31.1	ND	9.1	1.4	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	11.5-13	12	76	3.0	54.5	2.1	ND	ND	8.9	41.8	ND	4.1	1.7	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	10.5-13	12	78	1.7	48.7	2.7	ND	0.9	15.5	28.3	ND	5.2	1.3	ND
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-14	12	78	2.6	50.3	2.5	ND	ND	11.1	35.7	ND	4.9	1.0	ND
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	10-15	12	76	2.4	55.9	3.9	ND	ND	20.1	30.9	ND	5.6	1.0	ND
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	10.5-12.5	12	76	1.5	27.3	ND	ND	ND	4.4	21.8	ND	3.3	1.1	ND
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	13	68	4.0	68.9	2.6	ND	ND	9.9	54.3	ND	8.2	2.0	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	10.5-14.5	12	79	1.9	30.7	ND	ND	ND	6.3	22.2	ND	ND	2.3	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	11-15	12	79	2.6	35.7	1.3	ND	ND	4.9	29.5	ND	4.7	ND	ND
6/13/97	Berkeley	Striped Bass	Off	3	50-52	51	73	4.1	42.8	2.8	ND	ND	5.1	32.7	ND	7.7	2.2	ND
6/18/97	Berkeley	Striped Bass	Off	2	63,75	69	72	1.6	24.6	ND	ND	ND	3.8	19.3	ND	6.8	1.5	ND
7/8/97	Davis Point	Striped Bass	Off	3	50-53	51	77	0.5	27.2	ND	ND	ND	2.9	23.2	ND	1.9	1.1	ND
7/8/97	Davis Point	Striped Bass	Off	3	60-68	64	75	0.8	16.1	ND	ND	ND	2.1	14.0	ND	1.9	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	48-56	53	77	0.8	15.1	ND	ND	ND	3.0	11.0	ND	3.8	1.1	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	50-52	51	75	1.0	14.1	ND	ND	ND	3.7	10.4	ND	4.6	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	61-66	64	77	0.8	24.7	ND	ND	ND	3.5	19.9	ND	4.9	1.2	ND
6/2/97	South Bay Bridges	Striped Bass	Off	3	49-52	50	78	0.5	16.4	ND	ND	ND	2.4	12.8	ND	1.6	1.2	ND
6/2/97	South Bay Bridges	Striped Bass	Off	2	62,69	66	75	0.5	10.6	ND	ND	ND	1.8	8.8	ND	6.6	ND	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	50-52	51	78	0.6	14.4	ND	ND	ND	2.1	11.4	ND	2.1	0.9	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	117-128	124	74	1.3	25.5	1.6	ND	ND	4.7	17.9	ND	4.2	1.3	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	140-145	142	77	1.3	21.2	1.3	ND	ND	3.7	14.7	ND	3.8	1.5	ND
3/12/97	South Bay Bridges	Sturgeon	Off	3	119-124	121	79	0.6	5.4	ND	ND	ND	1.1	4.4	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	135,149	142	75	1.5	12.8	ND	ND	ND	3.4	9.4	ND	3.4	ND	ND
6/13/97	Berkeley	White Croaker	On	5	24-28	27	70	6.4	137.1	ND	1.6	1.3	35.3	93.2	ND	9.7	5.7	ND
6/13/97	Berkeley	White Croaker	On	5	20-30	24	72	7.4	72.1	ND	1.1	ND	16.1	52.0	ND	8.7	2.9	ND
6/13/97	Berkeley	White Croaker	On	5	21-29	24	72	6.1	77.8	ND	0.9	ND	21.6	50.3	ND	13.5	4.9	ND
6/13/97	Berkeley	White Croaker	On	5	20-29	23	68	5.4	71.7	ND	ND	ND	17.0	50.8	ND	8.2	3.9	ND
6/11/97	Oakland	White Croaker	On	5	20-28	25	70	7.5	113.5	1.8	2.9	ND	32.6	72.2	ND	9.9	4.0	ND
7/2/97	Oakland	White Croaker	On	5	21-30	26	68	7.3	163.0	2.4	1.6	ND	42.3	114.0	7.2	21.4	2.8	ND
7/2/97	Oakland	White Croaker	On	5	21-27	24	69	7.7	92.3	2.0	1.3	ND	30.4	54.4	7.7	9.8	4.2	ND
7/11/97	Oakland	White Croaker	On	5	23-30	27	72	6.8	189.2	3.4	1.9	1.6	88.4	88.1	11.0	13.4	5.8	12.5
7/1/97	S.F. Waterfront	White Croaker	On	5	22-29	25	70	7.3	86.8	ND	1.3	ND	21.0	61.6	ND	12.5	2.9	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	20-30	25	70	7.6	83.8	2.1	1.0	ND	20.0	57.9	ND	7.7	2.7	8.0
7/10/97	S.F. Waterfront	White Croaker	On	5	20-30	23	73	5.2	66.5	ND	0.9	ND	17.8	45.0	ND	8.6	2.8	ND
6/23/97	San Pablo Bay	White Croaker	On	5	23-29	26	69	9.3	94.1	ND	1.3	ND	23.5	64.5	ND	12.6	4.7	ND
6/26/97	San Pablo Bay	White Croaker	On	5	23-29	26	66	6.4	71.0	ND	ND	ND	13.9	54.9	ND	6.1	2.2	ND
7/9/97	San Pablo Bay	White Croaker	On	5	22-30	27	73	3.3	62.2	ND	ND	ND	16.7	41.1	ND	10.9	4.4	ND
6/13/97	Berkeley	White Croaker	Off	5	24-28	NA	69	4.7	57.0	ND	ND	ND	16.6	37.7	ND	8.3	2.7	ND
6/11/97	Oakland	White Croaker	Off	5	20-28	NA	65	5.5	93.7	ND	1.2	ND	25.5	64.3	ND	14.9	2.7	ND
7/1/97	S.F. Waterfront	White Croaker	Off	5	22-29	25	72	5.3	50.7	ND	ND	ND	11.6	37.7	ND	6.7	1.4	ND
6/23/97	San Pablo Bay	White Croaker	Off	5	23-29	NA	67	4.7	53.0	ND	ND	ND	11.7	41.3	ND	8.2	ND	ND

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 25. Pesticide concentrations (ng/g wet) in fish tissue, 1997 (continued). ND = not detected.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Avg Length (cm)	% Lipid	Total Chlordanes (SFEI)	alpha-Chlordane	cis-Chlordane	gamma-Chlordane	trans-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH
6/12/97	Berkeley	Halibut	Off	1	75	0.4	1.3	ND	0.3	ND	ND	0.3	0.7	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	79	0.5	1.8	ND	0.3	ND	0.8	ND	0.7	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	60	0.3	0.4	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	0.3	2.2	ND	0.3	ND	0.5	0.3	0.6	ND	ND	0.5	ND	ND	ND	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	0.3	0.9	ND	ND	ND	ND	ND	0.4	ND	ND	0.5	ND	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	0.4	0.4	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	0.2	2.1	ND	0.3	ND	0.7	0.3	0.8	ND	ND	ND	ND	ND	ND	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	0.5	2.8	ND	0.8	ND	ND	0.7	1.3	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	25	1.6	3.3	ND	0.5	ND	0.7	0.6	1.2	ND	ND	0.3	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	2.1	ND	ND	ND	1.2	ND	0.8	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	1.6	ND	0.3	ND	ND	ND	1.0	ND	ND	0.3	ND	ND	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	27	1.4	6.7	ND	1.3	ND	1.1	1.0	2.8	ND	ND	0.5	ND	ND	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	26	1.9	6.5	ND	1.0	ND	1.2	1.2	2.7	ND	ND	0.4	ND	ND	ND	ND
7/2/97	Oakland	Jacksmelt	On+	5	28	3.4	11.0	ND	1.8	ND	2.5	1.2	4.5	ND	ND	0.9	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.8	2.1	ND	0.3	ND	0.8	0.4	0.6	ND	ND	ND	ND	ND	ND	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.5	3.2	ND	0.5	ND	1.4	0.4	0.4	ND	ND	0.5	ND	ND	ND	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	25	2.5	5.1	ND	0.6	ND	1.2	0.7	1.6	ND	ND	1.0	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.5	3.9	ND	0.5	ND	1.6	0.7	1.1	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.4	3.1	ND	0.5	ND	0.7	0.3	1.7	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	28	2.4	3.6	ND	0.4	ND	1.0	0.7	1.5	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	92	0.2	0.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	98	0.2	0.4	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	100	0.3	0.3	ND	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	93	0.3	1.5	ND	0.3	ND	ND	0.2	0.6	ND	ND	0.3	ND	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	0.3	0.7	ND	ND	ND	ND	0.2	0.4	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	95	0.2	1.4	ND	0.4	ND	ND	0.4	0.7	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	118	0.6	4.3	ND	0.9	ND	0.5	0.7	1.8	ND	ND	0.5	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	96	0.1	1.7	ND	0.4	ND	0.3	0.3	0.7	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	3.9	7.8	ND	1.6	ND	2.5	0.6	2.7	ND	ND	0.4	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	2.6	6.8	ND	1.3	ND	2.1	0.9	2.1	ND	ND	0.3	ND	ND	ND	ND
6/13/97	Berkeley	Shiner Surf Perch	On+	20	12	2.1	1.3	ND	0.3	ND	0.3	ND	0.8	ND	ND	ND	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.5	50.6	0.6	13.6	0.4	4.9	9.7	17.9	ND	ND	4.5	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.9	40.2	0.7	10.6	ND	5.0	5.2	17.3	ND	ND	2.1	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	1.9	30.9	0.5	8.3	0.6	3.5	5.3	12.2	ND	ND	1.6	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	2.0	8.8	ND	2.0	ND	1.9	1.6	2.8	ND	ND	0.4	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	3.0	6.6	ND	1.3	ND	1.5	0.8	2.6	ND	ND	0.4	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	1.7	12.6	ND	3.7	0.4	2.7	1.4	4.7	ND	ND	ND	ND	ND	ND	ND
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.6	6.3	ND	1.6	ND	1.3	0.6	2.6	ND	ND	0.3	ND	ND	ND	ND
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.4	5.4	ND	1.5	ND	1.3	0.5	2.2	ND	ND	ND	ND	ND	ND	ND
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	1.5	3.8	ND	0.8	ND	0.9	0.6	1.2	ND	ND	0.3	ND	ND	ND	ND
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	13	4.0	11.6	ND	2.3	ND	2.7	1.4	4.6	ND	ND	0.6	ND	ND	ND	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	1.9	10.1	ND	2.2	ND	1.7	2.5	2.8	ND	ND	0.9	ND	ND	ND	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	2.6	10.3	ND	2.5	ND	1.9	1.2	4.2	ND	ND	0.4	ND	ND	ND	ND
6/13/97	Berkeley	Striped Bass	Off	3	51	4.1	5.7	ND	1.3	ND	0.8	0.8	2.3	ND	ND	0.5	ND	ND	ND	ND
6/18/97	Berkeley	Striped Bass	Off	2	69	1.6	3.7	ND	0.8	ND	0.5	0.8	1.7	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	51	0.5	3.0	ND	0.6	ND	ND	0.9	1.6	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	64	0.8	1.6	ND	0.5	ND	ND	0.4	0.8	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	53	0.8	3.7	ND	0.8	ND	0.5	0.8	1.3	ND	ND	0.3	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	51	1.0	4.5	ND	0.9	ND	0.5	0.9	1.4	ND	ND	0.6	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	64	0.8	2.3	ND	0.7	ND	ND	0.5	1.1	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	3	50	0.5	3.0	ND	0.6	ND	0.4	0.6	1.2	ND	ND	0.2	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	2	66	0.5	2.5	ND	0.6	ND	0.4	0.6	1.0	ND	ND	ND	ND	ND	ND	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	51	0.6	2.1	ND	0.4	ND	0.3	0.4	1.0	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	124	1.3	6.9	ND	1.9	ND	1.4	1.3	2.3	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	142	1.3	4.9	ND	1.5	ND	1.0	0.9	1.6	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	3	121	0.6	1.6	ND	0.4	ND	0.3	0.3	0.7	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	142	1.5	3.3	ND	0.9	ND	0.6	0.6	1.2	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	27	6.4	15.1	ND	3.6	0.5	2.8	2.6	5.6	ND	ND	0.6	0.8	ND	ND	0.8
6/13/97	Berkeley	White Croaker	On	5	24	7.4	13.7	ND	3.0	0.4	3.9	1.3	5.0	ND	ND	0.5	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	24	6.1	18.1	ND	4.8	ND	3.1	3.3	5.3	ND	ND	1.5	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	23	5.4	11.8	ND	2.9	ND	2.1	2.2	3.8	ND	ND	0.7	ND	ND	ND	ND
6/11/97	Oakland	White Croaker	On	5	25	7.5	21.2	0.6	4.9	0.6	5.8	2.4	6.6	0.5	ND	1.0	ND	ND	ND	ND
7/2/97	Oakland	White Croaker	On	5	26	7.3	33.3	0.7	6.6	0.8	7.5	4.4	12.6	0.5	ND	1.7	ND	ND	ND	ND
7/2/97	Oakland	White Croaker	On	5	24	7.7	23.9	0.4	5.7	0.6	6.4	3.5	7.5	ND	ND	0.9	ND	ND	ND	ND
7/11/97	Oakland	White Croaker	On	5	27	6.8	21.3	0.3	5.3	0.8	4.0	3.2	7.2	0.3	ND	1.2	ND	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.3	19.9	0.5	5.0	0.8	5.5	1.8	6.8	ND	ND	0.9	ND	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.6	21.0	0.6	5.8	0.9	5.0	2.7	6.1	ND	ND	1.5	ND	ND	ND	ND
7/10/97	S.F. Waterfront	White Croaker	On	5	23	5.2	17.4	ND	4.2	0.4	5.4	2.5	4.6	ND	ND	0.7	ND	ND	ND	ND
6/23/97	San Pablo Bay	White Croaker	On	5	26	9.3	18.4	0.3	4.0	0.4	5.7	1.8	6.0	ND	ND	1.0	ND	ND	ND	ND
6/26/97	San Pablo Bay	White Croaker	On	5	26	6.4	11.1	ND	2.8	ND	1.5	1.8	4.3	ND	ND	0.8	ND	ND	ND	ND
7/9/97	San Pablo Bay	White Croaker	On	5	27	3.3	15.8	ND	2.5	ND	2.2	3.7	4.6	ND	ND	2.8	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	Off	5	NA	4.7	9.4	ND	2.1	ND	2.0	1.6	3.3	ND	ND	0.5	ND	ND	ND	ND
6/11/97	Oakland	White Croaker	Off	5	NA	5.5	19.3	0.5	4.2	0.5	5.1	2.2	7.0	ND	ND	0.9	ND	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	Off	5	25	5.3	11.7	0.3	3.2	0.5	2.9	1.0	4.1	ND	ND	0.6	ND	ND	ND	ND
6/23/97	San Pablo Bay	White Croaker	Off	5	NA	4.7	9.8	ND	1.9	ND	3.1	0.8	3.4	ND	ND	0.5	ND	ND	ND	ND

