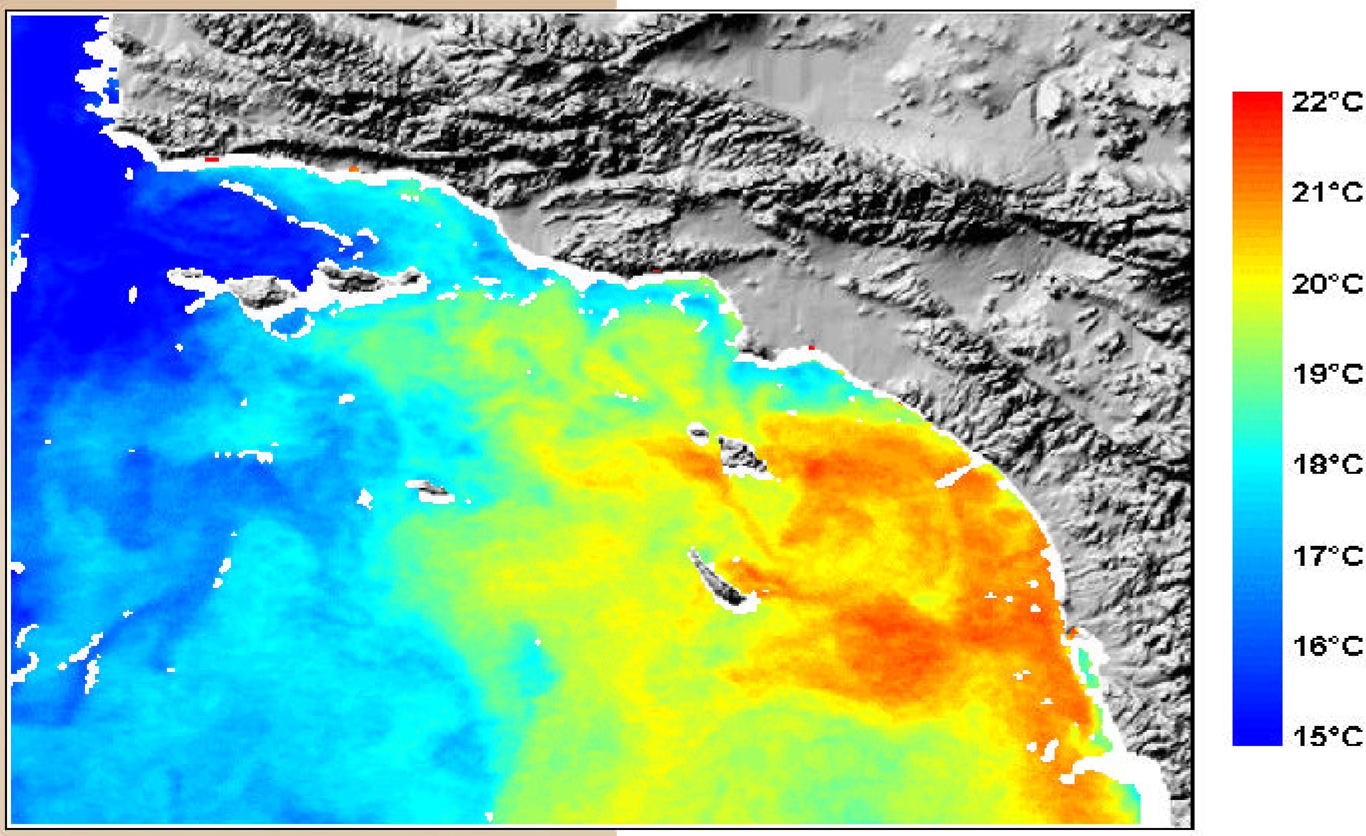
Executive Summary



Regional Marine Monitoring
BIGHT '98
Pt. Conception to Cabo Colnett

**SOUTHERN CALIFORNIA BIGHT
1998 REGIONAL MONITORING
PROGRAM
Executive Summary**

Organizations participating in the Bight'98 Regional Monitoring Program

AES Corporation
Algalita Marine Research Foundation
Aliso Water Management Authority
Aquatic Bioassay and Consulting
Center for Environmental Cooperation
Central Coast Regional Water Quality Control Board
Channel Islands National Marine Sanctuary
Chevron USA Products Company
City of Long Beach
City of Los Angeles Environmental Monitoring Division
City of Los Angeles Stormwater Division
City of Oceanside
City of Oxnard
City of San Diego
City of Santa Barbara
City of Ventura
Columbia Analytical Services
CRG Laboratories, Inc.
Divers Involved Voluntarily in Environmental
Rehabilitation and Safety
Encina Wastewater Authority
Goleta Sanitation District
Granite Canyon Marine Pollution Studies Lab
Houston Industries, Inc.
Instituto de Investigacione, Oceanologicas University
Autonomous de Baja California
Los Angeles Department of Water and Power
Los Angeles County Dept. of Beaches and Harbors
Los Angeles County Dept. of Health Services
Los Angeles Regional Water Quality Control Board
Los Angeles County Sanitation Districts
Marine Corps Base - Camp Pendleton
MBC Applied Environmental Sciences
MEC Analytical Systems, Inc.
National Fisheries Institute of Mexico
NOAA International Programs Office
NRG Energy, Inc.
Orange County Environmental Health Division
Orange County Public Facilities and Resources
Orange County Sanitation District
Riverside County Flood Control District
San Bernardino County Flood Control Department
San Diego County Dept. of Environmental Health
San Diego Interagency Water Quality Panel
San Diego Regional Water Quality Control Board
San Elijo Joint Powers Authority
Santa Ana Regional Water Quality Control Board
Santa Barbara Health Care Services
Santa Monica Bay Restoration Project
Secretaria de Marina (Mexican Navy)
Southeast Regional Reclamation Authority
Southern California Coastal Water Research Project
Southern California Edison
Southern California Marine Institute
State Water Resources Control Board
Surfrider Foundation
USC Wrigley Institute for Environmental Studies
University of California, Irvine
University of California, Santa Barbara
University of California Sea Grant
US EPA Region IX
US EPA Office of Research and Development
US Geological Survey
US Navy, Space & Naval Warfare Systems Center, San Diego

Southern California Bight 1998 Regional Monitoring Program:

Executive Summary

March 2003

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INTRODUCTION

Ocean dependent activities contribute over nine billion dollars to the coastal economy.

Southern California is home to nearly 20 million people making it one of the most densely populated areas in the United States. Its popularity results in part from access to the Pacific Ocean and a temperate climate that allows for year-round use of the coast. The coast is a valuable natural resource that contributes to the local economies of the region and enhances the quality of life for those who work in, live in or visit the area. Human uses of the coastline and ocean water of the Bight include recreation, tourism, aesthetic enjoyment, sport and commercial fishing, coastal development, and industry. Ocean-dependent activities contribute approximately nine billion dollars to the economies of southern California coastal communities and support over 175,000 jobs.

> ***What is the Southern California Bight?***
> *A bight is defined as a bend in the coastline, and the Southern California Bight is the 700 km (400 miles) of recessed coastline between Point Conception in Santa Barbara County and Cabo Colnett, south of Ensenada, Mexico. It is bordered in the east by land and in the west by the California Current. The dramatic change in the angle of the coastline creates a large backwater eddy in which subtropical waters flow north nearshore and subarctic waters flow south offshore. This unique oceanographic circulation pattern creates a biological transition zone between warm and cold waters that contains approximately 500 marine fish species and more than 5,000 invertebrate species.*

Less than 5% of the Southern California Bight is routinely monitored.

The high population density has led to extensive development, waste discharge and runoff along the southern California coast and in its watersheds. More than $31M is spent annually on environmental monitoring to assess the potential effects of human activities on southern California's coastal ocean, which is known as the Southern California Bight (SCB). Despite this large expenditure, only 5% of the SCB is routinely monitored because nearly all monitoring is focused on assessing individual sources of discharge. Moreover, the parameters measured, as well as the frequency and methodology by which they are measured, differ among monitoring programs throughout the SCB, hampering integration of data from these programs. While these programs generally collect high quality data, they are not designed to describe changes that occur on regional scales or to assess cumulative impacts from multiple sources.

The program consisted of three components: Coastal Ecology, Shoreline Microbiology and Water Quality.

