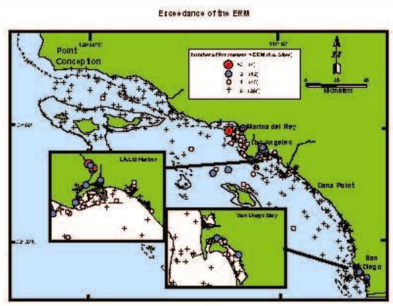
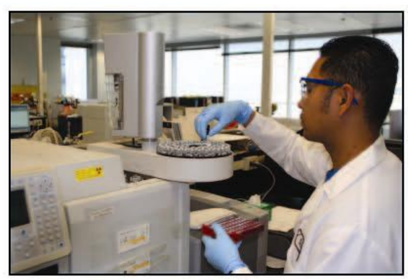
BIGHT'03

Executive Summary





Southern California Bight
2003 Regional Monitoring
Program
Executive Summary

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August 2007

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INTRODUCTION

Southern California is home to nearly 20 million people, making it one of the most densely populated areas in the United States. In part, its popularity results 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 waters of the southern California Bight include recreation, tourism, aesthetic enjoyment, sport and commercial fishing, coastal development, and industry. Ocean-dependent activities contribute approximately 11 billion dollars directly to the economies of southern California's coastal communities and support over 187,000 jobs; indirect activities could as much as double the value of the ocean as an economic resource in the SCB.

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 most monitoring is focused on assessing individual sources of discharge. Moreover, the parameters measured, as well as the methodology by which they are measured, sometimes differ among monitoring programs. While these programs generally collect high quality data, they are not designed to describe changes that occur on a regional scale, or to assess cumulative impacts from multiple sources.

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, in Mexico. It is bordered on the east by land and on the west by the California Current. The dramatic change in the angle of the coastline creates a large backwater eddy in which equatorial waters flow north nearshore and subarctic waters flow 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.

58 organizations collaborated in Bight'03 to provide a comprehensive assessment of southern California's coastal waters.

Recognizing the need for an integrated assessment of the southern California coastal ocean, 58 organizations collaborated in 2003 to conduct a comprehensive assessment of the ecological condition of the SCB. Referred to as Bight'03, 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 whether routine shoreline monitoring, which samples in shallow water, is protective of surfers who swim in deeper water. The goal of the Water Quality Component was to define the offshore effects of runoff from coastal watersheds and assess how remote sensing tools can help address that question.

Growth of Regional Monitoring

Bight'03 is the third of a series of cooperative regional surveys that began as a pilot project among 12 organizations in 1994. Bight'03 extends the previous surveys by adding new types of measurements (i.e., endocrine disruptors, remote sensing) and sampling new habitats (e.g., estuaries, continental slope and basins). Based on the success of these regional surveys, 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'08 regional survey.

This report provides an overview of the findings from Bight'03 and is intended for environmental managers and the general public. Volumes I through VI are intended for a scientific audience and provide supporting details for the conclusions presented in this report. All volumes are available at http://www.sccwrp.org.

COASTAL ECOLOGY

The waste products of human activities are introduced to the marine environment through a variety of means, including industrial and municipal wastewater outfalls, wet and dry weather runoff from urbanized watersheds, overboard disposal from boats and ships, and atmospheric deposition. Once in the ocean, these materials may contaminate the water column or 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.

388 sites were sampled for sediment chemistry, sediment toxicity, benthic macrofauna and fish, though not all sites were sampled for all parameters.

The Coastal Ecology Component of Bight'03 was intended to assess the spatial extent of contaminant accumulation in sediments and the effect of these contaminants on biota in the SCB. For the Southern California Bight 2003 Regional Monitoring Program, 359 sites were sampled for sediment chemistry, 191 for sediment toxicity, 388 for benthic macrofauna, and 210 for fish (Figure 1). We focused on the seafloor environment because sediments act as the primary sink for much of what is discharged. 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 defined by ecosystem habitats such as estuaries, continental shelf, slope and basins, as well as areas influenced by human activities such as ports/bays/harbors, marinas, and ocean outfalls from publicly owned treatment works (POTWs). Sampling sites were also placed surrounding the Channel Islands National Marine Sanctuary to assess its condition relative to the mainland.

Sediment Chemistry

Pollutants often associate with particles and settle on the ocean floor. While some of these sediment-associated pollutants are degraded by microorganisms or by natural geochemical processes, many toxic compounds are resistant to degradation and may persist in the sediments for long periods of time. Consequently, benthic sediments act as a reservoir for pollutants that can be reintroduced to the water column when the sediments are disturbed. Sediments also serve as a source of exposure for marine animals such as worms, crabs, sea urchins, and flatfishes that live in or feed within these habitats.