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 25. Pesticide concentrations (ng/g wet) in fish tissue, 1997 (continued). ND = not detected.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Avg Length (cm)	% Lipid	Aldrin	Dieldrin	Endrin	Chlorpyrifos	Dacthal	Endosulfan I	Endosulfan II	Endosulfan Sulfate	Hexachlorobenzene	Methoxychlor	Mirex	Oxadiazon
6/12/97	Berkeley	Halibut	Off	1	75	0.4	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	79	0.5	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Halibut	Off	1	60	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/17/97	Berkeley	Halibut	Off	1	73	0.3	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3/28/97	San Pablo Bay	Halibut	Off	1	92	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/24/97	San Pablo Bay	Halibut	Off	1	59	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/23/97	San Pablo Bay	Halibut	Off	1	77	0.2	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/3/97	South Bay Bridges	Halibut	Off	1	55	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	25	1.6	ND	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Jacksmelt	On+	5	26	3.2	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	27	1.4	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/30/97	Oakland	Jacksmelt	On+	5	26	1.9	ND	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/2/97	Oakland	Jacksmelt	On+	5	28	3.4	ND	2.5	ND	1.3	ND	ND	ND	ND	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.8	ND	0.4	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND
7/10/97	S.F. Waterfront	Jacksmelt	On+	5	25	1.5	ND	0.7	ND	1.4	ND	ND	ND	ND	ND	ND	ND	ND
7/11/97	S.F. Waterfront	Jacksmelt	On+	5	25	2.5	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	27	1.4	ND	1.0	ND	1.4	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Jacksmelt	On+	5	28	2.4	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	92	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Leopard Shark	Off	3	98	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	100	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Leopard Shark	Off	3	93	0.3	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Leopard Shark	Off	1	114	0.3	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	95	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	118	0.6	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Leopard Shark	Off	3	96	0.1	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	3.9	ND	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/12/97	Berkeley	Shiner Surf Perch	On+	20	12	2.6	ND	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Shiner Surf Perch	On+	20	12	2.1	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.5	ND	4.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	2.9	ND	3.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/5/97	Oakland	Shiner Surf Perch	On+	20	12	1.9	ND	1.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	2.0	ND	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	3.0	ND	1.7	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND
6/19/97	S.F. Waterfront	Shiner Surf Perch	On+	20	12	1.7	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/23/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.6	ND	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/9/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	2.4	ND	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/24/97	San Pablo Bay	Shiner Surf Perch	On+	20	12	1.5	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5/27/97	South Bay Bridges	Shiner Surf Perch	On+	20	13	4.0	ND	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	1.9	ND	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6
6/2/97	South Bay Bridges	Shiner Surf Perch	On+	20	12	2.6	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	Striped Bass	Off	3	51	4.1	ND	2.0	ND	ND	ND	ND	ND	ND	0.6	ND	ND	ND
6/18/97	Berkeley	Striped Bass	Off	2	69	1.6	ND	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	51	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	64	0.8	ND	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/8/97	Davis Point	Striped Bass	Off	3	53	0.8	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	51	1.0	ND	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/20/97	San Pablo Bay	Striped Bass	Off	3	64	0.8	ND	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	3	50	0.5	ND	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/2/97	South Bay Bridges	Striped Bass	Off	2	66	0.5	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/27/97	Suisun Bay	Striped Bass	Off	3	51	0.6	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	124	1.3	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10/8/97	San Pablo Bay	Sturgeon	Off	3	142	1.3	ND	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	3	121	0.6	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3/12/97	South Bay Bridges	Sturgeon	Off	2	142	1.5	ND	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9
6/13/97	Berkeley	White Croaker	On	5	27	6.4	ND	3.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	24	7.4	ND	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	24	6.1	ND	5.9	ND	ND	ND	ND	ND	6.0	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	On	5	23	5.4	ND	4.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/11/97	Oakland	White Croaker	On	5	25	7.5	ND	5.1	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND
7/2/97	Oakland	White Croaker	On	5	26	7.3	ND	5.5	ND	1.5	ND	ND	ND	ND	0.4	ND	ND	ND
7/2/97	Oakland	White Croaker	On	5	24	7.7	ND	4.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/11/97	Oakland	White Croaker	On	5	27	6.8	ND	5.4	ND	ND	ND	ND	ND	ND	0.8	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.3	ND	4.3	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	On	5	25	7.6	ND	4.4	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND
7/10/97	S.F. Waterfront	White Croaker	On	5	23	5.2	ND	3.2	ND	ND	ND	ND	ND	ND	0.3	4.7	ND	ND
6/23/97	San Pablo Bay	White Croaker	On	5	26	9.3	ND	5.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/26/97	San Pablo Bay	White Croaker	On	5	26	6.4	ND	3.2	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND
7/9/97	San Pablo Bay	White Croaker	On	5	27	3.3	ND	3.6	ND	ND	ND	ND	1.7	2.5	ND	ND	ND	ND
6/13/97	Berkeley	White Croaker	Off	5	NA	4.7	ND	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/11/97	Oakland	White Croaker	Off	5	NA	5.5	ND	4.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/1/97	S.F. Waterfront	White Croaker	Off	5	25	5.3	ND	2.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/23/97	San Pablo Bay	White Croaker	Off	5	NA	4.7	ND	3.4	ND	1.8	ND	ND	ND	ND	ND	ND	ND	ND

On—Skin on muscle, On+ —Skin on muscle with skeleton, Off—Skin off muscle

Table 26. Dibenzodioxin, dibenzofuran, and PCB 077, 126, and 169 concentrations (pg/g) in fish tissue, 1997. ND = not detected, units expressed as wet weight.

Date	Station	Fish Species	Tissue Analyzed	# Homogenized	Range of Lengths (cm)	Avg Length (cm)	% Lipid	ITEQ	PCB TEQ (3 PCBs)	PCB TEQ	TOTAL TEQ	2,3,7,8-TCDD	1,2,3,7,8-PCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8,9-OCDD	2,3,7,8-TCDF	1,2,3,7,8-PCDF	2,3,4,7,8-PCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	1,2,3,4,6,7,8,9-OCDF	PCB 077	PCB 126	PCB 169
6/13/97	Berkeley	White Croaker	On	15	20-30	25	6.6	1.5	4.2	6.9	8.4	0.33	0.55	ND	0.29	ND	ND	0.31	2.60	ND	1.20	ND	ND	ND	ND	ND	ND	ND	150	41	3
6/11/97	Oakland	White Croaker	On	15	20-30	26	7.2	1.6	11.2	18.1	19.7	0.50	0.62	ND	ND	ND	ND	ND	2.29	ND	0.95	ND	ND	ND	ND	ND	ND	ND	310	110	6
7/1/97	S.F. Waterfront	White Croaker	On	15	20-30	24	6.7	1.3	6.8	10.3	11.7	0.35	0.54	ND	0.22	ND	0.12	0.32	2.30	0.24	0.89	ND	ND	ND	ND	ND	ND	ND	240	66	3
6/23/97	San Pablo Bay	White Croaker	On	5	23-29	26	9.3	1.9	5.7	8.2	10.2	0.36	0.72	ND	0.41	ND	0.16	0.29	3.70	0.45	1.50	ND	ND	ND	ND	ND	ND	ND	170	56	5
6/26/97	San Pablo Bay	White Croaker	On	5	23-29	26	6.4	1.2	3.4	5.0	6.2	0.26	0.44	ND	0.27	ND	0.12	0.25	2.40	0.24	0.85	ND	ND	ND	ND	ND	ND	ND	120	33	3
7/9/97	San Pablo Bay	White Croaker	On	5	22-30	27	3.3	1.3	4.3	6.4	7.7	0.25	0.52	ND	0.36	ND	0.11	0.37	1.70	0.21	1.10	0.04	ND	ND	ND	ND	ND	ND	110	42	3
6/13/97	Berkeley	White Croaker	Off	15	20-30	25	NA	1.1	2.9	NA	NA	0.20	0.45	ND	0.23	ND	ND	0.25	1.90	0.24	0.87	ND	ND	ND	ND	ND	ND	ND	95	28	2
6/23/97	San Pablo Bay	White Croaker	Off	15	22-30	26	NA	0.7	2.4	NA	NA	0.15	0.29	ND	0.17	ND	0.07	0.30	1.20	0.14	0.55	ND	ND	ND	ND	ND	ND	ND	68	23	2

On	Skin on muscle
Off	Skin off muscle
TCDD	tetrachlorodibenzodioxin
PCDD	pentachlorodibenzodioxin
HxCDD	hexachlorodibenzodioxin
HpCDD	heptachlorodibenzodioxin
OCDD	octachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
PCDF	pentachlorodibenzofuran
HxCDF	hexachlorodibenzofuran
HpCDF	heptachlorodibenzofuran
OCDF	octachlorodibenzofuran
TEQ	dioxin toxic equivalent
TEF	dioxin toxic equivalency factor
ITEQs	dioxin toxic equivalents due to dibenzodioxins and dibenzofurans
PCB TEQs	dioxin toxic equivalents due to all measured dioxin-like PCBs
PCB TEQs (3 PCBs)	dioxin toxic equivalents due to PCBs 77, 126, and 169
total TEQs	dioxin toxic equivalents due to dibenzodioxins, dibenzofurans, and all measured dioxin-like PCBs

Appendix D
Summary of Trace Organic Sampler Intercalibration Results[1]

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Introduction

The sampling and analysis of large volumes of water for trace organic compounds (chlorinated pesticides, organochlorines [OCs], polychlorinated biphenyls [PCB], and polynuclear aromatic hydrocarbons [PAHs]) is a difficult task; there are only a few research groups in the world which routinely undertake this (e.g., deLappe *et al*., 1983; Sarkar and Sen Gupta, 1989; Hinckley and Bidleman, 1991; Cruz *et al*., 1993; Iwata *et al*., 1993; Kelly *et al*., 1993; Schreitmuller and Ballschmiter, 1995; Petrick *et al*., 1996). There are currently three absorbents used for the analysis of the dissolved fraction of large volumes (100 liters or greater) of water for trace analysis:

1) Liquid-liquid extraction, where water is run through an organic solvent and the non-polar compounds partition from the water into the organic phase.
2) XAD resin, where the water samples are run through a column filled with an organic resin (or XAD-2) that absorbs the non-polar compounds, which are then eluted off the column using an organic solvent.
3) Polyurethane foam (PUF), where large volumes of water are pumped through PUF plugs and then the PUF is extracted with organic solvents.

Between 1993 and 1996, the RMP used a polyurethane foam sampler for collection and analysis of trace organic compounds in water. In 1996, a new sampler using XAD-2 resin was phased in. This report compares the levels of organochlorine and polynuclear aromatic compounds in water from the San Francisco Bay generated during the June 1996 and January 1997 sampler intercalibration exercise. In this intercalibration, two trace organic sampling systems were compared side-by-side in six locations (1996—Redwood Creek BA40, Coyote Creek BA10, and Golden Gate BC20; 1997—Sacramento River BG20, San Joaquin River BG30, and Standish Dam BW10). The two sampling systems compared were a polyurethane foam- (for collection of the dissolved phase) glass fiber filter (particulate) and an XAD column- (dissolved) fiber glass cartridge system (particulate). In addition, for comparison, data generated during previous RMP cruises are compared to the intercalibration results to determine the magnitude of temporal variation.