Recognizing the need for an integrated assessment of the southern California coastal ocean, 62 organizations collaborated in 1998 to conduct a comprehensive assessment of the ecological condition of the SCB. Referred to as Bight'98, the program included three components: Coastal Ecology, Shoreline Microbiology and Water Quality. The goal of the Coastal Ecology Component was to assess condition of the living marine resources in the Bight and evaluate effects of their exposure to pollutants. The goal of the Shoreline Microbiology Component was to determine how much of the shoreline is meeting microbiological water quality standards. The goal of the Water

Quality Component was to define how far offshore we saw the effects of runoff from coastal watersheds.

This report provides an overview of the findings from Bight'98 and is intended for environmental managers and the general public. Volumes I through VIII are intended for a scientific audience and provide supporting details for the conclusions presented in this report. All volumes are available via the Internet (http://www.sccwrp.org).

Growth of Regional Monitoring

Bight'98 is an extension of a 1994 regional survey referred to as the Southern California Bight Pilot Project (SCBPP). The Pilot Project was an effort by 12 organizations to assess the feasibility of achieving regional assessments through integration of cooperative in-kind services. Bight'98 extends the Pilot Project by including more participants (62 vs. 12 organizations), new technical components (shoreline microbiology), and increased geographic range of sampling (Channel Islands, bays and harbors, Mexico). Based on the success of Bight'98, most of the participating organizations have agreed to continue their participation in ongoing regional monitoring every five years. Planning has already begun for the Bight'03 regional survey.

Bight'98 was a cross-border study.

While the focal point of Bight'98 was in the United States, it is the first study to compare coastal ecological condition of Mexico and the United States using the same sampling design, sampling methods and quality control procedures. Sampling in Mexico was coordinated through Univeristad Autonomous de Baja California and included a subset (sediment chemistry, benthic infauna, water quality and shoreline microbiology) of the parameters measured in the US. Since not all aspects of the Bight'98 monitoring program were conducted in Mexico, results from their sampling are reported in the technical scientific reports rather than in this summary document.

Introduction

The waste products of human activities are introduced to the marine environment through a variety of means, including industrial and municipal wastewater outfalls, runoff from urbanized watersheds, overboard disposal from boats and shipping, and atmospheric deposition. Once in the ocean, these materials may act as contaminants in the water column or in the seafloor environment, in some cases accumulating to levels that negatively affect the biological resources of our coastal waters. Introduced contaminants may also flow out of the SCB through ocean circulation, be degraded by organisms or become diluted below levels of concern.

415 sites were sampled for sediment chemistry, toxicity, benthic macrofauna and fish.

The Coastal Ecology Component of Bight'98 was intended to assess the spatial extent of contaminant accumulation in sediments and the effect of these contaminants on biota in the SCB. We focused on the seafloor environment because sediments act as the primary sink for much of what is discharged. A total of 415 sites were sampled for sediment chemistry, sediment toxicity, benthic macrofauna and fish (Figure 1), though not all sites were sampled for all parameters. Sample sites were selected using a stratified random sampling design that allowed the condition of the Bight to be accurately expressed in terms of surface area of seafloor affected. The stratified portion of the design allowed us to assess the relative condition of specific areas of interest within the Bight. These included areas influenced by ports, marinas, sewage treatment plant outfalls, and land-based runoff. Sampling sites were also placed in the Channel Islands to assess their condition relative to the mainland.

Sediment Quality Guidelines

Neither the State of California nor the U.S. EPA has yet to establish sediment quality criteria, but there are numerous sediment quality guidelines (SQGs) for relating sediment chemical concentrations to potential biological effects. There are two main types of SQGs - those based upon empirical relationships, and those based on the theory of equilibrium partitioning. For the Bight'98 survey, sediment contamination was evaluated using both the empirical and theoretical SQGs in an effort to provide the most thorough and accurate assessment of potential biological impacts. These two approaches agreed well on the overall amount of area in the SCB having contaminants at levels of biological concern, but they disagreed about the likelihood of effects on an individual site basis. Further work is needed to improve SQG performance at the contamination levels observed in the SCB.

Pollutant Exposure

Pollutants accumulate in sediments, which in turn become a source of contamination to marine food webs.

Pollutants often associate with particles and settle on the ocean floor. While some of the sediment-associated pollutants are degraded by microorganisms or by natural geochemical processes, many toxic pollutants are resistant to degradation and may persist in the sediments for long periods of time. Sediments act as a reservoir for pollution, which can be reintroduced to the water column when the

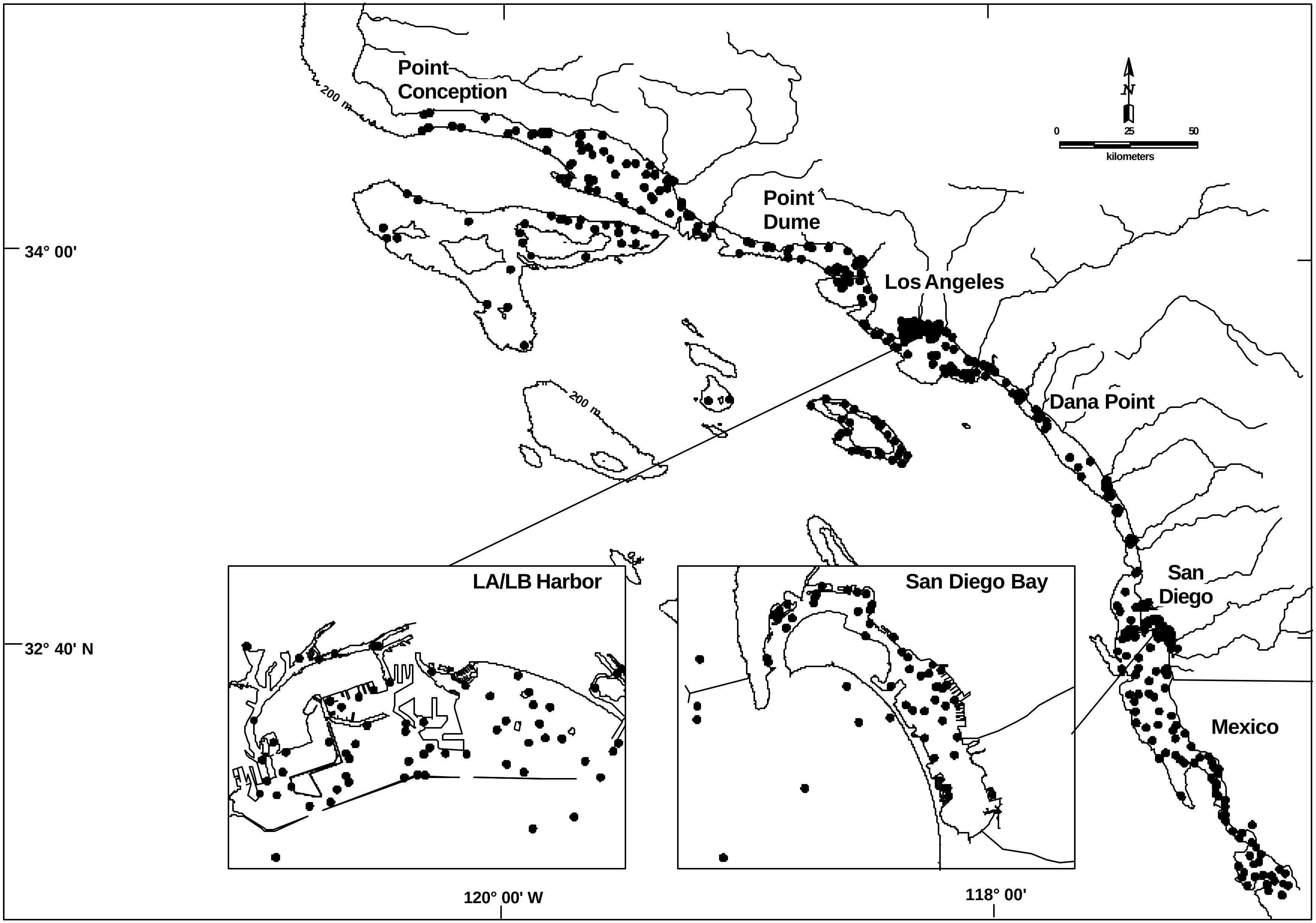

Figure 1. Coastal Ecology sampling locations for Bight'98.

sediments are disturbed. Sediments also serve as a source of exposure for animals that live in or feed within them, such as sea urchins, crabs, and flatfishes.