Because marine sediments act as both a reservoir and conduit for contamination, sediment quality was a main focus for Bight'03.

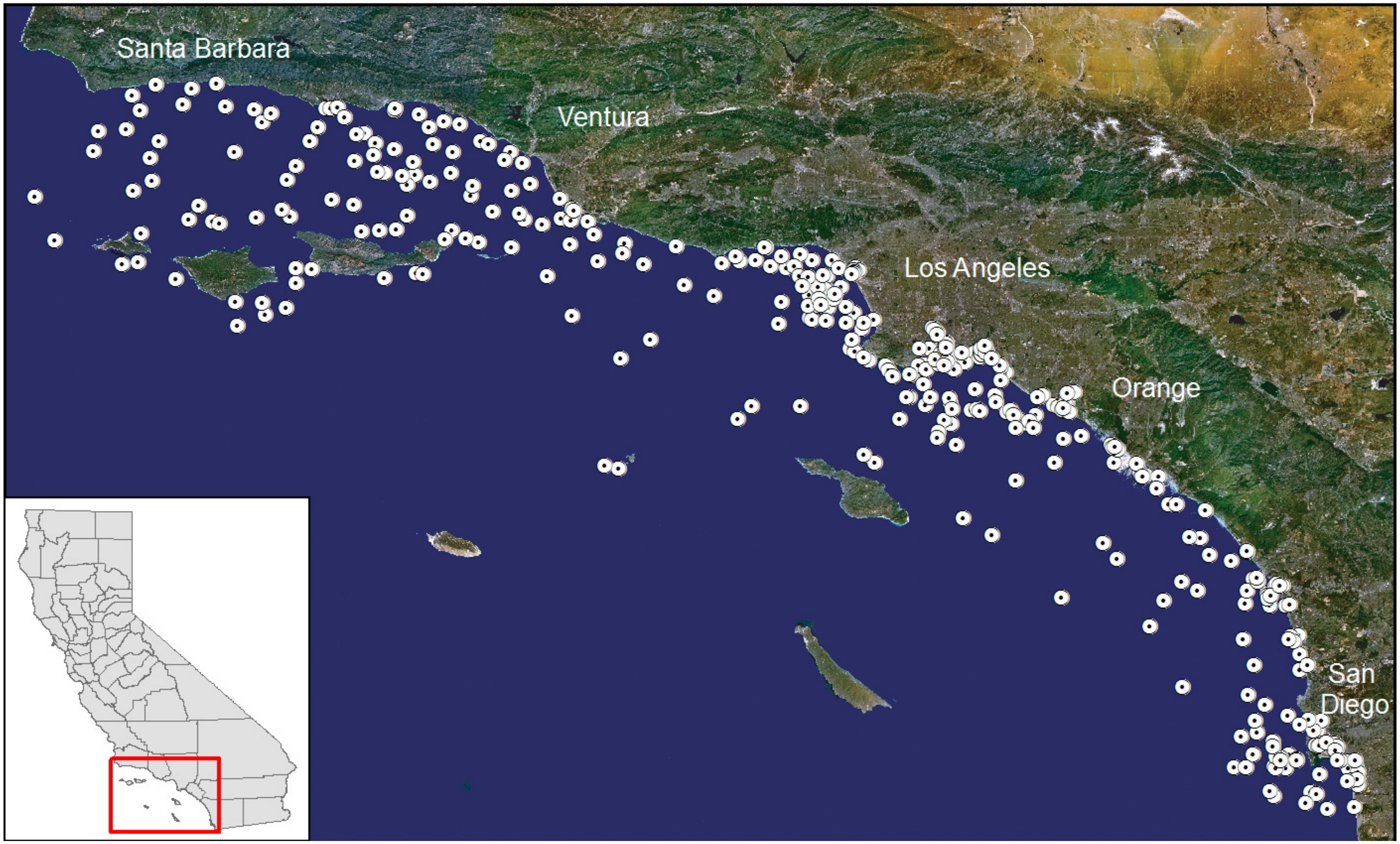

Figure 1. Sampling locations for the Southern California Bight 2003 Regional Monitoring Program.

Chemical characterization of sediments included general constituents (total organic carbon and total nitrogen), 11 metals (e.g., copper, lead, and zinc), and 74 organic constituents (e.g., polynuclear aromatic hydrocarbons (PAHs), chlordane, chlorinated pesticides (e.g., DDTs), and polychlorinated biphenyls (PCBs).

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

Approximately 94% of the SCB was enriched in at least one sediment constituent. Eighty-eight percent of the region was enriched by at least one trace metal constituent, while 71% was enriched by at least one organic constituent. Total DDT was the most widespread sediment contaminant enriching 71% of SCB sediments. The highest total DDT concentrations were observed on the Palos Verdes shelf and extended northward in the direction of the net coastal current. Trace metals and total PAHs, in contrast, were at their highest levels in sediments from embayments such as marinas and urban estuaries. The lowest concentrations were consistently observed in the Channel Islands and adjacent to ocean outfalls from small POTWs.