One aspect all of these sampling schemes share is the pre-filtering of the particulate fraction of the water prior to the absorbent. In general, this is done using a glass fiber filter of 0.3–1 µM (either a flat or cartridge filter).

One of the most important quality control parameters involving the analysis of water is a careful characterization of the absorbent. In general, this is accomplished three ways:

1) Direct laboratory experiments, where water is spiked with a known concentration of the compounds of interest, and then the amount absorbed from the water is calculated (percent recovery).
2) The comparison of one absorbent with another absorbent that has been well characterized (e.g., PUF versus liquid-liquid).

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[1] This is a summary of the full technical report which includes all the data tables. The full report is available through SFEI.

3) Determination of replicate analysis of one water sample—this provides information on the variability of the sampler.

Both liquid-liquid and the XAD resins have been extensively validated for the analysis of sea water for organic contaminants in a variety of field and laboratory studies (Ahnoff and Josefsson, 1974; Osterroht, 1974; Otson and Williams, 1981; Sarkar and Sen Gupta, 1989; Cruz *et al*., 1993; Kelly *et al*., 1993; Petrick *et al*., 1996).

There are less validation studies for PUF water samplers. Musty and Nickless (1974) spiked tap water with chlorinated pesticides and PCBs at µg/L concentrations and determined their recoveries in six different PUFs. They characterized the foam by its ability to absorb methylene blue. They found recoveries > 90% in foam which strongly absorbed methylene blue (Musty and Nickless 1974). In a field experiment, deLappe *et al*. (1983) compared the recoveries of PCB, OCs, and PAHs in PUF to the recoveries found in liquid-liquid extractors. In general, the concentrations in PUF plugs agreed well with those from the liquid-liquid extractors. In addition, deLappe *et al*. (1983) analyzed individual foam plugs in series (five plugs were used in series) and found the breakthrough of the majority of analytes was < 10%. Validation of PUF as an air sampler has been more rigorous; (Nerin *et al*., 1995) found excellent recoveries of OCs in foam and found better precision in the PUF than in XAD resins for air sampling.

During the period 1993 through 1996, the sampler used in the Regional Monitoring Program (RMP) was a modification of deLappe *et al*. (1983). The sampler consisted of four PUF plugs in series; each plug is held in a separate cartridge that directs the water stream exclusively through the plugs, eliminating waterflow around the plugs. This sampler had not been used in intercalibration exercises, nor had any laboratory studies been performed. However, the design of this sampler is excellent for the determination of the capacity (or breakthrough) of compounds because each PUF plug can be analyzed separately and the breakthrough determined.

In 1996, a decision was made to switch from the Bodega Bay Institute's (BBI) system BBI PUF sampler to a commercially made XAD sampler (AXYS Environmental Systems, Ltd., Sydney, British Columbia) for the 1997 RMP. Prior to switching systems, an intercalibration program was designed to examine the similarities/differences in the data generated by the two systems.

The BBI system consists of a Teflon® impeller pump with $^3/_4$ inch Teflon® tubing, a flat-glass fiber filter (GFF; 293 mm x 1 µm), and four polyurethane foam plugs mounted in series (to prevent channeling) which adsorb the dissolved material. No flow controller is used in this system (i.e., at low particulate loads on the GFF the flow is rapid, as the filter clogs the flow decreases). It is well known that flow has an important effect on the absorption of contaminants to the absorbent (Jarman *et al*., 1998).

The custom manufactured AXYS system consists of a constant flow PEEK gear-driven positive displacement pump, $^1/_2$ inch Teflon® tubing, 1 µm glass fiber cartridge (GFC) particulate filter, and two parallel Teflon® columns filed with -2 resin (parallel columns were employed to increase total flows). The use of the GFC system was chosen because of its high capacity for collecting particulates in water with high total suspended solids.

Outline of the Intercalibration Study

This study was divided into three separate studies:

- Initial comparison of the two sampling systems during non-RMP conditions.
- Comparison of the samplers during actual RMP sampling.
- Determination of the major factor(s) introducing variability between the systems.

The first objective of this study was twofold; first, it was an initial comparison of the two systems (XAD versus PUF) during non-RMP conditions. This preliminary study was done as a first look comparison between the systems at RMP sites that had low and high concentrations of contaminants (see *Methodology* for details). The objective of this part of the study was to determine if the two systems were at all comparable. Secondly, this phase of the study was undertaken to examine the actual ship worthiness and ease of use of the XAD system. Since this system had not been used in the RMP before, the usability (e.g., moving the sampler, determining time on station, etc.) was a key issue.

The second phase of the study was to sample water bodies simultaneously using the two systems during an actual RMP cruise. After determining during the first phase of the study that the data generated by the systems were comparable, the second phase of the study was a more rigorous side by side sampling during an RMP cruise (see *Methodology* for details). Data generated during this phase of the study were crucial because it represented true field comparisons of the samplers during a cruise.

The third phase of the program was to determine where the variability between the samplers came from. Variability could be generated during three steps in the analysis: first, in the sampling system, since the absorbents of the two samplers are very different (polyurethane foam and XAD-a nonionic macroreticular resin); secondly, in the laboratory extraction of the foam or XAD (e.g., use of different solvents in extraction); and thirdly, in the instrumental analysis (e.g., use of different detectors, columns, or gas chromatographs).

It was decided in this study that the samples would be collected, extracted, and analyzed completely by the one laboratory for the PUF samples (BBI) and similarly using one laboratory for the XAD samples (University of Utah; UU). This would eliminate any variability associated with one laboratory doing part of the work (e.g., sampling) and another laboratory doing the analysis.

Since the RMP has an on-going quality control project examining the bias associated with instrumental analysis (one sample extract is analyzed by several laboratories and the difference and similarities are noted), the magnitude of differences between laboratories has already been noted (Davis *et al*., 1997), and therefore, in theory, could be accounted for in this study.

Methodology

Sample Locations

The intercalibration was designed to sample four different possible water parameters that might be encountered during an RMP sampling event: 1) low contaminant concentration sites; 2) high contaminant concentration; 3) low and 4) high salinity locations.

Samples were collected at six locations, three in 1996 and three in 1997. In 1996, Redwood Creek (BA40) and Coyote Creek (BA10) were sampled on June 27, and Golden Gate (BC20) was sampled on June 28. In 1997, the Sacramento River (BG20) and San Joaquin River (BG30) were sampled on January 29, and Standish Dam BW10 was sampled on January 22. Redwood Creek, Coyote Creek, and the Standish Dam site have been shown to have high concentrations of contaminants in previous RMPs; Golden Gate has low concentrations of contaminants and high salinity, and the river sites have low salinity.

Samples were collected simultaneously with the intakes of the two sampling tubes less than one meter apart. All samples were collected as in previous RMP cruises (except the Golden Gate site of 1996, where approximately 200 L of water was collected, rather than the usual 100 L.

Analysis of Samples at the University of Utah

The extracts in this intercalibration were analyzed separately by BBI and the UU (i.e., the XAD samples were extracted and quantified at UU, and BBI samples were extracted and quantified by BBI). This is not normal protocol for RMP, and may explain some of the differences seen (see below).

Briefly, the method is:

Filter cartridges: Samples were spiked with surrogate recovery standards, and the cartridges were extracted in gravity flow columns sequentially with methanol and methylene chloride. The extractions were combined and the phases were separated. In addition, to check the method recovery, a post-extraction rinse (PER) was taken of each cartridge (pesticides only). This was essentially a second complete extraction of the cartridge.

XAD columns: Each of the two columns (samples consist of two parallel XAD columns) was spiked with extraction surrogates, and eluted in reverse with methanol and methylene chlorine in a method similar to the filter cartridges. The separate extracts were then combined and separated into two fractions on Florisil.

Both these extraction methods were based upon standard EPA and AXYS extraction protocols.

The extracts were subjected to Florisil column chromatography resulting in two fractions, a PCB/aliphatic and pesticide/aromatic fractions. In the 1996 intercalibration, a polar third fraction, which contains diazinon and dacthal, was not taken, however, it was added for the 1997 samples.

Blanks: Blanks of the XAD columns and GFCs were transported with the sample columns and filters on both the 1996 and 1997 cruises. Blank data are reported in the full technical report.

Results

Pesticides

Levels

The pesticide levels (total of particulate and dissolved) of the 1996 intercalibration cruise are near, or within the range of the previous values generated by the BBI system during the intercalibration and previous RMPs for all three stations. For example, total DDE levels for Redwood Creek range from 82 to 140 pg/L (cruises 5, 8–9), and are 69 pg/L during the intercalibration for the XAD sampler and 78 pg/L for the BBI system.

DDE levels at the Golden Gate range from 11 to 61 pg/L during the RMP, and are 36 pg/L (XAD) versus 85 pg/L (BBI) for the intercalibration. The BBI value of 85 pg/L is one of the highest values for DDE ever reported at Golden Gate.

In general, however, the agreement between systems, even at very low levels, is very good. For example, chlordane levels for both systems were very similar at all stations (Figure 1).

As with the 1996 pesticide intercalibration, there are no clear differences between the data generated in previous RMP cruises and either the XAD or BBI sampler in the 1997 intercalibration. For example, levels of diazinon in the Sacramento River are similar between the XAD and BBI sampler during the intercalibration, higher in the San Joaquin BBI samples, and higher in the XAD sample from the Standish Dam (Figure 2). However, the intercalibration samples for both the XAD and BBI sampler are similar to past RMP cruises. An exception to this is the 1997 San Joaquin samples which are higher (in both samplers) than past winter or spring RMP cruises (as is the values for sum DDTs; Figure 2).

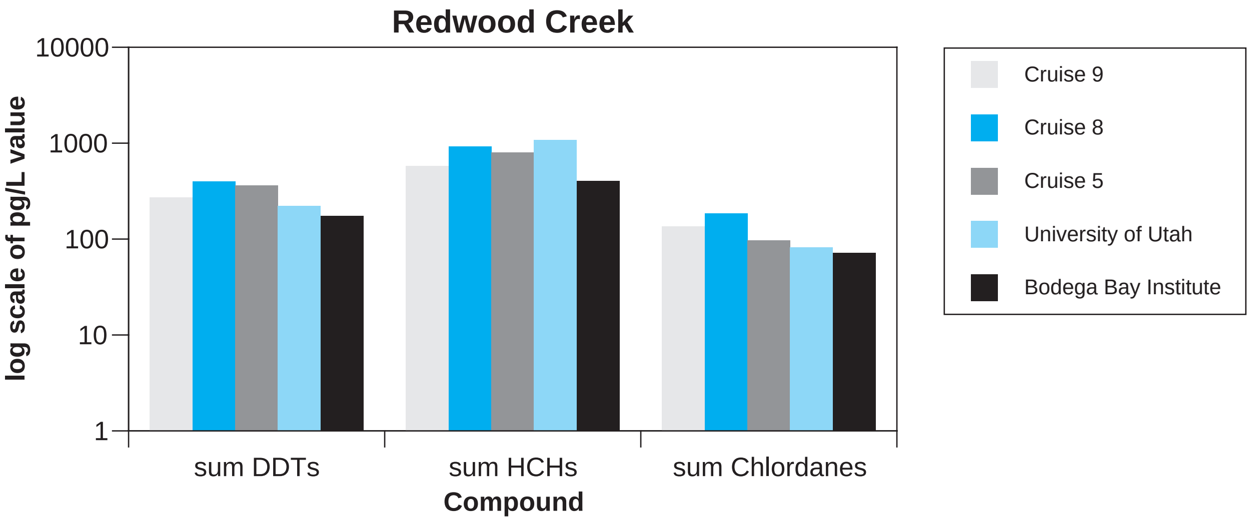
Levels of other pesticides (HCHs and chlordanes) are similar for both the intercalibration and past RMPs (Figure 2).

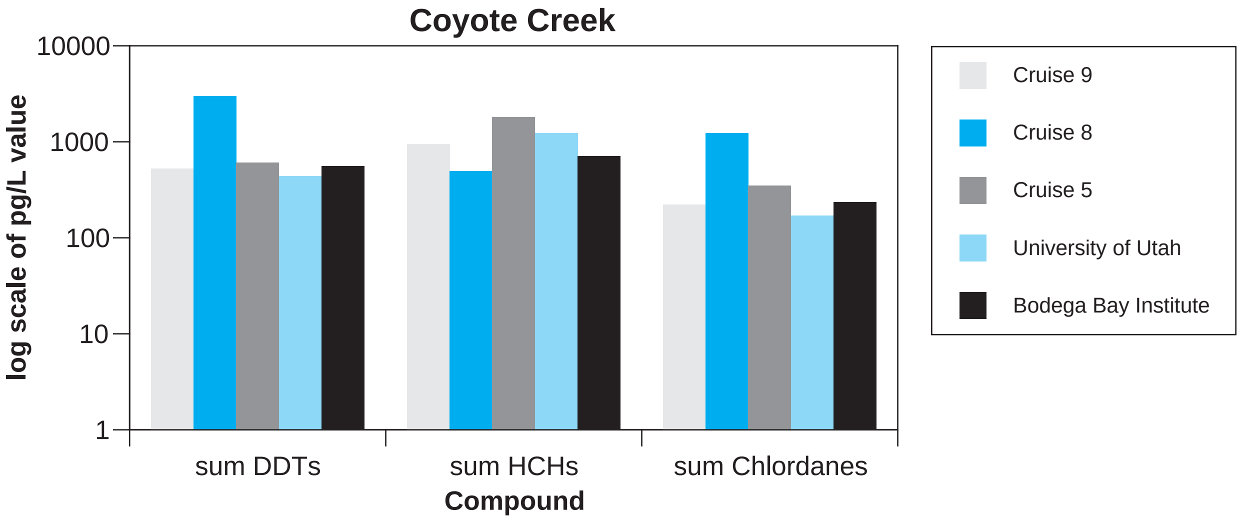
Ratios

One of the major differences between the PUF and resin systems is the particulate filter. As mentioned above, the AXYS system had a wound glass fiber cartridge system (GFC) and the BBI system uses a flat-glass fiber filter system (GFF).