History of DDT Contamination in Southern California

DDT was produced and discharged to the Southern California Bight (SCB) by the Montrose chemical plant in Torrance, from 1947 to 1971 (when discharge was banned). It was primarily discharged in wastewater effluent via Los Angeles County's White Point Outfall on the Palos Verdes Shelf or disposed of at off-shore dump sites. Prior to 1971, up to 1,800 metric tons of DDT was discharged onto the Palos Verdes Shelf and up to 600 metric tons were dumped in the San Pedro Basin; since then, inputs of DDT to the ocean have been very low or undetectable. Some DDT also entered the ocean via other routes (e.g., runoff, and aerial fallout). Although DDT is widespread in sediments and marine life, present levels are more than an order of magnitude less than those 30 years ago. The Palos Verdes Shelf has been named a Superfund Site by the US Environmental Protection Agency, which is currently testing the feasibility of capping contaminated sediments.

Because marine sediments act as both a reservoir and conduit for contamination, the pollutant exposure assessment for Bight'98 focused on sediment quality. Chemical characterization of sediments included organic matter (total organic carbon, total nitrogen), metals, chlorinated pesticides, polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs).

A remnant of historical inputs, DDT and related compounds were the most widespread contaminants in the SCB sediments.

Approximately 86% of the SCB had detectable levels of contamination resulting from human activities. Consistent with previous regional surveys, the chlorinated pesticide DDT and its breakdown products were the most widespread. Detectable levels of DDT were found in 82% of the SCB. The use of DDT was banned in 1972, and most of the DDT reflected historical discharges. Enrichment of other contaminants (PAHs, PCBs, and trace metals) generally occurred in less than half of the SCB.

Sediment contamination was not equally distributed throughout the SCB. A disproportionate amount occurred within bay/harbor areas and in the vicinity of Publicly Owned Treatment Works (POTW) discharge zones (Table 1). Within bays and harbors, higher levels of contamination were typically associated with

Table 1. Comparison between percent of total SCB contamination occurring in selected habitats and the areal extent of those habitats.

Parameters	Bays & Harbors	POTW Areas	River Mouths	Other Coastal
Percent of SCB area that occurs in selected habitats	6.1	5.6	1.0	87.3
Percent of SCB trace metal or organic contamination occurring in those habitats				
Trace Metals	14.5	9.3	0.9	71.7
Organics	33.6	21.4	2.6	42.0

industrial, port and marina areas. For POTWs, most of the contamination was associated with the large POTW outfalls and is more reflective of historical discharges than of current inputs.

Although sediment contamination was widespread, most was at levels not expected to cause adverse biological impacts.

Although detectable levels of pollution in the SCB were widespread, sediment contaminant concentrations were generally below levels expected to cause adverse biological impacts. None of the SCB had concentrations that exceeded either EPA's equilibrium partitioning or National Oceanic and Atmospheric Administration's (NOAA) bulk sediment quality guidelines for pooled chemical groups. Only 12% of the SCB had levels that exceeded NOAA's guidelines for individual contaminants; these guidelines are considered more protective, but less reliable than the pooled analysis approach. Of the contaminants failing the individual contaminant guidelines, most were organic compounds (Figure 2).

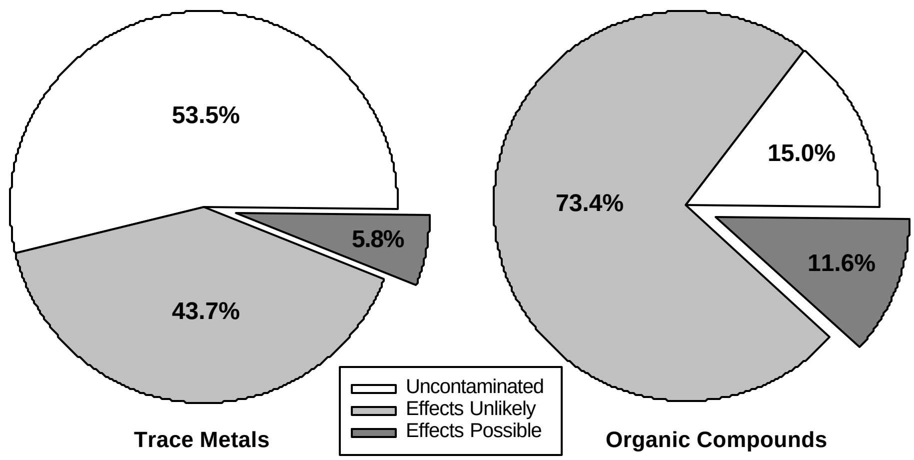

Figure 2. Percent of SCB area contaminated by trace metals and organic compounds, and the associated potential for biological effects.

Sediment Toxicity

Sediment toxicity tests are laboratory methods in which a sensitive species is exposed to whole sediment, or a sediment extract, and then observed for adverse effects such as mortality or reduced growth. These tests provide a direct measure of the biological effects of sediment contamination and provide data that is helpful for interpretation of the results of chemistry and benthic macrofauna analyses. Toxicity tests complement sediment chemistry data by providing a measure of the combined toxic effect of all contaminants present and accounting for the effects of factors (e.g., organic carbon) that may affect the biological availability of some constituents. Toxicity test data also aid in the interpretation of benthic community responses, which can be influenced by both habitat factors (e.g., grain size or salinity) and contamination. Laboratory tests are less influenced by habitat factors, so the toxicity results can be used to help determine the cause of population effects.

Eighty-one percent of the SCB had no evidence of concern for sediment toxicity.

High toxicity concern was present in only three percent of the SCB.

Sediment toxicity was most prevalent and more severe in port and marina areas.

Sediment Toxicity Tests

A wide variety of species and life stages are used in sediment toxicity tests. Several test methods should be used to measure sediment toxicity in order to accommodate species-specific variations in contaminant sensitivity and different modes of contaminant exposure. The toxicity tests used in Bight'98 included three methods. Bulk sediment was tested using an amphipod (Eohaustorius estuarius) survival test. Two additional tests were conducted to measure sublethal biological effects. Solvent extracts of the sediment were tested using the human cell reporter gene test, which measures the induction of an enzyme system involved in contaminant metabolism. In addition, the toxicity of sediment elutriates was evaluated by measuring the inhibition of bioluminescence in a species of phytoplankton (Gonyaulax polyedra). The results from all three test methods were combined using a weight of evidence approach to classify each sample with regard to relative concern for toxicity. A high level of concern was assigned to samples that produced severe toxic effects or that caused toxicity to multiple test species.

Eighty-one percent of the SCB contained sediment for which there was no toxicity concern (Figure 3). Three percent of the sediment showed high concern; sediments in this category caused high mortality (>50%) to a test species or caused toxicity to multiple species. The remaining 16% of SCB sediment had potential toxicity concern, meaning that it caused either less severe effects or produced toxicity in only a single test.

The greatest prevalence and severity of toxicity was present in port and marina areas within bays and harbors, where 35% of the area was of either potential or high concern. Toxicity was also detected in 22% of less developed bay habitats, but the effects were generally moderate (i.e., no sites were classified in the "High Concern" category). The extent of toxic concern within POTW and other coastal habitats were similar to one another (22% and 17%, respectively) and much less severe compared to port and marina areas. Sediments near river mouths showed the least extent of toxicity (13% of the area), although most of the toxicity was of high concern. All of the high concern river mouth sites were located near the Los Angeles River, which discharges behind the Long Beach Harbor breakwater, where calm waters enhance the deposition of contaminated sediments.

The Bight'98 toxicity results are similar to those reported in previous local studies of bays and harbors by the NOAA and the State Water Resources Control Board, where 14-66% of the area was reported to be toxic. The persistent occurrence of toxicity in port and marina areas indicates that sediment quality in many of these areas is not improving. These locations are good candidates for additional research designed to identify the cause and sources of toxicity.

The presence of toxic levels of concern in 17-22% of coastal and POTW areas contrasts with SCB regional monitoring results from 1994, when no sediment toxicity was detected in coastal habitats. The difference in results between these two studies is likely due at least in part to the use of different test methods. The 1994 toxicity assessment used only one measure of toxicity (amphipod survival) and the test species differed from that used in 1998. Differences in sensitivity between species and the lack of sublethal toxicity data in the 1994 assessment may have contributed to the different results obtained between studies.