Analytical Approaches

The extent of chemical contamination was assessed in three ways. The first was enrichment, defined as the presence of a chemical resulting from human activity. The second was concentration of a chemical at a level that is likely to lead to adverse biological impacts, which was based on NOAA's Effects Range thresholds. The third approach was ERMQ, in which the cumulative effects of contaminants are considered simultaneously.

The lowest contaminant concentrations were consistently observed in the Channel Islands.

Sediment contamination was not equally distributed throughout the SCB. A disproportionate amount occurred on the mainland slopes and basins, within embayment areas, and in proximity to large POTWs. Despite the relatively widespread anthropogenic enrichment of SCB sediments, roughly 1% of the SCB was at a moderate to high risk of adverse biological effects based on the average Effects Range Median Quotient (ERMQ >0.5; Figure 2). The least risk was observed at the Channel Islands and small POTWs where all sites were classified as a little to no risk of having adverse biological effects.

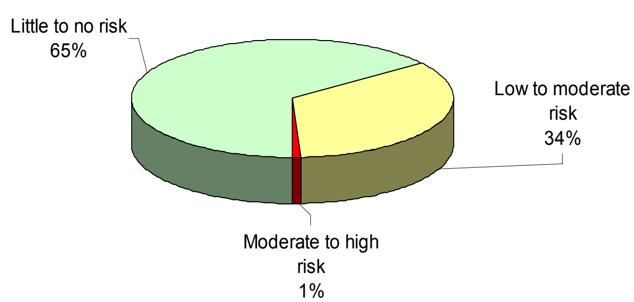

Figure 2. Percent of area in the SCB exceeding mean ERMq sediment quality guidelines.

Sediment Toxicity

Sediment toxicity tests are laboratory methods in which a sensitive species is exposed to sediments from each sample. For Bight'03, the amphipod *Eohaustorius estuarius* was added to whole sediments and mortality measured after 10 days. These tests provide a direct measure of the biological effects of sediment contamination and complement other types of measurements. For example, toxicity tests complement sediment chemistry data by providing a measure of the combined toxic effect of all contaminants present (including unmeasured chemicals) and account for the effects of other 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 that, unlike laboratory tests, can be influenced by physical and habitat factors (e.g., grain size, salinity, physical disturbance) as well as by contamination.

Identifying Causes of Sediment Toxicity

Toxicity identification evaluation (TIE) treatments were used for the first time in a Bight study to identify the causes of sediment toxicity in estuaries. Identification of pollutants or pollutant types is one important key to effectively remediating the sediment contamination.

These initial TIE assessments were conducted using whole sample and pore water techniques. The TIEs characterized nonpolar organic constituents, including pyrethroid pesticides, as a possible cause of toxicity in the estuaries with toxic sediments. The identification of pyrethroid pesticides as the possible source of toxicity is relatively new to southern California.

Less than 1% of the area of the SCB had highly toxic sediments.

Eighty-three percent of the SCB contained sediment that was classified as nontoxic. Seventeen percent of the sediments were classified as moderately toxic and less than 1% of sediments were classified as highly toxic (Figure 3).

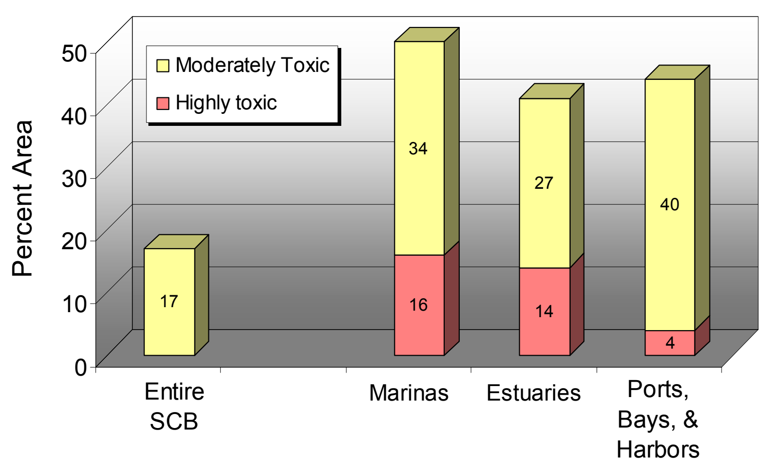

Figure 3. Percent of area toxic to amphipods.