In an attempt to examine the partitioning between the dissolved and particulate phases, the ratio of the pesticides (dissolved/particulate concentration) for the 1996 and 1997 intercalibration were compared.

In 1996, some of the ratios of dissolved to particulate concentrations were lower in the XAD sampler; however, many of the ratios were similar (e.g., DDTs, chlordanes-except HE). In particular, the ratios of the HCH compounds are much lower in the system. However, the ratios of the XAD sampler are within those values generated in cruises 5, 8, and 9.





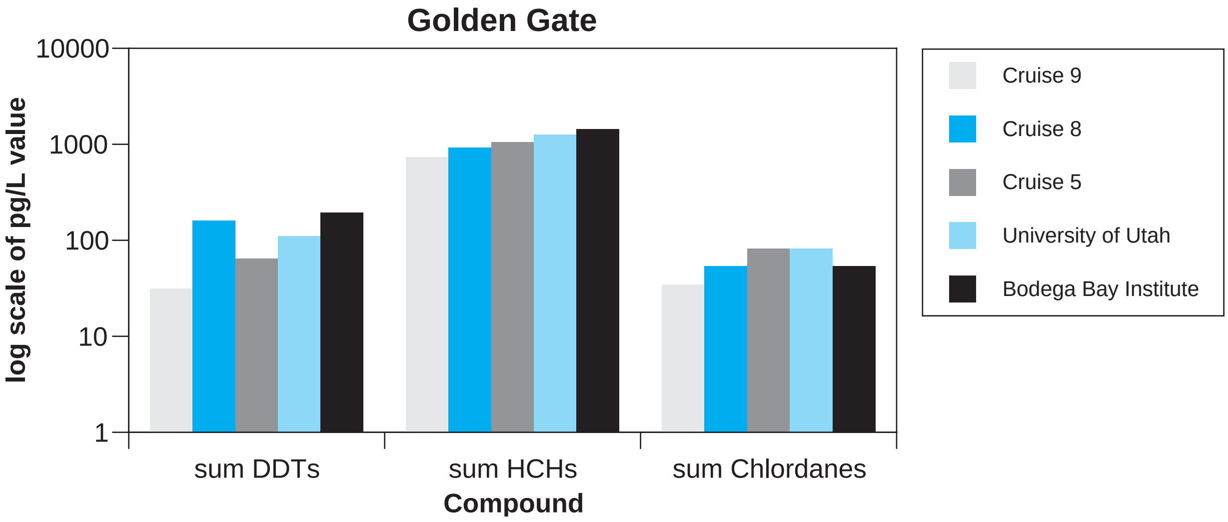


Figure 1. 1996 Dissolved + Particulate Pesticides.

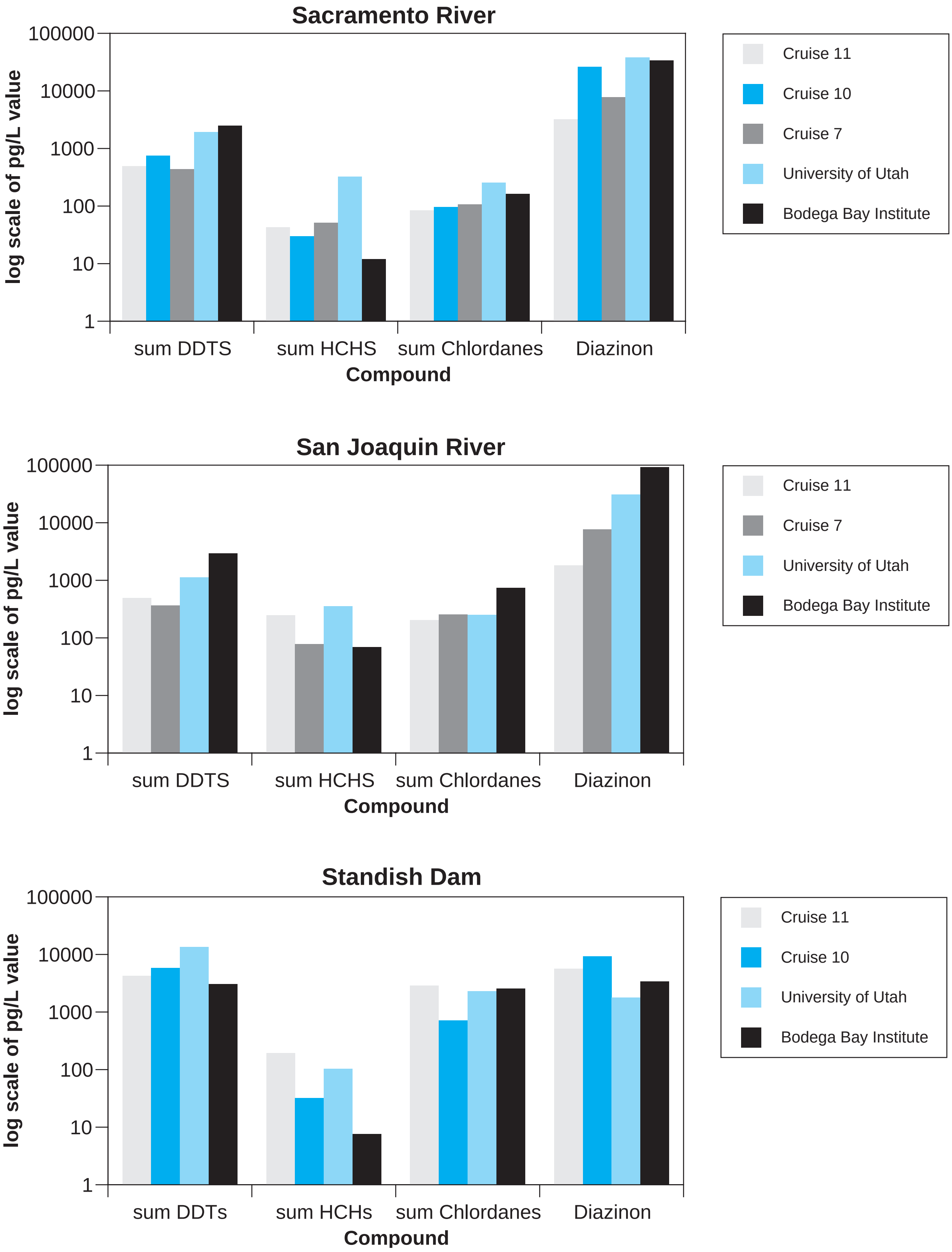


Figure 2. 1997 Dissolved + Particulate Pesticides.

In the 1997 intercalibration the ratios are more similar between the systems, and are often higher in the XAD system. In particular, with the HCH compounds there is a reverse of the 1996 data in that the XAD ratios are higher than the BBI ratios. In addition, the BBI DDE ratio for Standish Dam is 1,000, which is probably a data error.

At this time it is impossible to determine why the ratios were low in the 1996 cruise. It is very probable though, that the laboratory method used for extraction of the pesticides on the resin has improved though method development, resulting in higher ratios in 1997. We will continue to examine the dissolved/particulate ratio in the future to attempt to clarify this trend.

Blanks: Blanks for both the 1996 and 1997 intercalibration show no or very low pesticide contamination (data are reported in the full technical report).

Polychlorinated Biphenyls

Levels

In 1996, the levels of polychlorinated biphenyls in the blanks were very high in both the filters and columns. This contamination was traced to the ventilation air in the Applied Science building at U.C. Santa Cruz (UCSC; we have now moved into a cleaner laboratory at UU and do not have problems with blank contamination). Unfortunately, this source was not identified before the intercalibration samples were extracted. This necessitated subtracting the PCB values for the blanks from the concentrations in the intercalibration samples, a practice not usually employed in the RMP trace organic water samples.

As with pesticides, except for the values of PCBs in the Golden Gate site, most of the concentrations in the AXYS sampler fell between previous RMP values. For example, ΣPCBs ranged from 980 to 2,700 pg/L during cruises 5, 8, and 9 at Redwood Creek, and values of ΣPCBs during the intercalibration were 1,100 pg/L. Levels of ΣPCBs at Coyote Creek ranged from 1,200 to 6,800 pg/L during the RMP and were 1,500 pg/L during the intercalibration.

High levels in the blanks make it impossible to compare values in the Golden Gate site. Also, because of the uncertainty associated with the blank corrected values, PCB congener profiles and dissolved/particulate ratios were not compared in the 1996 site.

The 1997 PCB intercalibration did not have blank problems. The sum PCBs (sum of the congeners for both the dissolved and particulate fraction) is presented in Figure 3. The sum PCB values for the XAD sampler are similar to previous cruises for the same season for all three sites. However, sum PCB data from the BBI sampler is much higher than in previous RMPs and the 1997 intercalibration sites (Figure 3). In addition, the congener profiles from the BBI 1997 samples are different than the sampler or previous RMP data; the 1997 BBI data has a greater percentage of higher chlorinated biphenyls (or lower percentage of lighter chlorinated biphenyls; Figure 4).

This bias probably results from differences in analytical methodology, rather than differences in the sampler characteristics. This conclusion is supported by two observations. First, as mentioned in the methods, the PCB data in the intercalibration was generated entirely by the BBI, and this is not normal protocol for the RMP; in all of the past RMPs all the water sample chemical extracts were analyzed by the UU (or prior to 1997 by the same group at the UCSC). Secondly, is has been noted by Davis *et al.* (1997) that there is a great deal of analytical variation between laboratories in the analysis of PCBs in water extracts from RMP sites.

Ratios

The clean blank in the 1997 intercalibration allow the comparison of dissolved to particulate ratios between the samplers. There is no clear trend between the XAD and BBI samplers as to higher or lower ratios. In other words, the particulate/dissolved ratio is sometimes higher in the XAD sampler, and sometimes lower. There is no discernable pattern with regard to degree of chlorination, nor is there a pattern relating to high or low concentration sites (i.e., the river sites versus the Standish Dam)

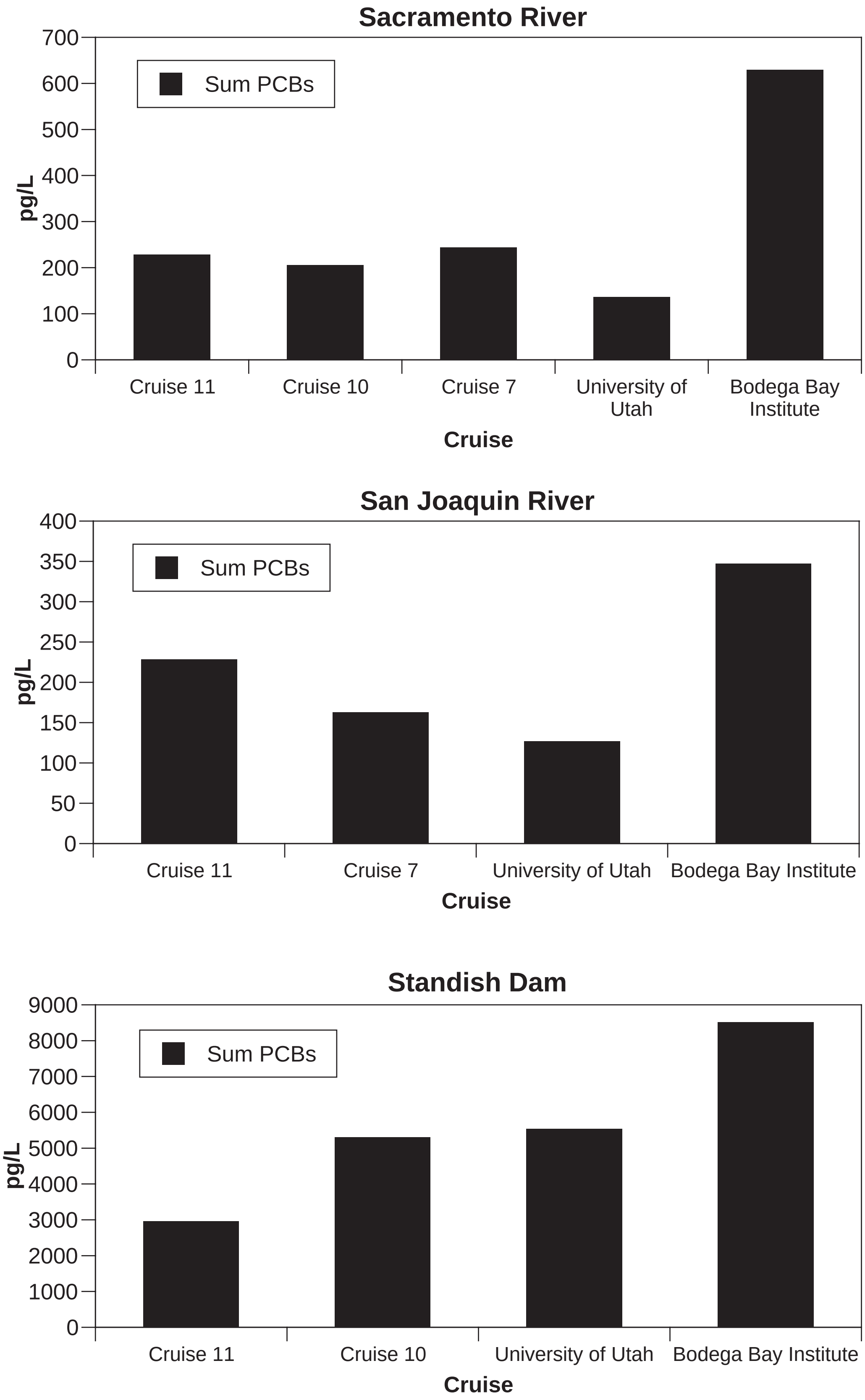


Figure 3. 1997 Sum PCB Congeners Dissolved + Particulate.