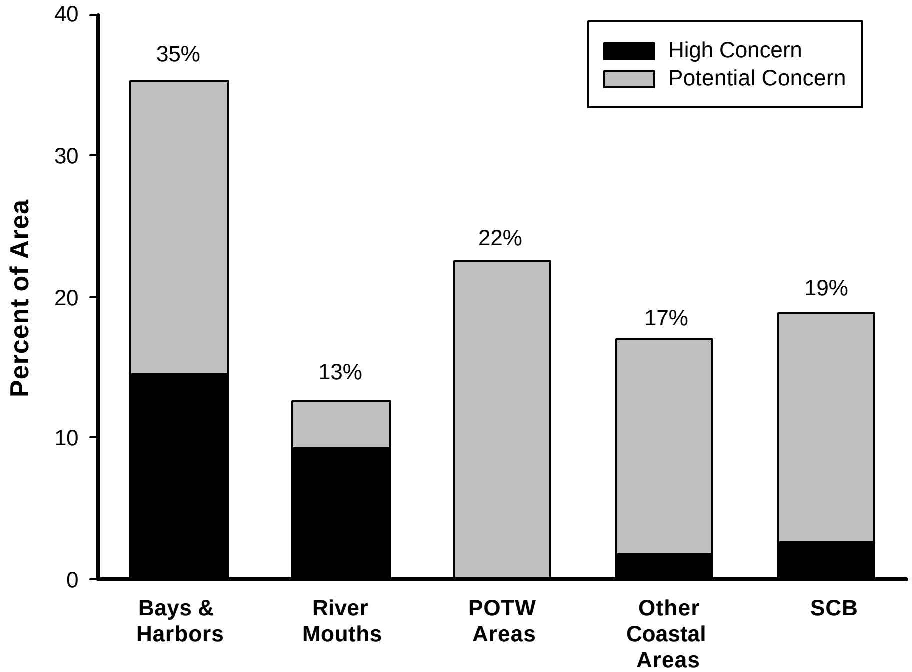

Figure 3. Percent of area within the SCB containing sediment toxicity of concern. The data reflect the combined effects of three toxicity tests.

Benthic Infauna

Benthic macrofauna, the community of animals (small worms, crustaceans, clams, etc.) that live within or on the sea floor sediments, have long been used as an indicator of human impacts in marine environments. They are suitable indicators of impacts because the sediments in which they live are a sink for pollutants resulting from man's activities. Because these animals have limited mobility and often directly consume sediments, they are sensitive to physical and chemical alterations of their environment. Additionally, the animals making up these communities have life spans (less than one to a few years) for community level responses to become evident on time scales appropriate to temporal changes in pollution levels.

Disturbance within benthic macrofaunal communities is detected by comparison to reference community condition. The reference condition has several alternate states depending on the nature of the habitat. We recognized five distinct reference communities in this study, primarily determined by water depth and sediment grain size characteristics. Understanding this variability in reference condition is necessary for the evaluation of impacts over the range of habitats considered in the study.

Eighty-eight percent of the SCB had macrofaunal communities typical of reference areas.

Clear evidence of community disturbance was evident in only two percent of the area.

Bays and harbors had the greatest extent of disturbed macrofaunal communities.

We found 88% of southern California sediments support benthic communities in reference condition (Figure 4). Another 10% were found to deviate only marginally from the condition (response level 1). Macrofaunal communities in the remaining 2% of the Bight exhibited stronger responses. These successively higher response levels (levels 2-4) provide clear evidence of community disturbance. At each level, fewer and fewer species are able to thrive, and deviation from the reference condition is greater.

Among the major habitats studied, bays and harbors were found to have the highest proportion (17%) of disturbed benthic communities. The extent of this disturbance was disproportionate at a regional scale, as bay and harbor habitats represent only 4% of the area of the Bight, but accounted for 37% of the area in which we found disturbed communities. Disturbed benthic communities were also observed in river mouth and offshore wastewater discharge areas, but the extent of disturbance in these areas was not substantially different from that in other open coastal areas. The islands were free of areas with disturbed communities.

> ***Biointegrity Indices***
>
> *Benthic macrofaunal animal communities are useful indicators of effects, but they are complex. Over 2000 species are found in SCB sediments, with more than 100 typically occurring in an individual sample. This complexity makes interpretation of macrofaunal data challenging and resource managers need a means of reducing this complexity to a concise, ecologically meaningful measure of community health. The 1994 Southern California Bight Pilot Project met this need by developing the Benthic Response Index (BRI). The BRI is a biointegrity index that provides a numeric representation of the degree to which the community at a given site differs from that found in reference areas. In Bight'98, we extended this approach to develop a similar index for enclosed bays and harbors. A description of how this index was developed and validated is presented in Volume VII of the Bight'98 reports.*

The macrofaunal community findings of this survey are similar to those of the SCBPP regional survey conducted in 1994 and are in contrast to historical benthic

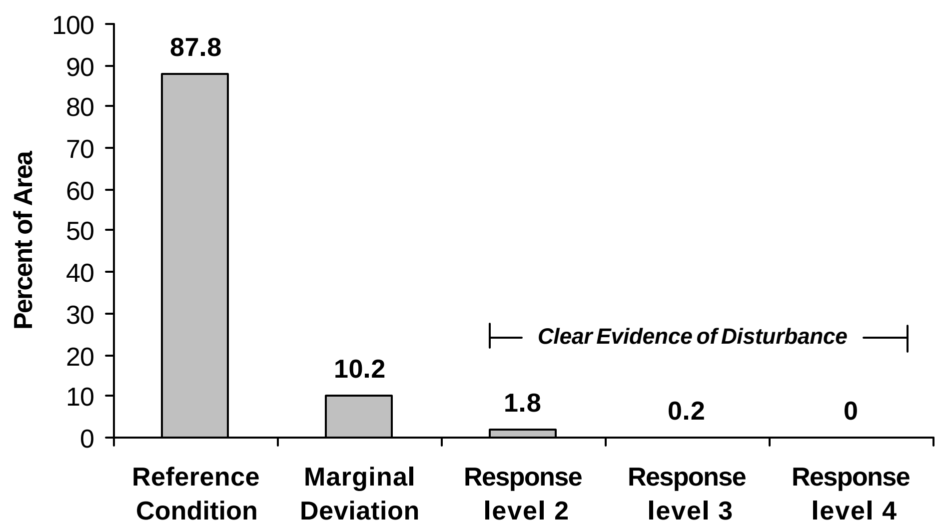

Figure 4. Percent of SCB containing reference or altered benthic macrofaunal communities

conditions. Twenty to thirty years ago, macrofauna in extensive areas of open coast habitat surrounding the larger wastewater outfalls were severely degraded. The modest degree and extent of disturbance found in this study (and in 1994) attest to the effectiveness of reduced emissions from these sources since the 1970s in ameliorating benthic impacts.

Non-Indigenous Species

Non-indigenous species (NIS) are foreign species that have been introduced to habitats beyond their natural range by the actions of man. These introductions are becoming more common as a result of the increasingly global nature of trade and transport. Among marine habitats, bays and harbor are particularly vulnerable to invasion, as they are sites of global shipping traffic. Many NIS have been introduced to US harbors through transport of larvae in the ballast water of transoceanic ships. NIS have the potential to be extremely disruptive when they invade native communities of plants and animals. They can displace native species, alter predator-prey relationships, change levels of primary productivity, and negatively alter the physical nature of habitats.

Non-Indigenous species where ubiquitous and disproportionately abundant in bays and harbors.

Within bays and harbors, we found non-indigenous species (NIS) to be ubiquitous and disproportionately abundant (Figure 5). NIS occurred at 121 of 123 of the bay and harbor sites we sampled. While only 4% of the species captured at these sites were NIS, they accounted for an average of 28% of the macrofaunal abundance, reaching 93% at one site. NIS were not confined to the major industrial harbors of Los Angeles/Long Beach and San Diego, but also occurred in abundance in all but one of the small recreational harbors. The dominant NIS were native to the Northwest Pacific (Japan and China), although species from other Pacific regions and the Atlantic were also represented. Despite the prevalence of these invaders, we found little evidence they were causing major disruption in the species richness or organism abundance of the native communities they have invaded. Rather, the invaded communities were characterized by greater numbers of native species and higher native species abundance when compared to bay and harbor communities lacking NIS. From this perspective, NIS in southern California's bays and harbors appear to act as additive elements to the communities in which they occur. However, in other settings NIS are known to displace or otherwise inhibit individual native species. The effects of NIS on individual native species was not examined in this study. Given the observed prevalence of NIS in southern California's bay and harbors, this should be a focus of future studies.