Stations located near the Channel Islands National Marine Sanctuary were found to have the lowest incidence of toxicity. Only 4% of the area had moderate toxicity and no samples were found to be highly toxic. Marinas and estuaries contained the greatest incidence of sediment toxicity. Toxicity was present in 50% of the marina area and 41% of the estuarine area. In addition, marina and estuary strata had the greatest relative contribution of highly toxic sediments (16% and 14%, respectively; Figure 3).

Benthic Macrofauna

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 they live in sediments, which are a sink for contaminants resulting from human activities. Because these animals have limited mobility and often directly consume sediments, they are sensitive to physical and chemical alterations of the sediment. Benthic macrofauna have life spans from a few months to a few years, so that community level responses occur on the same time scale as changes in pollution levels.

Benthic Assessment Tools

As SCB regional monitoring expands into new habitats, new assessment tools have been developed to meet the challenge of assessing them. Species composition varies from habitat to habitat and assessment tools and definitions of reference condition must vary accordingly. The Benthic Response Index (BRI) was developed in 1994 to assess mainland shelf benthos. Similar benthic assessment tools for bays and estuaries were developed for the first time in Bight'03.

Two percent of the SCB had moderately or highly disturbed benthic communities; most disturbance was associated with embayments.

This study found that 89% of southern California sediments support benthic communities in reference condition (Figure 4). Another 9% were found to deviate only marginally from reference condition. Macrofaunal communities in the remaining 2% of the SCB exhibited stronger responses.

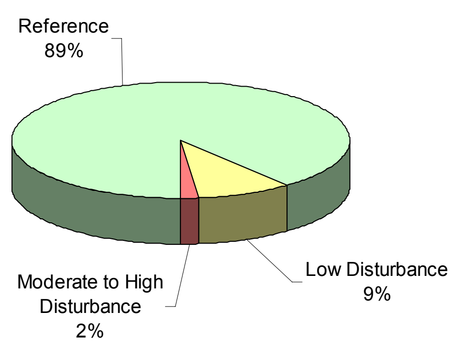

Figure 4. Benthic condition for the Southern California Bight.

Of the habitats sampled, the Channel Islands were in the best state, characterized entirely as reference condition. Even the areas surrounding large (>100 mgd) and small (<100 mgd) POTWs showed no evidence of moderate or high disturbance, although some low disturbance was noted. Most of the moderate and high disturbance was observed in embayments (13%) and the inner mainland shelf (7%) indicating that shore-based sources may be producing biological community effects such as loss in biodiversity.

> ***Improving Estuarine Benthic Sampling***
>
> *Because sampling and analysis methods have not been optimized for estuaries, the Bight'03 regional monitoring program applied standard open ocean procedures in this habitat. These methods proved to be relatively inefficient and costly, primarily because of the large amount of debris to be separated from the animals in each sample. Studies are under way to identify whether accurate and more cost-effective sampling methods are available for estuarine habitats.*

Demersal Fishes and Megabenthic Invertebrates

Demersal (living on or near the bottom) fishes and invertebrates are an important part of the marine ecosystem, as well as targets for commercial and recreational fisheries. Demersal species are good indicators of pollution effects because they live in close proximity to the sediments where contaminants can accumulate. Many species have low mobility and are most likely to respond to local sources of contamination. These responses can include elevated tissue contaminant levels, increased incidence of diseases, or disrupted communities. Two of these responses (diseases and community integrity) were used to assess the health of demersal fishes and invertebrates on the southern California shelf in Bight'03.

96% of the SCB had healthy fish assemblages.

Demersal fish and invertebrate populations and assemblages on the SCB shelf were healthy in 2003. Biointegrity indices identified 96% of the shelf as "reference" (i.e., in normal condition) for fish, 84% for invertebrates, and 92% for fish and invertebrates combined. Non-reference (disrupted) assemblages occurred primarily on the inner shelf and bay/harbor areas, suggesting nearshore influences. There was no incidence of fin erosion, which is an important fish response to contaminated sediments.

> ***Endocrine Disruption***
>
> *A study of the occurrence of endocrine disruption in fish was conducted for the first time in 2003. Flatfish blood, liver, and gonad tissue were collected from a subset of stations were analyzed for markers of endocrine disruption. Several indicators of endocrine disruption were found in some of the male fish, including elevated concentrations of an egg yolk protein and the presence of developing eggs in the testes. Additional studies are in progress to confirm these findings and determine if these effects are associated with exposure to contaminants from ongoing or legacy discharges.*

Previous regional surveys have looked at the bioaccumulation of contaminants in demersal fishes. The Bight'03 survey looked at bioaccumulation in pelagic (water column) forage fishes including sardines, anchovy, mackerel, and squid because most seabirds and marine mammals forage mainly on pelagic prey rather than on demersal flatfish. DDT was prevalent in the tissues of pelagic fish species in the SCB and tissue concentrations were generally highest in the central SCB, the location with the highest sediment DDT concentrations. Contamination above screening values (see adjacent box) protective of seabird and marine mammal consumers of fish was restricted primarily to DDT. Virtually none of the pelagic fish exceeded screening values for PCBs. An estimated 99% of northern anchovy, 86% of Pacific sardine, and 33% of Pacific chub mackerel exceeded Canadian wildlife screening values for total DDT. All California market squid samples were below these values.