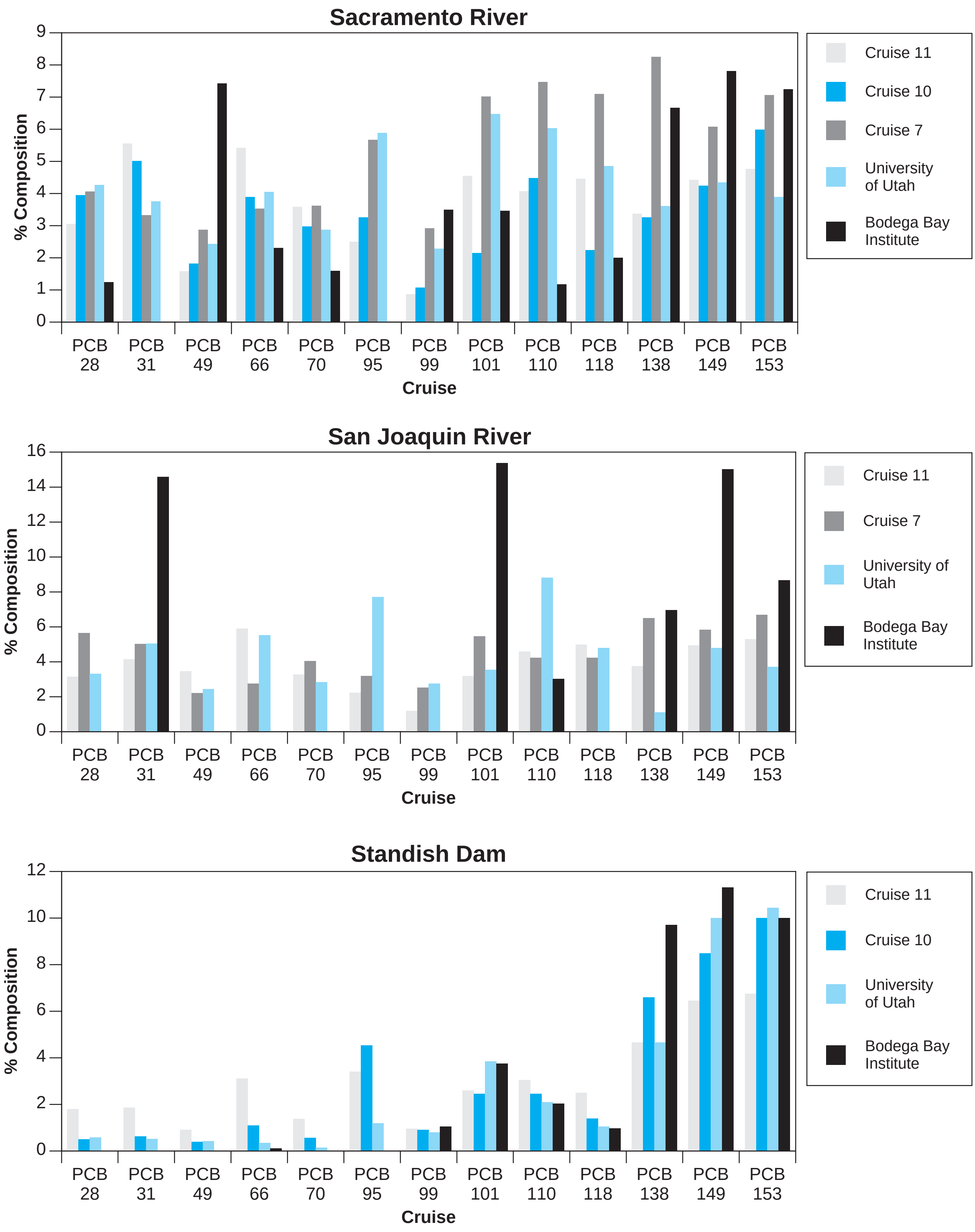


Figure 4. 1997 PCB Congeners Dissolved + Particulate.

As far as PCBs are concerned, the dissolved/particulate ratio is very similar between samplers.

Polycyclic Aromatic Hydrocarbons (PAHs)

Levels

Levels of PAHs in the blanks were very low in both the columns and glass fiber filters, except naphthalene and 2-methylnaphthalene in the blank in 1996.

The concentrations of the PAH compounds between the samplers used during the intercalibration and for the previous RMP are similar for most of the compounds analyzed (Figures 5 and 6).

In the 1996 intercalibration, the levels of PAHs in the XAD sampler were slightly lower, in general, than in those reported by the BBI sampler in the intercalibration or during RMP cruises 9 and 8 (levels of PAHs compounds during Cruise 8 in the south bay were some of the highest recorded to date in the RMP).

The levels at the Golden Gate site, which are some of the lowest in the RMP, are in general very comparable, with some exceptions (e.g., fluoranthene). However, as mentioned above, PAH levels are generally lower in the AXYS system.

However, in the 1997 intercalibration the value of individual PAHs are more similar between the systems.

The sum PAHs for the 1997 intercalibration, and RMP cruises 7, 10, and 11 are summarized in Figure 5. Both the Sacramento River and Standish Dam sum PAHs are similar between the samplers and within values generated in previous RMPs. Values for the sum PAHs for the San Joaquin River samples are elevated in BBI sampler (Figure 5). This is probably due to the extremely high value reported for benzo[g,h,i]perylene (13,000 pg/L).

Profiles of the major individual PAHs for cruises 10, 11, and the intercalibration show similar profiles for most compounds except for 1-methylnaphthalene, 2-methylnaphtalene, fluorene, and as mentioned above, benzo[g,h,i]perylene. Similar to the PCBs, these discrepancies are probably a result of difference in the method of quantification, rather than inherent differences between samplers.

Ratios

Ratios of the dissolved to particulate concentration for RMP cruises 8–11 and the 1996 and 1997 intercalibrations are very similar between samplers; for example, ratios high in the RMP often have high ratios in the intercalibration (e.g., phenanthrene (s)); and similarly low ratios in the RMP are often accompanied by low ratios in the intercalibration (e.g., benzo[e]pyrene). The extremely high ratios of naphthalene are probably indicative of contamination (possibly in the resin).

Quality Control

Besides blanks, two other quality assurance (QA) steps were investigated during the intercalibration. The first was the checking of efficiency of the XAD columns to extract the analyte from water; this was done by attaching a second column in series with the first during sampling at Redwood Creek (BA30).

A second QA check was performed by extracting the particulate filter two separate times with solvents to check the extraction efficiency of the solvents. This was done because surrogates spiked onto the filters do not truly mimic compounds that may be attached or “trapped” to particulates or solids.

Serial Columns

Most of the breakthroughs for the pesticides are less than 20%. Only DDE has significant breakthrough (34 and 44 %) in both (columns 1 and 2) “after” columns.

Excluding the naphthalene compounds (because of their high blank values), the PAH compounds have a breakthrough percentage of between 2 and 36%. Most of the compounds have a breakthrough of less than 20%.

Since this type of experiment has never been done before in the RMP, interpretation of the data is difficult. As a general rule, recoveries of surrogates in extractions should be between approxi-

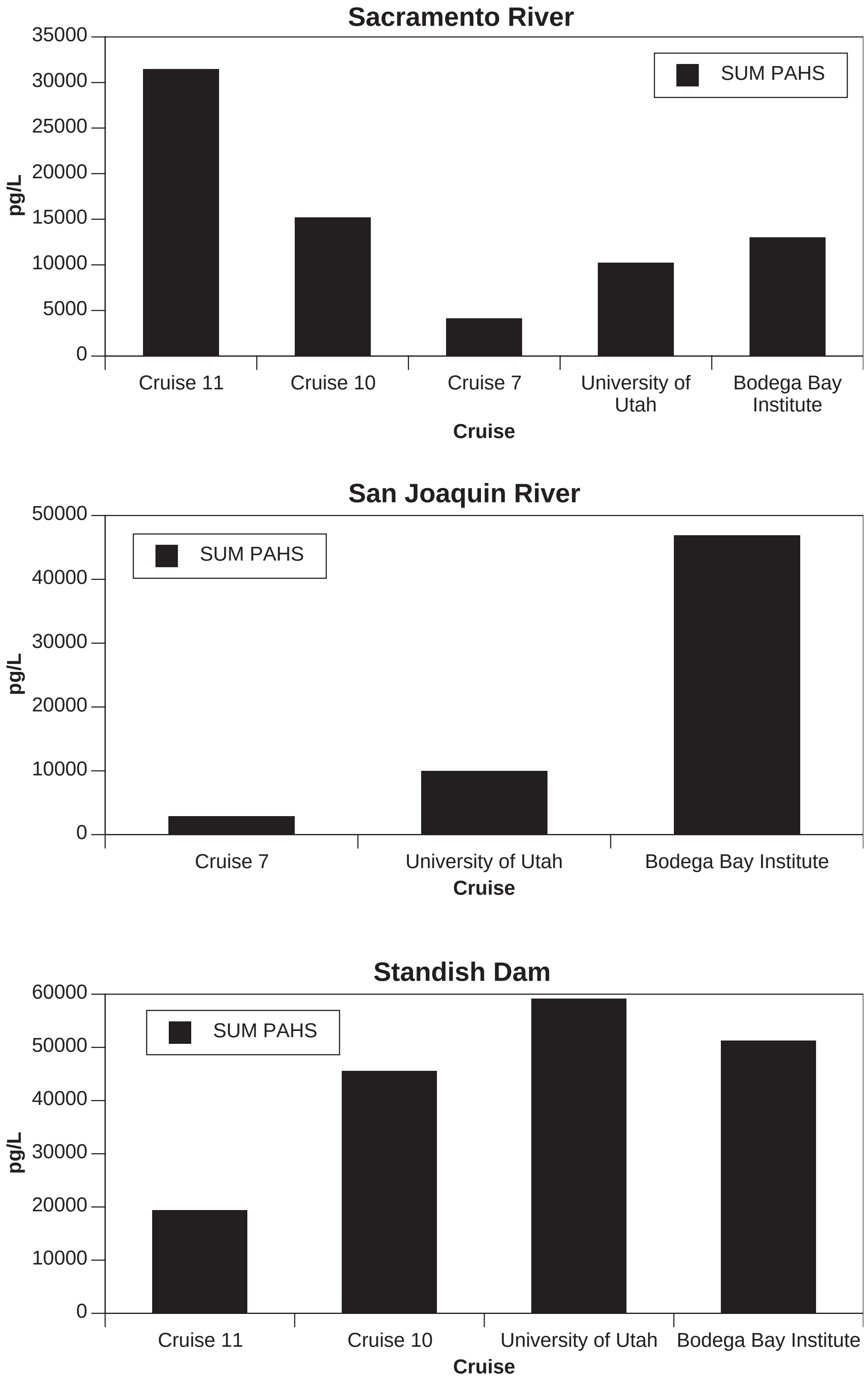


Figure 5. 1997 Sum of PAHs Dissolved + Particulate.