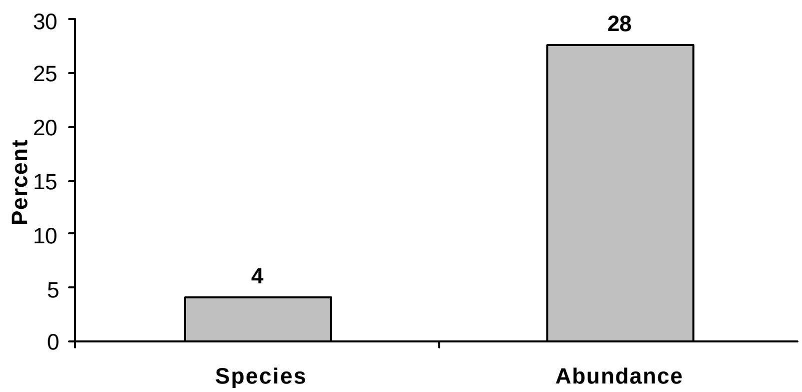

Figure 5. Non-indigenous species as a percent of species and abundance within southern California bays and harbors.

Demersal Fish

Demersal fish (fish living on or near the bottom) are an important part of the marine ecosystem, as well as being targets for commercial and recreational fisheries. They are good indicators of pollution effects because they live on the sediments where contaminants often accumulate. They generally have low mobility and are therefore responsive to local sources of contamination. These responses can include elevated tissue contaminant levels, prevalence of diseases or disrupted communities. These three responses (contamination, diseases, and community integrity) were used to assess the health of southern California's demersal fish in Bight'98.

Demersal fish communities were healthy in 1998, with normal (reference) communities being found in 97% of southern California. The few sites having communities that differed from reference were located near river mouths.

Fish communities were healthy, with a normal mix of species and low levels of disease.

The levels of diseases and parasites were low. We encountered no fin erosion, an important fish response to contaminated sediments. Disease prevalence was 0.5%, which is substantially less than the 5% prevalence that was typical of southern California in the 1970's. It is now comparable to background levels of disease in other areas of the United States.

Three-quarters of the SCB had fish with DDT at levels of ecological concern.

DDT in fish tissue was prevalent at levels of concern throughout the SCB, although it is the only contaminant that was prevalent. Ninety-nine percent of the fish examined had detectable levels of DDT (or its metabolites), including nearly 100% of the fish from the Channel Islands Marine Sanctuary. Seventy-one percent of the fish had concentrations above predator-risk guidelines. While this is of concern, further studies will be needed to assess true predator risk because bird and mammal predators are more likely to consume pelagic forage fish, rather than the demersal flatfishes that we measured. Moreover, DDT concentrations in southern California fishes have decreased more than an order of magnitude during the past three decades in both outfall and reference areas. While present predator risk needs to be better quantified, it is likely to be of lesser concern than it was two or three decades earlier.

DDT levels in fish have been declining over time.

> ***Are predators at risk?***
>
> *One objective of Bight'98 was to assess the percentage of fish that are contaminated at concentrations of concern to predators. There are no US DDT and PCB guidelines for predator risk, so we used guidelines developed by Environment Canada. While a large percentage of southern California fish exceeded these guidelines, assessing the risk to southern California predators will require further study. Bight'98 focused solely on demersal fish, which are more likely to be contaminated than pelagic fish. Pelagic fish are also more likely to be consumed by marine birds and mammals. Future studies are needed to examine whether other trophic pathways are of equal contamination concern as that of demersal fish.*

Some effects of the 1997-1998 El Niño on fish communities were apparent. Relative to the 1994 SCBPP regional survey, coldwater species were less widespread on the mainland shelf in 1998 and warm water species occurred more widely. Many important community members expanded or shifted their distributions to deeper parts of the shelf in 1998. Two fish species and three invertebrate species collected in the 1998 survey had never been reported in California prior to 1998; all normally occur south of southern Baja California.

> ***Is It Safe to Eat the Fish?***
> *The objective of the fish contamination study was to assess ecological risk rather than human health risk. Whole fish composites of fish were analyzed for DDT, PCB, and chlordane to assess potential health-risks to bird and mammal predators, using predator-risk guidelines. These data cannot be used to assess human health risks from seafood consumption as people typically consume muscle tissue rather than whole fish and because human health risk guidelines are higher. Typically, contaminant levels in muscle tissue are lower than those in whole fish. The National Oceanographic and Atmospheric Administration is presently conducting a comprehensive study of human health risk from DDT in southern California.*

The condition of bottom-living fish was assessed using small bottom trawls, which also catch debris. Anthropogenic debris, mostly plastic, metal, and cans, occurred in 25% of the southern California shelf. It was most common in areas frequented by boats, such as ports, marinas, and Santa Catalina Island.

Integration

Three types of indicators of coastal condition were used in Bight'98: chemical exposure (sediment and tissue), health of living resources (benthic macrofauna and demersal fish), and toxicity (e.g., survival). Each indicator provides valuable information about the health of the coastal environment, but no single indicator alone is sufficient to describe the overall status of the SCB. Integration of information from all indicators provides the most accurate assessment of the SCB. Comparisons among indicators also provide insight into the causes of observed impact.

Contaminant levels in fish and sediment were correlated.

The concentration of chlorinated hydrocarbons (DDTs and PCBs) in flatfishes was highly correlated with concentrations in adjacent sediments (Figure 6), indicating that sediment contamination is a dominant source of contaminant exposure to SCB marine life. Moreover, the strong relationship between sediment and fish tissue concentrations suggests that it is feasible to develop sediment quality guidelines that are related to food web responses.

Seventy-seven percent of the SCB did not exceed any impact threshold.

There was no evidence of impact from any of the three indicator types in 77% of the SCB (Figure 7). This assessment was based on the following thresholds: elevated sediment contaminants (mean ERMq >0.1), toxicity in the high concern category, and nonreference fish or benthic communities. Impacted areas were dominated by sediment contamination, with little correspondence among indicator types; 71% of the affected area was impacted by contamination only and less than 4% of the affected area showed impacts from both contaminants and any biological indicator.

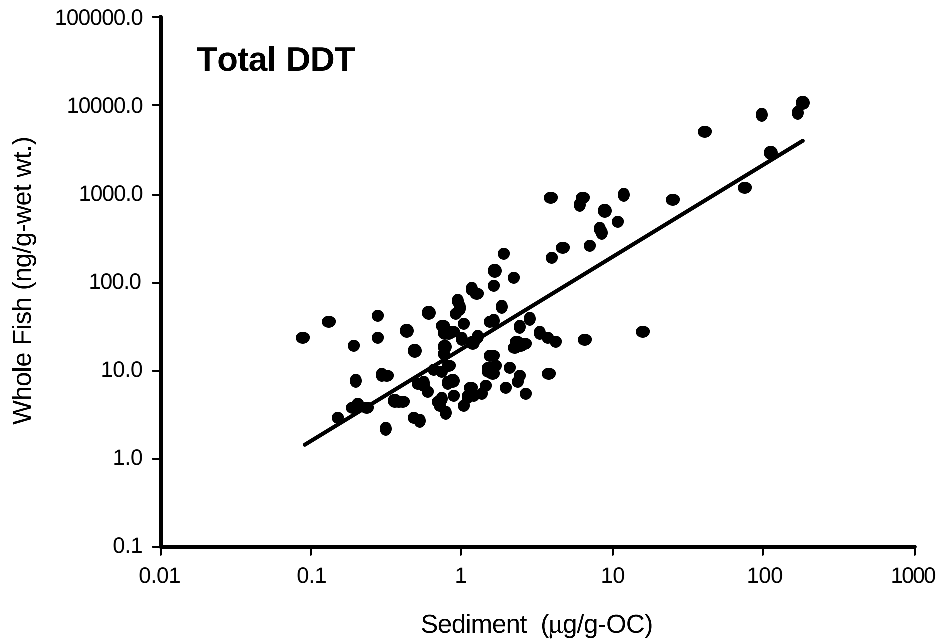

Figure 6. The relationship between total DDT bioaccumulation in whole fish and sediment concentration. Data for five species of flatfish are shown. Sediment concentrations have been normalized to sediment organic carbon content.