99% of the anchovies exceeded Canadian wildlife risk screening values for DDT.

Are wildlife predators at risk?

There are no State or National DDT and PCB guidelines for wildlife risk, so Bight'03 used guidelines that were developed by Environment Canada as screening values that may pose health-risk concerns to sensitive wildlife species. Tissue concentrations below these screening values are not likely to pose a risk to wildlife consumers of pelagic fishes. However, concentrations above these values may or may not be pertinent to local seabirds or marine mammals of concern in the SCB. Additional study is necessary to determine what tissue concentrations in pelagic forage fishes pose risks to local bird and mammal species of concern.

The demersal fish and invertebrate assemblages were found to differ from those of the previous regional surveys, but the changes appear to result from changes in climate regime rather than from changes in water quality. Prevailing ocean climate has changed from a cold regime in the early 1970s to a warm regime in the 1990s and a return to a cold regime in 2003. The dominant fish species in 2003 were more similar to that in 1972 than they were to that in the 1994 (warm regime) or 1998 (El Niño) regional surveys. These results suggest that assessments of demersal fish communities must consider the oceanic regime of the assessment period to avoid confusing natural changes with anthropogenic effects.

Fish Parasites

A detailed baseline study of fish ectoparasites was conducted regionally for the first time in 2003. It revealed that fish ectoparasites included flatworms, leeches, and crustaceans, with copepods comprising 88% of the parasites. This study can serve as a baseline for future regional monitoring.

Integration

Three types of indicators were used to assess coastal sediment condition in Bight'03: chemistry, toxicity and benthic macrofauna. Each indicator provides valuable information about the health of the coastal environment, but no single indicator alone is sufficient to describe overall status. Chemical concentration data fails to differentiate between the fraction that is tightly bound to sediment and that which is biologically available. Toxicity tests integrate the effects of multiple contaminants, but are conducted under laboratory conditions using species that may not occur naturally at the site. Benthic community condition directly measures the resources at risk from sediment contamination, but their use alone is problematic because they are potentially affected by other factors, such as physical disturbance or hypoxia. Integration of information across these indicators provides a more comprehensive assessment that resolves many of the difficulties of using them alone.

Approximately 0.1% of the total SCB area showed evidence of impact from all three indicators.

One method of integration is to examine concordance, or the frequency in which indicator exceedences co-occur (Figure 5). None of the indicators showed evidence of impact for 77% of the SCB (based on the sediment chemical contaminants with a mean ERMq >0.5, amphipod survival <83%, and moderate or highly disturbed benthic communities). Most of these areas were near the Channel Islands and on the mainland shelf. Of the remaining area, there was little concordance among indicators. Approximately 0.1% of the area showed evidence of impact from all three indicators, which primarily occurred in embayments.

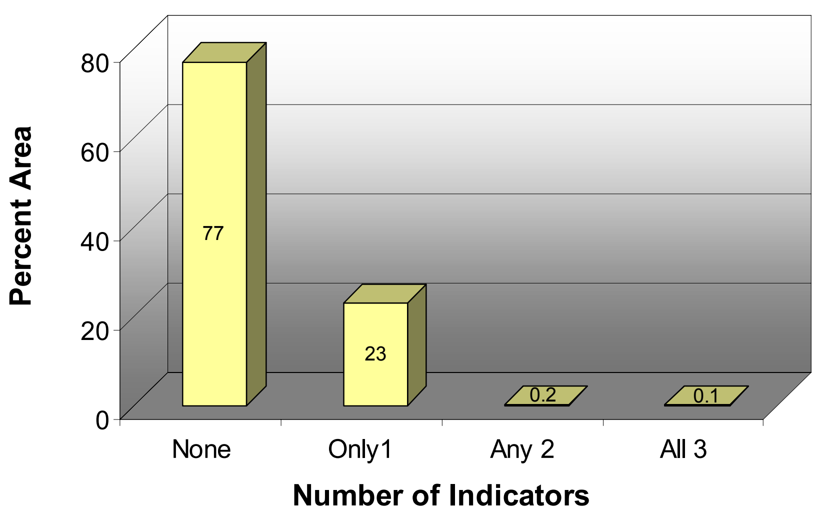

Figure 5. Concordance among sediment chemistry, toxicity, and/or benthic macrofauna indicators based on area of observed effect.