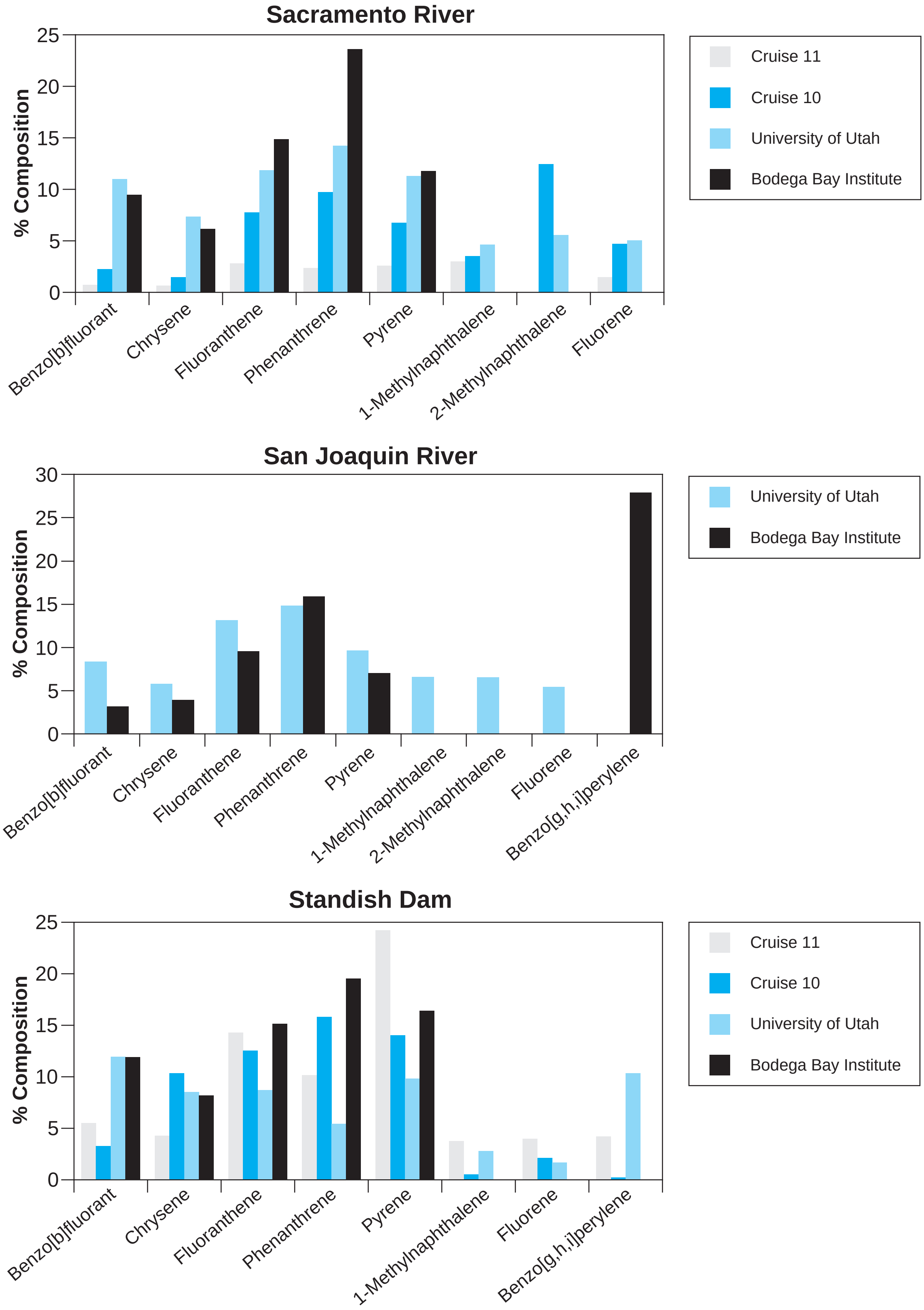


Figure 6. 1997 Primary PAHs Dissolved + Particulate.

mately 50–120%, but this is widely considered very liberal.

To better interpret these data, we recommend that serial recovery columns be analyzed at least once a year in the RMP. In addition, recovery data from the BBI sampler consisting of the analysis of individual plugs will allow comparisons to these data.

Post-extraction rinse

Except for DDE and some of the chlordane compounds, greater than 90% of the pesticides are extracted in the first extraction step. Because of the carry-over of DDE in the post-extraction rinse (PER), additional extractions will be performed on filters in the future. This method will also then be validated for PCBs, pesticides, and PAHs.

Conclusions

In general, levels of pesticides, PCBs, and PAHs are similar between the XAD sampler and BBI sampler. In addition, comparison of temporal trends in past RMPs show the data generated by the sampler to be very similar to past RMP data from the same season.

In fact, it appears from these data that differences generated during laboratory and instrumental methods are probably greater than the differences between the sampling systems.

The ratios of the dissolved to particulate concentrations between the systems was different for some of the 1996 compounds, but in the 1997 intercalibration, the ratios are very similar. This probably reflects improved laboratory methods used in the extractions of the absorbent. This indicates that the differences between the GGF and the GFC particulate filters are not as great as originally believed, and in fact the filters seem to have very similar properties.

High blank levels of PCBs from the UCSC laboratory prohibit detailed (e.g., congener profiles) comparisons in 1996, but by 1997 this contamination had been addressed, and blanks were found to be clean. High naphthalene concentrations were found in some blanks, but not all, and this contamination will be further investigated. Other than the high PCB (in 1996 only) and naphthalene blank levels, all other compounds were very low in both the glass fiber filter and columns.

Data from the serial columns indicate some breakthrough (generally < 20%) from the first column into the second. We recommend continuing this practice to better quantify breakthrough.

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Appendix E
Tables for Chapter 5:
A Review of Monitoring with Bivalves

Table 1. Regressions of *Mytilus californianus* measurements versus chlorophyll, dissolved oxygen, salinity, temperature, and total suspended solids. For non-significant regressions, the most important environmental parameters and the direction of the effects are indicated. For example, tissue concentrations of copper are negatively related to chlorophyll and positively related to dissolved oxygen.

Bivalve Variable	R^2	P	Regression Equation[a]
Condition	.650	<.0001	Y = 0.007chl + 0.020DO – 0.089
Tissue Growth	.729	<.0001	Y = 0.751DO + 0.067sal – 7.271
Percent Lipid	.490	.0005	Y = 0.440chl + 3.109 DO + 0.438sal – 29.718
Survival	.588	<.0001	Y = 31.337sal – 0.596sal^2 – 308.851
Tissue Silver	.242	.0157	Y = 0.235DO + 0.067temp – 2.655
Tissue Cadmium	.236	.0031	Y = 7.722 – 0.320chl
Tissue Chromium	.212	.0710	-DO, -sal, +TSS
Tissue Copper	.120	.1294	-chl, +DO
Tissue Lead	.419	<.0001	Y = 0.197temp – 1.237
Tissue Mercury	.103	.1751	-chl, +TSS
Tissue Nickel	.198	.0066	Y = 34.095 – 0.931sal
Tissue Selenium	.124	.1050	+sal, -temp
Tissue Zinc	.578	<.0001	Y = 80.621DO + 28.981temp – 11.296chl – 817.999
Tissue PAHs	.451	.0003	Y = 104.444 – 8.691DO – 0.475TSS
Tissue PCBs	.229	.0075	Y = 1.424sal – 8.202
Tissue Chlordanes	.183	.0183	Y = 6.723 – 0.136sal
Tissue DDTs	.192	.0564	-chl, -sal
Tissue HCHs	.142	.0402	Y = 0.933 – 0.025sal

[a] chl = chlorophyll (mg/m^3), DO = dissolved oxygen (mg/L), sal = salinity (parts per thousand), temp = temperature (°C), TSS = total suspended solids (mg/L)

Table 2. Regressions of *Crassostrea gigas* measurements versus chlorophyll, dissolved oxygen, salinity, temperature, and total suspended solids. For non-significant regressions, the most important environmental parameters and the direction of the effects are indicated. For example, tissue concentrations of silver are positively related to chlorophyll and negatively related to dissolved oxygen and total suspended solids.

Bivalve Variable	**R^2**	**P**	**Regression Equation**[a]
Condition	.384	.0091	Y = 0.212 - 0.007temp
Tissue Growth	.719	.0010	Y = 4.903 – 0.293temp
Percent Lipid	.745	.0007	Y = 5.982DO + 0.501sal + 0.037TSS – 49.953
Survival	.197	.0568	-temp
Tissue Silver	.323	.1303	+chl, -DO, -TSS
Tissue Cadmium	.369	.0251	Y = 39.501 - 2.8DO - 0.315sal
Tissue Chromium	.255	.0389	Y = 0.553temp – 4.695
Tissue Copper	.578	.0060	Y = 49.677 + 14.159sal + 2.421TSS– 19.677chl
Tissue Lead	.496	.0042	Y = 0.002TSS + 0.060temp – 0.447
Tissue Mercury	.276	.0208	Y = 0.113 + 0.009sal
Tissue Nickel	.294	.0618	-DO, -sal
Tissue Selenium	.328	.0510	-chl, +TSS
Tissue Zinc	.511	.0159	Y = 415.714 + 34.040sal + 4.699TSS – 32.394chl
Tissue PAHs	.697	<.0001	Y = 540.967 – 55.126DO
Tissue PCBs	.405	.0081	Y = 168.680 – 16.648DO
Tissue Chlordanes	.213	.2102	-DO, -temp
Tissue DDTs	.200	.2354	-DO, -sal
Tissue HCHs	.212	.2117	-chl, +TSS

[a] chl = chlorophyll (mg/m^3), DO = dissolved oxygen (mg/L), sal = salinity (parts per thousand), temp = temperature (°C), TSS = total suspended solids (mg/L)

Table 3. Regressions of *Corbicula fluminea* measurements versus chlorophyll, dissolved oxygen, salinity, temperature, and total suspended solids. For non-significant regressions, the most important environmental parameters and the direction of the effects are indicated. For example, tissue concentrations of cadmium are negatively related to salinity and positively related to temperature.

Bivalve Variable	R^2	P	Regression Equation[a]
Condition	.744	.0084	Y = 0.176 + 0.025sal – 0.006temp
Tissue Growth	.011	.8650	+sal
Percent Lipid	.133	.4218	-chl
Survival	.493	.0236	Y = 100.46 – 4.482chl
Tissue Silver	.789	.0095	Y = 0.303 – 0.019chl – 0.002TSS
Tissue Cadmium	.376	.1918	-sal, +temp
Tissue Chromium	.128	.3454	+TSS
Tissue Copper	.223	.1687	+temp
Tissue Lead	.173	.2316	+chl
Tissue Mercury	.194	.2028	+temp
Tissue Nickel	.354	.0696	-sal
Tissue Selenium	.147	.2741	-chl
Tissue Zinc	.362	.2072	-sal, +temp
Tissue PAHs	.346	.2192	+temp
Tissue PCBs	.761	.0105	Y = 38.666 – 7.327chl
Tissue Chlordanes	.580	.1765	-temp, -TSS
Tissue DDTs	.187	.3322	+chl
Tissue HCHs	.788	.0448	Y = 2.455 – 0.312chl – 0.070temp

[a] chl = chlorophyll (mg/m^3), DO = dissolved oxygen (mg/L), sal = salinity (parts per thousand), temp = temperature (°C), TSS = total suspended solids (mg/L)

Table 4. Regressions of mussel tissue contaminants versus water dissolved and particulate fractions. For non-significant regressions, the most important water fraction and the direction of the effects are indicated. For example, adjusted and unadjusted tissue concentrations of cadmium are both positively related to the dissolved fraction of cadmium.

Bivalve Variable	R^2	P	Regression Equation[a]
Adjusted Silver	.119	.0569	+dissolved
Unadjusted Silver	.189	.0091	Y = 0.186 + 24.379dissolved
Adjusted Cadmium	.022	.3928	+dissolved
Unadjusted Cadmium	.037	.2288	+dissolved
Adjusted Chromium	-	-	-
Unadjusted Chromium	.083	.2978	-dissolved
Adjusted Copper	-	-	-
Unadjusted Copper	.357	.0069	Y = 534.775 – 67.675particulate
Adjusted Lead	.046	.2406	-dissolved
Unadjusted Lead	.060	.1510	-dissolved
Adjusted Mercury	-	-	-
Unadjusted Mercury	.298	.0191	Y = 0.369 – 4.911particulate
Adjusted Nickel	.061	.1455	-particulate
Unadjusted Nickel	.015	.4465	+dissolved
Adjusted Selenium	-	-	-
Unadjusted Selenium	.016	.6065	-particulate
Adjusted Zinc	.014	.5016	+dissolved
Unadjusted Zinc	.152	.0118	Y = 329.643 – 108.827dissolved
Adjusted PAH	.023	.4931	+dissolved
Unadjusted PAH	.100	.1078	+dissolved
Adjusted PCB	.338	.0023	Y = 18.667 + 0.052dissolved
Unadjusted PCB	.128	.0567	+particulate
Adjusted Chlordane	.165	.0442	Y = 2.708 + 0.007dissolved
Unadjusted Chlordane	.472	.0002	Y = 1.824 + 0.011dissolved + 0.015particulate
Adjusted DDT	-	-	-
Unadjusted DDT	.207	.1595	+particulate
Adjusted HCH	.008	.6790	+particulate
Unadjusted HCH	.004	.7519	-dissolved

[a] dissolved = concentration of dissolved fraction (parts per billion for metals, parts per trillion for organics), particulate = concentration of particulate fraction (parts per billion for metals, parts per trillion for organics).

Rows without regression equations (-) indicate non-significant relationships between independent and dependent variables (see text).

Table 5. Regressions of oyster tissue contaminants versus water dissolved and particulate fractions. For non-significant regressions, the most important water fraction and the direction of the effects are indicated. For example, adjusted and unadjusted tissue concentrations of cadmium are both negatively related to the particulate fraction of cadmium.