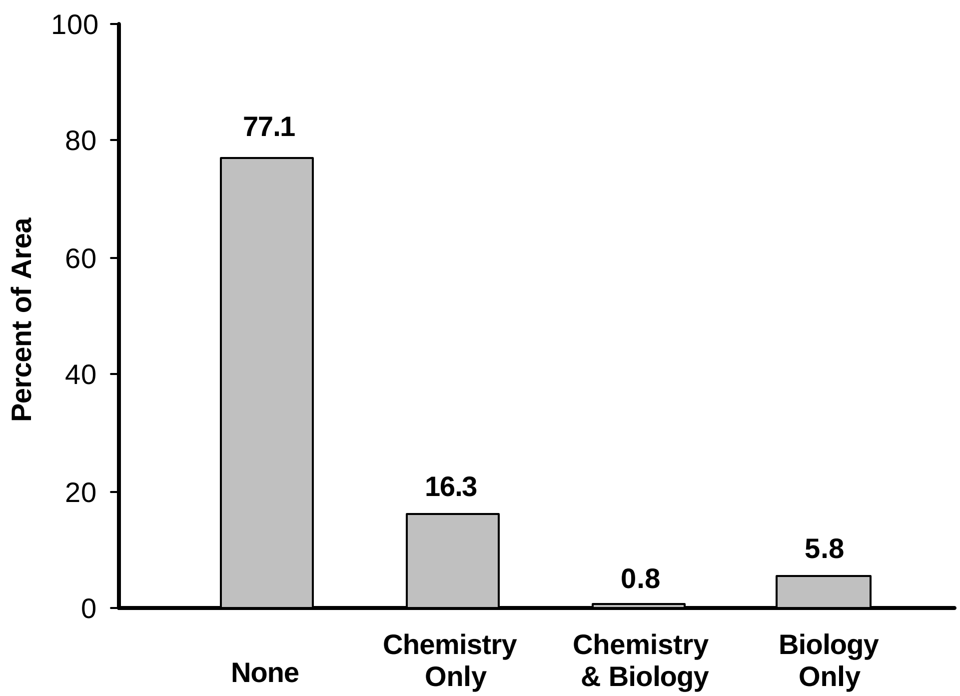

Figure 7. Percent of area within the SCB showing impacts to coastal ecology indicators based on sediment chemistry and/or biological effects (toxicity, benthic macrofauna, or fish).

Sediment contamination and biological effects co-occurred most frequently in Bays and Harbors.

Bays and harbors showed the greatest prevalence of impacts, with 66% of the area showing alterations in at least one indicator. A greater concordance among indicators was also observed in bays and harbors, where 37% of the impacted area exceeded both contaminant and biological thresholds.

Examination of the sediment chemistry, toxicity, and benthic macrofauna data for individual Bight'98 sites suggests several reasons for the relatively poor correlation among indicators in this study. First, the magnitude of sediment contamination in the SCB, as summarized by the mean ERM quotient, was relatively low compared to elsewhere in the United States. None of the Bight'98 sites contained mean quotients above 0.5, values that are usually associated with a greater incidence of toxicity. Previous studies have shown that the mean ERM quotient is not a reliable predictor of toxicity at the low to moderate contamination levels present at most areas of the SCB.

Changes in benthic macrofauna community composition showed a poor correspondence with the ERM-based sediment contamination index. Incremental increases in the contamination index were not associated with increasing alteration of the benthic community (Figure 8). This result suggests that existing methods for evaluating sediment contamination (e.g., ERM quotient) are not adequate to predict benthic macrofauna community-level impacts at individual sites in southern California.

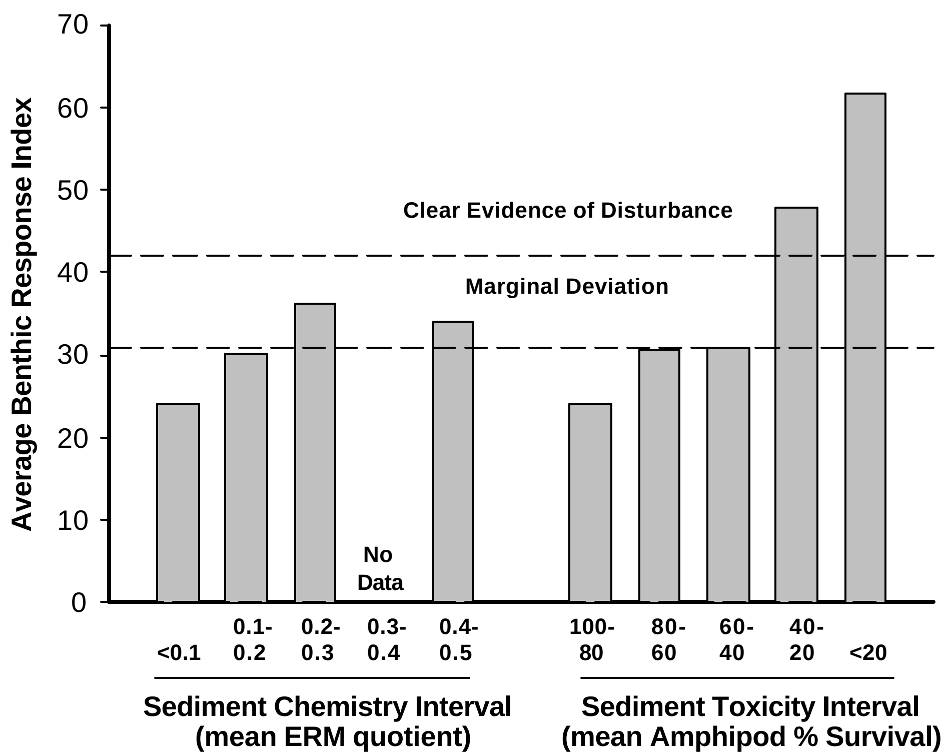

Figure 8. Relationship between measures of sediment contamination (ERM quotient) or sediment toxicity (amphipod survival) and embayment benthic macrofauna community composition (benthic response index) for Bight'98 sites.

Sediment toxicity was a better predictor of benthic community effects than existing SQGs.

Benthic macrofaunal community condition in embayments corresponded better with sediment toxicity than it did with sediment chemistry. The magnitude and frequency of occurrence of benthic community disturbance increased with incremental increases in the magnitude of sediment toxicity (Figure 8). Sediment toxicity was a relatively insensitive indicator of benthic community impacts, with only 50% of the sites having clear evidence of disturbance to benthic macrofauna being toxic. These results provide the first synoptic comparison of toxicity and macrofaunal community response for the SCB and indicate that sediment toxicity tests are more reliable predictors of the potential for community impacts than currently available sediment quality guidelines.

MICROBIOLOGY

Southern California's beaches are the most popular in the nation, with more than 175 million annual visitors. They are also the most intensively monitored in the country, with 21 organizations collecting more than 100,000 microbiological samples annually. Mandatory health warnings are issued to the public if any one of seven public health thresholds is exceeded. The large number of public warnings associated with this higher level of monitoring scrutiny has resulted in several national publications concluding that southern California beaches are the most polluted in the nation. While epidemiological studies have demonstrated that there is increased health risk from swimming in some areas, these studies and most beach monitoring are focused on known areas of concern and do not provide a representative assessment of regional condition. To obtain an unbiased assessment, all of the organizations that conduct routine beach monitoring in southern California joined their efforts towards a regional beach condition assessment as part of Bight'98.

Three beach surveys were conducted. The first was a dry weather survey conducted during a five-week period in the summer of 1998. The second was a dry weather survey conducted during a five-week period in the winter of 1999. The third was a wet weather survey conducted on a single day immediately following a large storm event in February 2000. Between 251 and 307 sites were sampled during each survey using a stratified random sampling design to ensure an unbiased set of sampling locations. Samples were analyzed for three fecal indicator bacteria: total coliforms, fecal coliforms (or *E. coli*), and enterococci and results were evaluated with respect to the State of California's public health water quality standards.

96% of the shoreline met water quality standards during dry weather.

Beach water quality was generally good during dry weather. Ninety-six percent of the shoreline met water quality standards during the summer of 1998. Furthermore, the few water quality failures that were encountered exceeded the standard by only a small margin and typically for only one of the three indicator species that were measured. Similar results were found in the dry weather survey conducted in the winter of 1999.

58% of the shoreline failed water quality standards during wet weather.

In contrast, beach water quality was consistently poor during wet weather. Fifty-eight percent of the shoreline waters failed water quality standards during the storm event study. Moreover, most of the failures were for multiple indicators. Most of the wet weather exceedances also occurred at concentrations that were more than twice the State standard.