An alternative approach to examining concordance among indicators is to integrate them into a single multiple line of evidence (MLOE) assessment score. The State of California is standardizing such a framework in establishing sediment quality objectives (SQOs) for bays and estuaries. Their framework involves two key questions from a risk assessment paradigm: 1) Is there biological degradation at the site and 2) Is chemical exposure at the site high enough to potentially result in a biological response? Benthos and toxicity are integrated to answer the first question, while chemistry and toxicity are combined to answer the second. The answers to these two questions are then integrated to place sites into one of five categories of potential impact. While the State's SQOs are still in development, we applied their draft framework to the bay and estuarine data from Bight'03.

Sediment Quality Objectives (SQOs)

The State Water Resources Control Board is required to develop SQOs in accordance with Section 13393 of Division 7 of the California Water Code. SQOs are presently planned for implementation in 2008 and represent the regulatory standard by which ambient sediment quality in bays and estuaries will be assessed in the future. The SQOs being proposed will apply to programs such as the State 303(d) lists and 305(b) reports. SQOs will also be applicable within regulatory programs such as NPDES permits. Because the SQOs are applicable only to surface sediments, the SQOs will not be intended for dredged materials evaluations.

For more information: www.swrcb.ca.gov/bptcp/sediment.html

12% percent of embayment area was clearly or likely impacted using a multiple lines of evidence assessment.

Based on the MLOE framework, 62% of the SCB's embayments were unimpacted, but 12% of the embayments were considered impacted (Figure 6). The remaining 26% of the SCB's embayments was possibly impacted meaning we are not sure if impacts were mediated by chemical sediment quality. Of the embayment areas, marinas and estuaries had the greatest percentage of impacted area. Over one-quarter of the area in each of these two embayment types was either likely or clearly impacted.

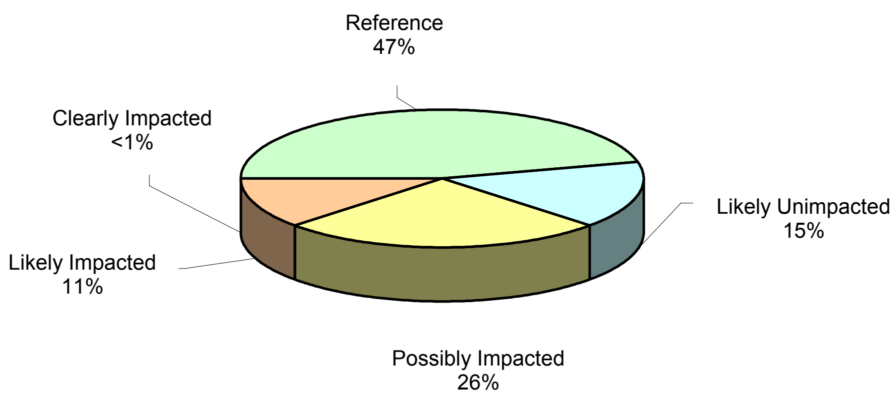

Figure 6. Multiple line of evidence assessment for embayment areas of the Southern California Bight.

Mass Balance Inventory of Total DDT in the SCB

The majority of the total DDT in the SCB can be found in sediments rather than in biota or the water column.

Most monitoring programs in the SCB are conducted to assess the fate of discharged chemicals, but it is unclear whether the spatial extent or the media being sampled (typically sediments) allow complete understanding of the fate of historical discharges. Bight'03 addressed this question by sampling multiple media (fish, sediment and the water column) over a wider geographic area than that of the routine monitoring programs. Sampling also included coring to assess how much of the chemicals were deposited in deeper sediments. These data were integrated into a mass inventory and compared to known historical discharges. Analysis was conducted for multiple chemicals, but focused primarily on total DDT because it was found to be the most widespread chemical in the SCB and had the best historical discharge records.

More than half of the total DDT was found on the continental slope and deep ocean basins, rather than on the shallower continental shelf where it was originally discharged.

An estimated 200 metric tons (mt) of total DDT was found in the SCB (Table 1). Over 99% of this DDT resides in sediments, with more than half of that found in sediments on the continental slope and deep ocean basins, rather than on the shallower continental shelf where it was originally discharged (Figure 7). The water column contains the next largest reservoir of total DDT, but it still amounts to less than 0.1% of the estimated total DDT mass in the SCB. Biological compartments such as pelagic or benthic fishes contain an even smaller mass of total DDT, as little as 0.01% of what was measured in the SCB.

Table 1. Estimates of total DDT mass in the Southern California Bight.