Bivalve Variable	R^2	P	Regression Equation[a]
Adjusted Silver	-	-	-
Unadjusted Silver	.049	.4262	-dissolved
Adjusted Cadmium	.091	.2104	-particulate
Unadjusted Cadmium	.055	.3333	-particulate
Adjusted Chromium	.017	.6391	-particulate
Unadjusted Chromium	.094	.2654	-particulate
Adjusted Copper	.182	.0771	-particulate
Unadjusted Copper	.357	.0069	Y = 543.775 – 67.675particulate
Adjusted Lead	.072	.2976	-particulate
Unadjusted Lead	.139	.1399	-particulate
Adjusted Mercury	.241	.0387	Y = 0.335 – 3.697particulate
Unadjusted Mercury	.298	.0191	Y = 0.369 – 4.911particulate
Adjusted Nickel	-	-	-
Unadjusted Nickel	.045	.3828	+dissolved
Adjusted Selenium	-	-	-
Unadjusted Selenium	.016	.6065	-particulate
Adjusted Zinc	.119	.1751	+dissolved
Unadjusted Zinc	.083	.2453	+dissolved
Adjusted PAH	.092	.3651	-particulate
Unadjusted PAH	.055	.4862	-particulate
Adjusted PCB	.198	.1708	+dissolved
Unadjusted PCB	.501	.0148	Y = 16.86 + 0.092dissolved
Adjusted Chlordane	-	-	-
Unadjusted Chlordane	.948	<.0001	Y = 2.297 + 0.025particulate
Adjusted DDT	-	-	-
Unadjusted DDT	.207	.1595	+particulate
Adjusted HCH	-	-	-
Unadjusted HCH	.007	.8100	-dissolved

[a] dissolved = concentration of dissolved fraction (parts per billion for metals, parts per trillion for organics), particulate = concentration of particulate fraction (parts per billion for metals, parts per trillion for organics).

Rows without regression equations (-) indicate non-significant relationships between independent and dependent variables (see text).

Table 6. Regressions of clam tissue contaminants versus water dissolved and particulate fractions. For non-significant regressions, the most important water fraction and the direction of the effects are indicated. For example, adjusted and unadjusted tissue concentrations of silver are both negatively related to the particulate fraction of silver.

Bivalve Variable	R^2	P	Regression Equation[a]
Adjusted Silver	.104	.4357	-particulate
Unadjusted Silver	.047	.6043	-particulate
Adjusted Cadmium	-	-	-
Unadjusted Cadmium	.110	.3483	-dissolved
Adjusted Chromium	-	-	-
Unadjusted Chromium	.097	.4522	+particulate
Adjusted Copper	-	-	-
Unadjusted Copper	.293	.1059	-dissolved
Adjusted Lead	-	-	-
Unadjusted Lead	.213	.2115	+particulate
Adjusted Mercury	.450	.0338	Y = 10.666 + 47767.19dissolved
Unadjusted Mercury	.233	.1574	-dissolved
Adjusted Nickel	-	-	-
Unadjusted Nickel	.0001	.9743	+particulate
Adjusted Selenium	-	-	-
Unadjusted Selenium	.549	.0224	Y = 4.292 – 10.527dissolved
Adjusted Zinc	-	-	-
Unadjusted Zinc	.096	.3833	+particulate
Adjusted PAH	-	-	-
Unadjusted PAH	.934	.0334	Y = 13.643 + 0.002particulate
Adjusted PCB	.971	.0288	Y = 19.31 + 0.006particulate – 0.032dissolved
Unadjusted PCB	.431	.2290	+particulate
Adjusted Chlordane	-	-	-
Unadjusted Chlordane	.096	.6114	+particulate
Adjusted DDT	-	-	-
Unadjusted DDT	.572	.1390	+dissolved
Adjusted HCH	.408	.3614	-dissolved
Unadjusted HCH	.979	.1439	-dissolved, -particulate

[a] dissolved = concentration of dissolved fraction (parts per billion for metals, parts per trillion for organics), particulate = concentration of particulate fraction (parts per billion for metals, parts per trillion for organics).

Rows without regression equations (-) indicate non-significant relationships between independent and dependent variables (see text).

Acronyms

AF	accumulation factor
Ag	silver
Al	aluminum
AMS	Applied Marine Sciences
ANCOVA	analysis of covariance
ANOVA	analysis of variance
As	arsenic
ASC	Ambient Sediment Criteria
BBI	Bodega Bay Institute
BDL	below detection limit
BPTCP	Bay Protection and Toxic Cleanup Program
Cd	cadmium
CHC	chlorinated hydrocarbons
CMP	Sacramento Coordinated Water Quality Monitoring Program
Cr	chromium
CTD	conductivity temperature depth
CTR	California Toxics Rule
Cu	copper
DDD	dichlorodiphenyldichlorethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DO	dissolved oxygen
DOB	dibromooctafluorobiphenyl
DOI	Delta Outflow Index
DWR	Department of Water Resources
EDTA	ethylene diamine tetraacetic acid
EIP	Estuary Interface Pilot Study
ELISA	enzyme-linked immunosorbent assay
EPA	Environmental Protection Agency
ERL	Effects Range-Low
ERM	Effects Range-Median
Fe	iron
GC/ECD	gas chromatograph/electron capture detectors
GFF	flat-glass fiber filter
HCH	hexachlorocyclohexane
Hg	mercury
HMB	hexamethyl benzene
HMW PAH	high molecular weight polycyclic aromatic hydrocarbon
ICP-AES	inductively coupled plasma atomic emission spectrometry
ITEQ	dioxin toxic equivalent due to dibenzodioxins and dibezofurans
LMW PAH	low molecular weight polycyclic aromatic hydrocarbon
MDL	method detection limit
mERMq	mean Effects Range-Median Quotient
mg/kg	milligram per kilogram
mg/L	milligram per liter

µg/kg	microgram per kilogram
µg/L	microgram per liter
Mn	manganese
MPSL	Marine Pollution Studies Laboratory
MSD	minimum significant difference
NA	not analyzed
ND	not detected or below the detection limit
ng/g	nanogram per gram
Ni	nickel
NiEDTA2	nickel complexed with ethylene diamine tetraacetic acid
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWQA	USGS National Water Quality Assessment
OBS	optical backscatter sensors
OC	organochlorines
OEHHA	Office of Environmental Health Hazard Assessment
PAH	polycyclic or polynuclear aromatic hydrocarbons
Pb	lead
PBO	piperonyl butoxide
PCA	principal components analysis
PCB	polychlorinated biphenyl
pg/g	picograms per gram
pg/L	picograms per liter
ppb	parts per billion
ppm	parts per million
ppq	parts per quadrillion
ppt	parts per trillion
psu	practical salinity unit
PUF	polyurethane foam
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
Regional Board	San Francisco Bay Regional Water Quality Control Board
RMP	Regional Monitoring Program for Trace Substances in the San Francisco Estuary
Se	selenium
SFEI	San Francisco Estuary Institute
SFBRWQCB	*see* Regional Board
SIM	selected ion monitoring
SJSC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SRCSD	Sacramento Regional County Sanitation District
SRTPCP	Sacramento River Toxic Pollutant Control Program
SRWP	Sacramento River Watershed Program
SQG	sediment quality guidelines
SSC	suspended-solids concentration
SWI	sediment water interface
TEF	dioxin toxic equivalency factor
TEQ	dioxin toxic equivalent
TIE	toxicity identification evaluation

TL	tolerance limit
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WER	water effects ratio
WQC	water quality criterion
WQO	water quality objective
XAD	cross-linked amberlight divinyl benzene (adsorbent resin)
Zn	zinc

Glossary

Ag: The chemical symbol for silver, a trace metal measured by the RMP.

Al: The chemical symbol for aluminum, a trace metal measured by the RMP.

aliquot: A subsample taken from a field sample (e.g., of sediment).

ambient: Refers to the overall conditions surrounding a place or thing. In the case of the RMP, *ambient monitoring* is used to determine existing pollutant levels in the San Francisco Estuary.

ammonia: A colorless gas which is less dense than air and has a penetrating odor. It is the fourth largest industrial chemical produced, with over 80% used in the manufacturing of agricultural fertilizers.

amphipods: An order of small shrimp-like crustaceans, such as sand fleas. Many live on the bottom of the Estuary (i.e., are benthic) and feed on algae and detritus.

analyte: A targeted compound that is analyzed in a test.

anthropogenic: Effects or processes that are derived *from human activities*, as opposed to natural effects or processes that occur in the environment without human influences.

arenaceous: Resembling, derived from, or containing sand.

arthropod: Any member of a large phylum of invertebrate animals with jointed legs and a segmented body, such as insects, crustaceans, arachnids, myriapods, and trilobites.

As: The chemical symbol for arsenic, a trace element measured by the RMP.

assemblage: A group of persons, animals, plants, or things gathered together.

(automated) Winkler titration: The process of determining the amount of a certain substance contained in a known volume of a solution by measuring volumetrically how much of a standard solution is required to produce a given reaction.

axial transect: A line which follows the deep channel along the length or “axis” of the Estuary. Most RMP stations are on this axial transect, also known as the “spine”.

Base Program: Standard RMP monitoring conducted primarily for the purposes of characterization and trends, i.e. water, sediment, and tissue cruise sampling and analyses at the stations normally sampled, excluding special and pilot studies.

Basin Plan: The SFBRWQCB’s plan for the Estuary basin. This includes the land and waters within the boundaries of the immediate San Francisco Bay watershed, Suisun Marsh, and the western part of the Sacramento-San Joaquin Delta.

benthos, benthic: Bottom dwelling; non-planktonic; attached to or resting on the substrate.

bioaccumulation: The buildup of contaminants in an organism’s tissues (usually fatty tissue) through ingestion, or contact with the skin or respiratory tissue. Contaminants that bioaccumulate may also biomagnify in the food web, resulting in higher tissue concentrations in predators relative to ambient environmental concentrations.

bioassay: A laboratory test using live organisms to measure biological effects of a substance, factor, or condition. The effect measured may be growth, reproduction, or survival.

bioavailability: The extent to which a compound is available for intake by organisms. Bioavailable compounds have the potential to cause biological effects, such as increased mortality.

biogeochemical cycle: The cycle in which nitrogen, carbon, and other inorganic elements of the soil, atmosphere, etc. of a region are converted into the organic substances of animals and plants of the region and released back into the environment.

biological condition index: A measure of the biological condition of RMP transplanted bivalves expressed as the ratio of tissue dry weight to shell cavity volume.

biomagnification: The net effect of bioconcentration (accumulation of pollutants via dermal or respiratory tissue exposure), bioaccumulation (accumulation via ingestion), and depuration (excretion or loss of pollutants via metabolic processes).

biomass: Total weight of all organisms in a particular habitat or area.

biomonitoring: Monitoring conducted to determine existing environmental conditions, pollutant levels, rates, or species in the environment.

biota: The animals, plants, and microbes that live in a particular location or region.

bivalves: Any mollusk, such as an oyster or clam, that has a shell with two hinged “valves” or shell halves.

blooms (algal): A population burst that remains within a defined part of the water column.

brackish: Somewhat salty water that is less salty than seawater.

calcareous: Being made of calcium carbonate.

Cd: The chemical symbol for cadmium, a trace metal measured by the RMP.

chironomids: Small, two-winged flies in the adult stage, closely related to mosquitoes and Chaoborus (Phantom Midge or Glassworm). Most lay eggs singularly or in strings while skimming over the water surface. The eggs hatch into larvae and form mud tubes from bottom material and muscous. A few species have free swimming larva.

chlordanes: A contact insecticide used in agriculture until 1978 to control soil pests, particularly termites. It belongs to a group of closely related organochlorines, which includes aldrin, dieldrin, endosulfan, and heptachlor.

chlorinated hydrocarbons: A group of organic compounds which includes PCBs, DDTs, chlordanes, and dieldrin.

chlorophyll *a*: A key substance in the process of photosynthesis. It is found with photosynthesizing organisms and is used in the RMP as a measure of the abundance of photosynthetic organisms in the water column (phytoplankton).

community: The organisms inhabiting a common environment and interacting with one another.

congener: A compound of the same kind.

conventional pollutant: As specified under the federal Clean Water Act, conventional pollutants are total suspended solids, fecal coliform bacteria, biochemical oxygen demand, pH, oil, and grease. In addition, there are a large number of nonconventional and toxic pollutants that are of concern.

copepod: A type of herbivorous microscopic crustacean. They are important in the food chain because they are eaten by many fish or by other organisms that are eventually eaten by fish.

Cr: The chemical symbol for chromium, a trace metal measured by the RMP.

criterion: A standard rule or test on which a judgment or decision can be based.

crustacean: Any of a class of arthropods, including shrimps, crabs, barnacles, and lobsters, that usually live in the water and breathe through gills; they have a hard outer shell and jointed appendages.

Cu: The chemical symbol for copper, a trace metal measured by the RMP.

DDD (dichlorodiphenyldichlorethane): DDD was a commonly used pesticide in the past, but is now banned in the United States.

DDE (dichlorodiphenyldichloroethylene): DDE is found in the environment as a result of the breakdown of the insecticide DDT. DDE has been listed as a pollutant of concern to the U.S. EPA's Great Waters Program due to its persistence in the environment, potential to bioaccumulate, and toxicity to humans and the environment. *See also* DDTs.

DDT (dichlorodiphenyltrichloroethane): The combination of DDT and its degradation products, DDD and DDE. A chlorinated hydrocarbon that was a highly effective, but extremely persistent organic pesticide. DDT was extensively used in the past for the control of insects (crop protection and disease control). In 1972 its use was banned in the United States, except in the case of a public health emergency.