Beaches near flowing storm drains had poor water quality regardless of weather.

Regardless of weather, beach water quality was poorest in beach areas near urban runoff outlets. In the two dry weather surveys, almost half of the beaches in front of flowing storm drains exceeded water quality standards (Figure 9). In the storm study, almost 90% of these shoreline areas failed water quality standards.

Moreover, most of the water quality exceedences near drains were for multiple indicators regardless of weather condition, and the magnitude by which they exceeded State thresholds was greater than for other shoreline areas.

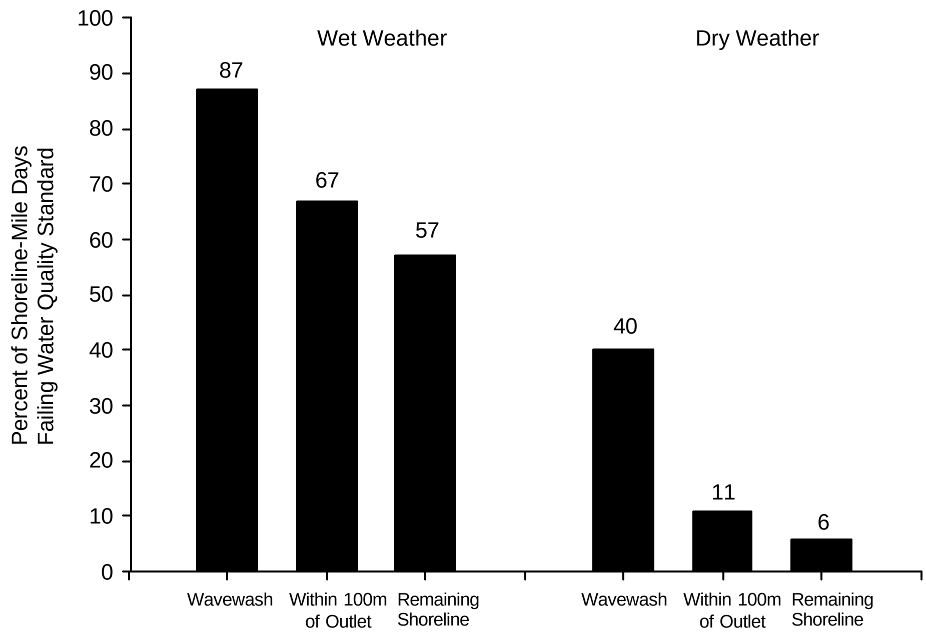

Figure 9. Percent of shoreline falling California daily water quality standards during wet and dry weather in relation to distance from stormdrains.

WATER QUALITY

Urban runoff is among the largest sources of contamination to southern California's coastal ocean, containing bacterial contamination, inorganic nutrients, various organic compounds, and metals. Contributions from these sources are relatively small during dry weather, but large amounts of freshwater drain the urban landscape and flood the coastal ocean during rain events. The Water Quality component of Bight'98 assessed the spatial scales of impacts from these freshwater inputs on the physical structure of the coastal ocean and compared them with the scale of influence from offshore POTW discharges.

> ***New measurement opportunities***
>
> *Bightwide studies of regional stormwater plumes require a combination of observational tools because ship sampling alone is insufficient to resolve spatial and temporal evolution of storms. Remote sensing technology provides new opportunities to quantify stormwater runoff frequently and synoptically over large spatial scales. Satellite imagery, including synthetic aperture radar (SAR) and SeaWifs color sensors, provides comprehensive views of the entire southern California coastal ocean at least at daily intervals, and Advanced Very High Resolution Radiometer (AVHRR) images are obtained several times daily. Shore-mounted high frequency radar systems are now deployed in San Diego County and provide a continuous description of surface currents. Moored systems are now in place at several locations in the SCB, providing continuous measurement of physical parameters .*

Water quality profiles were taken at nearly 500 sites.

Four oceanographic surveys were conducted in which as many as nine ships simultaneously sampled the water column at nearly five hundred sites using Conductivity-temperature-depth (CTD) profilers. These profilers measured salinity, temperature, light penetration and chlorophyll (via fluorescence) through the entire depth of the water column. CTD profilers were supplemented with direct measurement of nutrients and chlorophyll at about 10% of the sampling sites. The first survey conducted in October 1998 characterized the ambient ocean prior to any major rainfall events. Three subsequent sampling events were conducted immediately after storms and were intended to characterize the impacts of rainfall-induced runoff. The first two of these storms were relatively small and the third storm was a medium-sized storm that spread over several days.

The influence of the Los Angeles and San Gabriel Rivers on coastal water quality was apparent at a distance of 5 km offshore and 20 km alongshore, even during dry weather.

The plumes from most land-based runoff sources were not measurable in the ocean during dry weather. Two exceptions were the Los Angeles and San Gabriel Rivers, which yield a single freshwater plume that was evident in the upper few meters of the coastal ocean and is present throughout the year. The spatial extent of this dry weather plume was approximately 20 km alongshore, 5 km cross-shelf, and 5-10 meters vertically. A small signal was also detected from Ballona Creek.

Following storms, most of the major drainage systems had a coastal freshwater plume that was measurable for at least 3-5 days. The first two storms studied in

Bight'98 were small (less than 2.5 cm), but plumes were still evident to a distance of almost 10 km offshore (Figure 10). The third storm yielded more than 5 cm of rainfall and its plume extended almost 20 km offshore .

Chlorophyll concentrations in the near coast increased from land-based runoff following a storm.

Stormwater runoff appeared to promote phytoplankton plumes approximately 3-5 days following the storm event. Elevated chlorophyll fluorescence was correlated with low salinity and the pattern of surface phytoplankton patches was coincident with the pattern of surface runoff sources. Other potential effects from stormwater runoff, such as pathogenic bacteria, toxic organic compounds and metals, were not measured in the study and should be addressed in future surveys.

Figure 10. SeaWiFS image from Jan 28 1999 illustrating stormwater plume dimensions measured during Bight'98.

INTERCALIBRATION

Intercalibration studies were conducted to ensure consistent data among Bight'98 participants.

Sixty-two organizations participated in Bight'98, thirty-six of which were directly involved in data collection or laboratory sample processing. Developing a technically defensible regional assessment required implementing quality assurance procedures to ensure that the data from these disparate sources were comparable. These procedures not only led to higher data quality during Bight'98, but also have been the basis for improved data quality by the participants in their ongoing monitoring programs.

> ***Regional Professional Organizations***
>
> *Standardization and intercalibration in Bight'98 was enhanced through cooperation with preexisting scientific organizations that focus on developing regional consistency. One example is the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT), whose goal is to develop regionally standardized taxonomy for marine invertebrates. All of the benthic taxonomists who participated in Bight'98 are SCAMIT members and SCAMIT directed many of its activities to the needs of the survey. Even after completion of Bight'98, SCAMIT continues working to resolve taxonomic issues in preparation for future surveys. Similar organizations exist within the region for environmental chemists and toxicologists.*

Quality assurance included three types of activities. The first was preparation of manuals to standardize field collection, laboratory procedures and data management. These manuals have subsequently been adopted in many ongoing monitoring efforts to ensure compatibility with data collected during Bight'98. The second was group-training exercises. The third was proficiency demonstrations required of each participating organization prior to their collecting data in the regional survey. These demonstrations involved field audits of onboard activities and analysis of blind samples to assess competency in laboratory sample processing.

Chemical processing required the greatest effort to achieve comparability.

Blind sample laboratory proficiency examinations were conducted for chemistry, toxicology, microbiology and benthic macrofauna identifications. For most of these parameters there were only small discrepancies among laboratories, usually requiring minor supplemental training for one or two individual laboratories. The one exception was the chemistry intercalibration, for which there was wide discrepancy among the seven participating labs, even though all were certified by the California's Environmental Laboratory Accreditation Program.