Compartment	Estimate of Total DDT (metric tons)
Benthic Fish	< 0.001 mt
Pelagic Fish	0.001 – 0.025 mt
Water Column	0.014 – 0.230 mt
Sediment	Approx 200 mt
Total DDT Discharged	Approx 2,400 mt

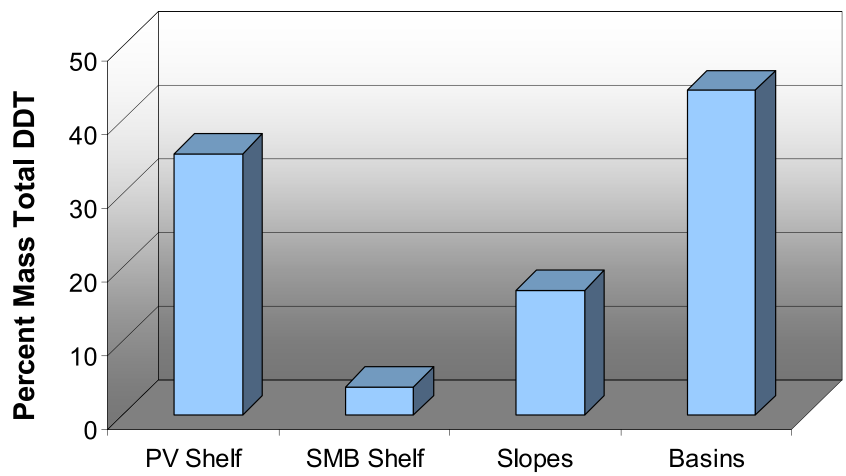

Figure 7. Relative distribution of total DDT (ca. 200 metric tons) on the Los Angeles Margin between the Palos Verdes (PV) shelf, Santa Monica Bay (SMB) shelf and the continental slope and basins.

The 200 mt of total DDT estimated to reside in the SCB represents roughly one-tenth of the total DDT estimated to have been discharged to the SCB (Table 1). Approximately 2400 mt was estimated to have been discharged since the product was introduced into the environment, approximately three-quarters of which was discharged to the Palos Verdes shelf through the Los Angeles County Sanitation District outfall between 1953 and 1971.

About 10% of historically discharged total DDT was found in the SCB.

The fate of the other 90% that was discharged is unknown, but several compartments have yet to be explored including other portions of the food chain, unmeasured degradation products of DDT, and loss due to continual flux from the sediments to the water and subsequent transport out of the SCB. The DDT in the sediments appears to be acontinuing source to the water column and fish. Sediments were significantly correlated with nearby water column and fish tissue concentrations (Figure 8). While the mass in fish tissue was low relative to the sediment pool,

Where is the remaining 90% of historically discharged DDT?

Our inability to account for 90% of historically discharged total DDT could mean that it has been redistributed beyond the SCB, however other possibilities need to be investigated before reaching that conclusion. DDT could reside in other biological compartments such as plankton, birds or mammals, though these pools are likely to be small. Second, a large percentage of DDT was found in the basins, but few samples were collected there leading to uncertainty in that estimate. Finally, it is possible that the DDT remains in the SCB in late-stage degradation products that were not measured as part of this project.

there was still sufficient total DDT in fish tissues that the majority of some fish populations (e.g., Northern anchovy, Pacific sardine and Pacific sanddab) exceeded potentiallevels of concern for wildlife predators and others (e.g., white croaker) had consumption warnings for anglers.

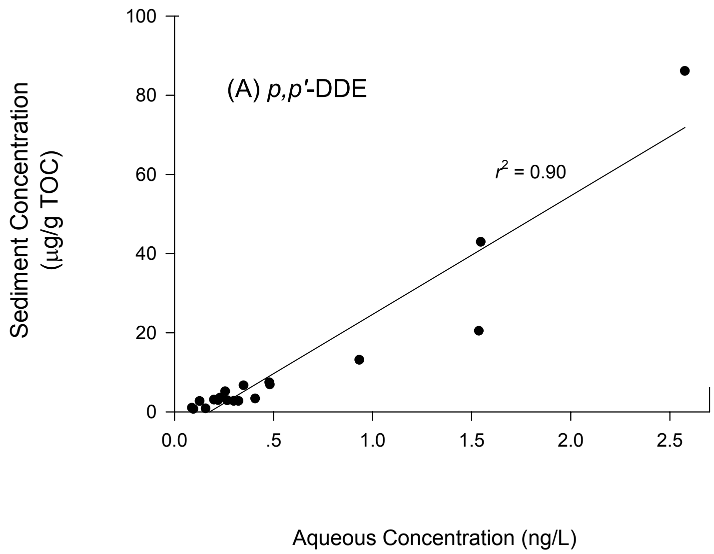

Figure 8. Relationship between water column and sediment *p,p'*-DDE concentrations in the SCB.