Delta Outflow Index (DOI): Freshwater flows from the Delta into San Francisco Bay. The DOI is calculated as total Delta inflow plus precipitation, minus in-Delta uses and exports.

depuration: The loss of contaminants from an animal's gut or tissue.

"detectable difference" criterion: A significance test which is based on the minimum significant difference (MSD) values.

dinoflagellate: Any of numerous minute, chiefly marine protozoans or algae of the order *Dinoflagellata*, having two flagella and a cellose-covering. They are a main constituent of plankton.

dischargers: Public and private organizations that discharge treated wastewater, cooling water, or urban runoff, or are involved in dredging activities.

dissolved compounds: Compounds that are present (dissolved) in the water and, therefore, are available for fish and other aquatic animals.

dry-season sampling period: RMP sampling carried out between July and September.

Effects Range-Low (ERL): Part of the Effects Range sediment quality guidelines, established by the National Oceanic and Atmospheric Administration. The guidelines were developed to identify concentrations of contaminants associated with biological effects in laboratory, field, or modeling studies. The ERL value is the concentration equivalent to the lower 10th percentile of the compiled study data. Sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects. *See also* ERM.

Effects Range-Median (ERM): Part of the Effects Range sediment quality guidelines established by the National Oceanic and Atmospheric Administration. The guidelines were developed to identify concentrations of contaminants associated with biological effects in laboratory, field, or modeling studies. The ERM is the concentration equivalent to the 50th percentile of the compiled study data. Sediment concentrations above the ERM are "frequently" associated with adverse effects. *See also* ERL.

effluent: An outflow from a sewer or sewage system.

ELISA analysis: Enzyme-linked immunosorbent assay that tries to determine the nature, proportions, and function of the examined parts.

El Niño: El Niño is a disruption of the ocean-atmosphere system in the tropical Pacific and have important consequences for weather around the globe.

elutriate: To purify, separate, or remove by washing, decanting, and settling.

embayment: Forming into a bay or a formation resembling a bay.

equilibrium predictions: A theoretical model or experimental determination of reactions, that describes the ratio of concentrations of the product to the reactant. It expresses chemical activity in terms of related concentration.

estuary: A body of water at the lower end of a river which is connected to the ocean and semi-enclosed by land. In an estuary, sea water is measurably diluted by freshwater from the land.

Fe: The chemical symbol for iron, a trace metal measured by the RMP.

fluorometer: An instrument to detect and measure the emission of fluorescence.

food web: The rather linear food chains (from plants through herbivores and carnivores) tend to be woven into a complex food web, where energy is transferred to all different levels.

foraminifera: Protozoan group (usually) secreting a calcareous shell; both planktonic and benthic representatives exist.

genus: A classification of plants or animals with common distinguishable characteristics. It is the main subdivision of a family and is made up of a small group of closely related species or of a single species.

grab: Benthic sampling device with two or more curved metal plates designed to converge when the sampler hits the bottom and grab a specific volume of sediment.

gravimetric method: Measurements by weight or of the pull of gravity.

HCH (hexachlorocyclohexane): A manufactured chemical that exists in eight forms, or isomers.

Hg: The chemical symbol for mercury, a trace metal measured by the RMP.

hydrocarbons: Organic compounds containing carbon and hydrogen.

ligand: An ion, a molecule, or a molecular group that binds to another chemical entity to form a larger complex.

linear regressions: A common practice in science to try to explain natural phenomena by models. The true regression of Y on X consisting of the means of populations of Y values, where a population is determined by X values. The regression line needs to be straight to develop a computation procedure.

LC_{50}: The concentration of a contaminant that is lethal to half the organisms in a bioassay.

loadings: The total amount of material entering a system from all sources.

marshes: A wetland where the dominant vegetation is non-woody plants, such as grasses and sedges, as opposed to a swamp where the dominant vegetation is woody plants, such as trees.

matrix: Any non-living, intercellular substance, in which living cells are embedded, as in bone, cartilage, etc.

mean Effects Range-Median quotient: Reflects the increasing contaminant concentrations in sediment from many contaminants and appears to provide a useful way to express the degree of overall sediment contamination. It was shown to have a highly significant correlation with amphipod survival.

method detection limit (MDL): The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. It is determined by analysis of a sample in a given matrix containing the analyte.

microfauna: Animals whose shortest dimension is less than 0.1 mm.

minimum significant difference (MSD): The lowest distinguishable difference that is statistically meaningful.

morphology: The study of form and structure, at any level or organization.

mysid: Small, shrimp-like, chiefly marine crustaceans of the order *Mysidacea*.

National Pollutant Discharge Elimination System (NPDES): A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the United States unless a special permit is issued by the U.S. EPA, a state, or other delegated agency.

neap tide: Tides with the smallest height difference between high tide and low tide, usually occurring during the moon's quarters. *Compare with* spring tide.

nematode: Any of a phylum of worms, often parasites of animals and plants, with long, cylindrical, unsegmented bodies and a heavy cuticle (e.g., hookworm, pinworm).

Ni: The chemical symbol for nickel, a trace metal measured by the RMP.

Niskin bottle: An oceanographic water sampling device.

oligochaete: Any of a class of segmented worms, such as the earthworm, lacking a definite head and having relatively few body bristles. They are mostly found in moist soil and freshwater.

oligotrophic: Water bodies or habitats with low concentrations of nutrients.

optical backscatter sensor: An instrument that measures total suspended solids (TSS), organic and inorganic particles of all sizes, in a certain volume of water.

organochlorine: A group of organic chemicals to which varying amounts of chlorine have been added. Organochlorine or chlorinated hydrocarbons (insecticides) are part of a broader class of halogenated hydrocarbons.

oxygen electrode: A terminal that conducts an electric current into or away from various conducting substances and collects and controls the flow of oxygen electrons.

“p” value: A confidence coefficent or a statistical value used in the multiple comparison procedure for comparing several treatments with a control.

PAHs (Polycyclic or Polynuclear Aromatic Hydrocarbons): A class of complex organic compounds, some of which are persistent and carcinogenic. PAHs are formed from the combustion of organic material and are ubiquitous in the environment.

particulate: A small, solid piece of matter that is easily lifted into the air, such as dust or ash. Smaller, fine particulates are more hazardous than larger, coarse ones because they are more easily inhaled deep into the lungs.

Pb: The chemical symbol for lead, a trace metal measured by the RMP.

PCBs (Polychlorinated Biphenyls): A group of manufactured chemicals including 209 different, but closely related, compounds made up of carbon, hydrogen, and chlorine. If released to the environment, they persist for long periods of time and can biomagnify in the food web. They are an organic toxicant suspected of causing cancer, endocrine disruption, and other adverse impacts on organisms.

pH: The acidity of water. A water quality parameter analyzed by the RMP.

peristaltic: Rhythmic, wavelike motion of the walls of the alimentary canal and certain other hollow organs. Alternating contraction and dilation of transverse and longitudinal muscles move the contents of the tube through the system.

pesticide: A general term to describe chemical substances used to destroy or control pest organisms, including herbicides, insecticides, algicides, and fungicides.

phaeophytin: A gray accessory plant pigment in green leaves. Accessory pigments help the plant to make more efficient use of sunlight because, unlike chlorophyll, they can trap energy from the wavelengths of light.

phytoplankton: Microscopic photosynthesizing organisms that drift with the currents.

pilot study: A study which employs methods that are under evaluation for potential incorporation into the RMP.

pollutant: A substance that adversely alters the physical, chemical, or biological properties of the environment.

pollution-index species: Species that are sensitive to a certain pollutant and that are monitored in terms of abundance and death in unpolluted and polluted areas. Measured in deaths per unit of pollution.

polychaete: (“with much hair”) Any of a class of primarily marine, annelid worms that have a pair of fleshy, leg-like appendages covered with bristles on most segments.

principal components analyses (PCA): A method that gives ecologists their first ordination technique in which ordination scores are derived from the data matrix alone. It involves the simultaneous production of species and sample ordination scores in one integrated analysis. PCAs are used for the indication and indirect measurement of environmental complexes.

protozoan: Any of a large group of single-celled, usually microscopic eukaryotic organisms, such as amoebas.

pseudopod: A temporary cytoplasmic protrusion from an ameobid cell which functions in locomotion or in feeding by phagocytosis.

red tide: A dense outburst of phytoplankton (usually dinoflagellates) often coloring the water reddish brown.

resuspension: The condition of a substance whose particles are dispersed through a fluid but not dissolved in it.

runoff: An overflow of fluid not absorbed by soil, such as rainfall.

salinity: The number of grams of dissolved salts in 1,000 grams of sea water. In the RMP it is expressed as ‰ (parts per thousand).

Se: The chemical symbol for selenium, a trace element measured by the RMP.

sediment pore water: The parts of water that are in channels or passages in the suspended material on the bottom of a fluid through which it may be absorbed or discharged.

sediment quality guidelines (SQG): The National Oceanic and Atmospheric Administration (NOAA) provided these guidelines, which are based on data compiled from numerous studies in the United States that linked sediment contamination and biological effects information. They were developed to identify concentrations of contaminants associated with biological effects in laboratory, field, or modeling studies.

sediment quality triad: A sediment assessment technique that incorporates information about sediment chemistry, toxicity, and benthos. The RMP is monitoring all three components and uses this information to evaluate the condition of the estuarine sediment.

sediment water interface (SWI): An exposure system that mimics situations that may occur in nature when negatively buoyant bivalve embryos contact sediment before hatching. Comparison of test results with other manipulating tests allows for the evaluation of possible effects related to the elutriate preparation process.

semidiurnal tide cycle: The two high and two low tides per lunar day (24.84 hours). In the San Francisco Bay-Delta, the cycle is known as a mixed semidiurnal cycle, since the two high and the two low tides are of unequal height.

shoals (broad and lateral): Shallows or sandbars in a body of water.

special study: A study initiated by the RMP in order to help improve interpretation or collection of RMP data.

speciation: The process of formation of a new species.

species: A fundamental biological classification, comprising a subdivision of a genus and consisting of a number of plants or animals all of which have a high degree of similarity, can generally interbreed only among themselves, and show persistent differences from members of allied species.

spectrophotometric method: A method used for comparing the color intensities of different spectra.

spring tide: Tides with the greatest range between highs and lows, usually occurring during the full or new moons. *Compare with* neap tide.

sulfides: A compound of sulfur with another element or a radical.

suspended-solids concentration (SSC): Organic or inorganic particles that are suspended in and carried by water. The term includes sand, mud, and clay particles, as well as solids in wastewater.

taxon: A group of organisms that has been formally named (e.g., species, genus, family, order, etc.).

tolerance limits: It is the maximum amount of a contaminant residue legally permitted by U.S. EPA, for example in drinking water.

total maximum daily load (TMDL): The TMDL process provides a flexible assessment and planning framework for identifying load reductions or other actions needed to attain water quality standards (i.e., water quality goals to protect aquatic life, drinking water, and other water uses). The Clean Water Act §303(d) established the TMDL process to guide application of state standards to individual water bodies and watersheds.

total organic carbon (TOC): This is the sum of organic carbon and is a monitoring parameter analyzed in environmental water programs. It is a physical sediment factor which can influence the concentration of other compounds. Represented variations in concentration can be attributable to spatial and temporal variations in sediment type.

toxic: Poisonous, carcinogenic, mutagenic, teratogenic, or otherwise directly harmful to life.

toxic equivalent: The combined potency of complex mixtures of compounds as an equivalent in toxicity.

toxic hot spots: Locations in enclosed bays, estuaries, or the ocean where pollutants have accumulated in the water or sediment to levels which (1) may pose a hazard to aquatic life, wildlife, fisheries, or human health, (2) may impact beneficial uses, or (3) exceed State Water Resources Control Board or Regional Water Quality Control Board-adopted water quality or sediment quality objectives.

toxicity: A measure of characteristics which are poisonous, carcinogenic, or otherwise harmful to life.

toxicity identification evaluation (TIE): A process used to determine the compound(s) responsible for toxicity in ambient waters, effluents, and sediments.

trace contaminants: Substances that pollute another substance, air, or water, and are found in low concentrations.

trace element: One of a group of naturally occurring elements found in low ("trace") concentrations in the water, sediment, and tissue measured by the RMP.

trace organic: An organic compound found in low ("trace") concentrations in the water, sediment, and tissue measured by the RMP.

transport: To carry from one place to another, especially over long distances.

trophic level: Representing one step in the food web with number of individuals, energy, or biomass.

trophic transfer: The energy transfer from one trophic level to another.

Total Suspended Solids (TSS): Organic and inorganic particles of all sizes suspended in a measured volume of water.

t-test: Statistical method for testing differences between two samples.

upstream: In the direction against the current of a stream.

upwelling: Vertical or upward movement of water. This usually occurs near the coasts and is driven by onshore winds that bring nutrients from the depths of the ocean to the surface layer.

water column: The water in a lake, estuary, or ocean which extends from the bottom sediments to the water surface. The water column contains dissolved and particulate matter and is the habitat for fish, plankton, and marine mammals.

water quality criteria: Specific levels of water quality which, if exceeded, are expected to render a body of water unsuitable for its designated beneficial use.

water quality guidelines: Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are non-enforceable guidelines issued by a governmental agency or other institution.

wet-season sampling period: RMP sampling carried out between January and April.

Zn: The chemical symbol for zinc, a trace metal measured by the RMP.