The chemistry intercalibration involved all laboratories processing two field collected sediment samples for PAHs, PCBs and metals. The preestablished requirement was that all laboratories must be within 40% of the group mean for the measured contaminants. In the first round of this exercise, the disparity among laboratories was more than twenty-fold in both samples. This realization of inconsistency led to a comprehensive review of all analytical procedures by the participants. The review involved trading personnel among fa-

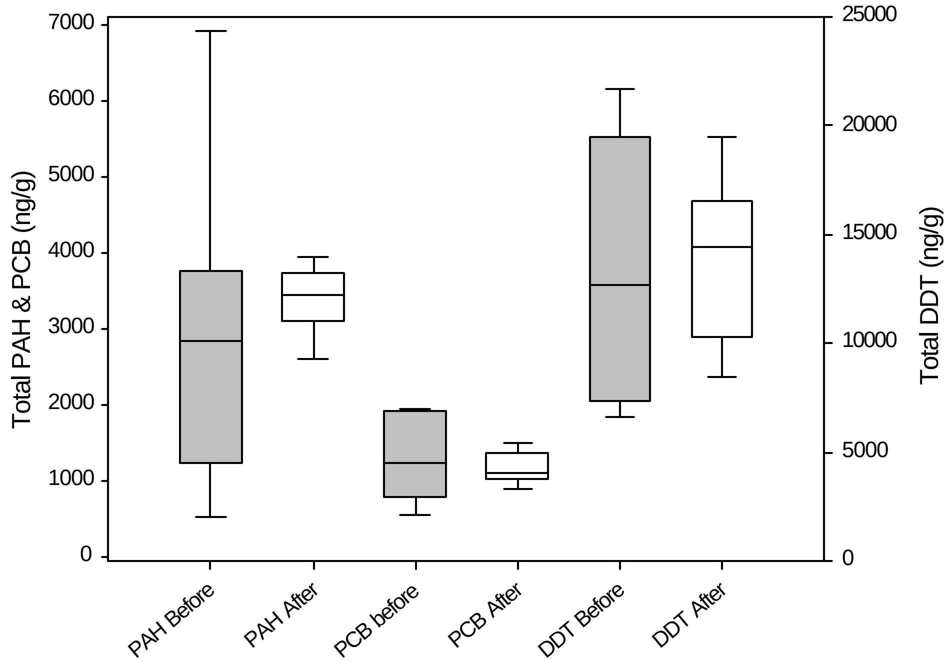

Figure 11. Sediment contaminant concentrations for reported intercalibration test samples by the seven participating laboratories before and after corrective actions to increase consistency. The boxes show the 25th, 50th (median) and 75th percentiles, and the bars show the range of the data.

cilities and special studies to assess the importance of differences in procedure. This consumed almost a year, but led to corrective measures that ultimately resulted in the laboratories meeting the initial performance guidelines (Figure 11). While the intercalibration exercises required a large investment of time and resources from the participants, they provided quality assurance benefits that will continue to accrue well beyond the term of Bight'98.

Microbiological Method Certification

Laboratories in California have historically used two state-certified methods, membrane filtration and multiple tube fermentation, to measure bacterial concentrations in ocean water. Recent advances have produced the chromogenic substrate technique, which is less expensive and faster. This method, produced commercially by Idexx Laboratories, is used widely for drinking water applications, but has had only limited testing in marine waters. Bight '98 conducted the first comprehensive side-by-side field tests, which were conducted during wet-weather when potential interfering compounds were most likely to be present. The new method produced comparable data to that of conventional methods. Based on these findings, the State of California Department of Health Services has certified the chromogenic substrate method as acceptable for use in marine waters.

FUTURE DIRECTIONS

Bight'98 has provided southern California with a regional perspective about the condition of the marine environment that is available for very few areas of the country. This perspective will improve management by providing a foundation for regional management priorities. It will also help by providing context and perspective for assessing the relative severity of issues occurring at local scales.

Beyond its definitive findings, Bight'98 also serves to identify the deficiencies in our knowledge that prevent effective management. In some cases, these deficiencies are related to a lack of data. In other cases, they reflect our limited ability to interpret data that we have already collected. The 62 organizations that participated in Bight'98 have developed the following recommendations for actions that should be taken to continue improving the scientific foundation for coastal management in southern California.

Recommendation 1: Improve Sediment Quality Assessment Tools

Chemical, toxicological and biological community measures were all used to assess sediment quality in Bight'98. These measures all indicated that contaminant concentrations in the SCB were generally below levels of biological concern and there was greater incidence of biological effects in bays and harbors than offshore. However, there was poor correspondence among these measures at individual sampling sites. These inconsistencies suggest that the available tools for assessing the significance of sediment contamination are of limited accuracy when used alone. Additional analyses of the Bight'98 results and future studies are planned in order to develop more effective sediment quality assessment tools. Until improved tools become available, management decisions such as listing impaired water bodies, prioritizing sites for cleanup, identifying contaminants of concern, and establishing cleanup levels should be based upon data from multiple indicators that are interpreted using a weight of evidence approach.

Recommendation 2: Better assess the level of predator-risk associated with DDT contamination in the SCB.

Nearly three-quarters of the fish we examined had DDT levels above predator-risk guidelines. While this is a cause for concern, it does not mean that predators are truly at risk. First, Canadian guidelines were used because such guidelines have not yet been developed in the United States. U.S. guidelines need to be developed because it is unclear how well the Canadian guidelines apply to southern California. Second, Bight'98 focused on examination of bottom-dwelling flatfish. Birds and mammals feed more often on pelagic forage fish, such as anchovies, which are likely to have lower contaminant levels because they have less contact with contaminant-laden sediments. Future surveys need to assess whether pelagic fish also have DDT concentrations above predator risk guidelines.

Recommendation 3: Better characterize land-based runoff

The Shoreline Microbiology Component of Bight'98 found that most of southern California's beach water quality problems are associated with land-based runoff. The Water Quality Component found that land-based runoff influences extend far from shore, even during dry weather. Effective runoff management will require a greater understanding of these issues than that provided by Bight'98 alone.

The most critical need is for source characterization. Managers need to know whether runoff-based bacterial problems result from leaking sewer lines, which are best addressed by sanitation agencies, or from animal waste, which is better addressed by stormwater agencies. Alternatively, runoff-based bacteria in some watersheds could result from birds or wild animals and represent natural background conditions that require little or no management action.

A second need is for understanding the fate of land-based runoff when it reaches the coastal zone. For bacteria, the public health risk associated with specific runoff sources partly depends on how quickly the material is diluted or transported. Very little is known about contaminant transport within the shorezone. For chemical contaminants, low concentrations were observed in sediments near the mouths of freshwater outlets in Bight'98, presumably because high episodic flows transport it to more offshore locations. Knowing these locations is essential to assessing the biological effects of this runoff.

Recommendation 4: Regional monitoring surveys of the SCB should be repeated at periodic (e.g. five year) intervals.

Individual, isolated monitoring programs do not generate all of the information necessary for effective management of coastal resources. They cannot assess the spatial extent of ecological disturbances in the SCB, measure relative condition among different portions of the region or adequately define a background upon which monitoring agencies can evaluate their local environmental conditions. Bight'98 and its Pilot Project predecessor have demonstrated that this information can be developed cost-effectively through multi-institutional collaboration.

In addition to assessments of regional environmental condition, the two previous surveys have produced new methods that will enhance local monitoring on an ongoing basis. These include tools for evaluating the health of benthic infaunal and fish communities, a new method for differentiating background versus anthropogenic sources of heavy metals, and adoption of new methods for bacteriological testing. Additionally, the regional survey quality control efforts have provided the opportunity for participants to assess and improve the quality of data they produce in their ongoing monitoring programs.

Emphasis should be placed during the planning of future regional surveys to enlist as many participants as possible. One virtue of regional monitoring is the dialog among disparate groups. This dialog was enhanced by expansion from 12 to 62 organizations in 1998, but there remains opportunity for involving other sectors of the community in this dialog in future surveys.

Recommendation 5: Conduct intercalibration exercises as an ongoing activity.

The intercalibration exercises conducted during Bight'98 exposed some substantial differences in measurements among laboratories in southern California, even though all of the participants were state-certified. These exercises provided a tremendous forum for interaction among professionals, allowing them to assess their capabilities and identify opportunities for improvement. Even for those parameters, such as microbiology, for which there was agreement among laboratories, success in the exercise provided participants greater confidence about their ability to exchange or integrate their data. The value derived from these intercalibration exercises warrants their institution as an ongoing activity, either as part of an enhanced state certification process or as part of periodic regional surveys. These exercises should also be expanded to include other laboratories. The laboratories that participated in Bight'98 were among the largest in the state, with extensive internal quality control procedures. The differences in results are likely to be even larger when small, less experienced laboratories, which conduct routine analyses for many organizations in southern California, are involved.

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