SHORELINE MICROBIOLOGY

With 21 organizations conducting over 185,000 microbiological analyses annually, southern California has the most extensive beach monitoring program in the nation. This monitoring effort is focused in shallow water, approximately 0.3 meters (m) depth, because it is safer and more practical to sample than deeper water. However, it is unclear how well these shallow samples protect surfers, who chronically get full-body exposure in deeper water. The goal of the Bight'03 shoreline monitoring component was to determine if shallow samples are predictive of concentrations in the surf zone where surfers are exposed.

Over 250 paired shallow (ankle depth) and deep (surfer line-up zone) samples were collected at 12 beaches during both dry and wet weather. Up to 9 sites per beach were sampled at distances ranging from 0 to 500 m from the mouth of freshwater outlets. Samples were analyzed for enterococcus, fecal coliforms, and total coliforms.

Sampling in shallow water is adequate to determine whether offshore waters comply with California's bacterial standards.

Sampling in shallow water was adequate to determine whether offshore waters comply with California's bacterial standards. Concentrations of enterococci were typically higher in shoreline samples than offshore, with the difference being nearly three-fold under dry conditions and only 25% higher under wet conditions. Enterococcus concentrations were generally low in dry weather with 95% of the samples below water quality standards in both shallow and offshore samples. Concentrations in wet weather were greater, but concordance among shallow and offshore samples still exceeded 84%. For only one sample pair in dry weather and three sample pairs during wet weather, constituting less than 1% of total samples, did shoreline samples meet water quality standards when a corresponding offshore sample failed the standard.

Table 2. Percent agreement regarding the California single-sample water quality standard of 104/100 ml for enterococci between samples taken simultaneously during dry or wet weather at shallow (shoreline depth) and offshore (in the surfzone where surfers line-up).

DRY WEATHER		Offshore	
		Below Standard	Above Standard
Shallow	Below Standard	94.7%	0.9%
	Above Standard	4.4%	0.0%

WET WEATHER		Offshore	
		Below Standard	Above Standard
Shallow	Below Standard	54.9%	2.1%
	Above Standard	14.8%	28.2%

WATER QUALITY

Southern California has highly developed watersheds and, following storms, large amounts of freshwater drain the urban landscape flooding the coastal ocean. This water contains bacterial contamination, inorganic nutrients, various organic compounds and metals. The primary goals of the Bight'03 Water Quality component were to describe the temporal evolution of stormwater plumes produced by major southern California rivers and to describe how the physical and ecological properties of the plume (e.g. turbidity, temperature, salinity) relate to water quality (toxicity and bacteria).

Water quality data were collected offshore from eight major river systems within the SCB. For each of these systems, two stormwater events were sampled for up to three days, resulting in 574 water column CTD profiles and 705 discrete water samples. These data were analyzed in combination with MODIS ocean color satellite remote sensing, buoy meteorological observations, drifters, and high frequency radar current measurements to evaluate the dispersal patterns, dynamics, and impacts of the freshwater runoff plumes.

Turbidity plumes from stormwater runoff often extended 50 km from shore; toxic and bacterial effects did not extend more than 2 km from shore.

Stormwater runoff plumes of turbid water were found to be spatially extensive, covering up to 2500 km^2 of the SCB. The spatial extent of the contaminant plume was far less than that of the turbidity plume. While turbidity plumes often extended more than 50 km from the mouth of individual river systems, the areal extent of bacterial contamination and water column toxicity was in most cases constrained to the nearfield region of the river discharge. Elevated concentrations of fecal indicator bacteria (FIB) were found offshore of each of the major river systems, but exceedances of standards were generally limited to within 1-2 km^2 of the river mouth. Of over 700 water samples analyzed, 5% exhibited toxicity and only three samples exhibited high toxicity. The vertical distributions of FIB and toxicity were confined to the upper 5-10 m of the water column, consistent with the buoyant nature of runoff plumes. The extent of these effects was also temporally limited. FIB typically decreased below concern thresholds within two days. Plumes were found to evolve

Harmful Algal Bloom

Pseudo-nitzschia, an alga (diatom) that produces the neurotoxin domoic acid was found to be more abundant than previously reported. While the potential presence of Pseudo-nitzschia was only examined in a portion of the Bight'03 study area, a high-density bloom was observed in the Los Angeles Harbor following one of the runoff events. Associated with this bloom were the highest concentrations of domoic acid ever reported along the West coast of the U.S. The study, however, did not specifically address potential relationships between runoff and algal density, or the relationship between algal density and mammal strandings within the SCB.

rapidly, with mean daily alongshore plume advection as high as 50 cm s^{-1}. Alongshore movement of plumes was found to be as or more prevalent than across-shore movement, suggesting that contaminants discharged from a river system can be quickly transported to coastal waters offshore of adjacent river systems. This was especially apparent for the Santa Clara River plume, which was observed to extend toward Santa Monica Bay (Figure 9).

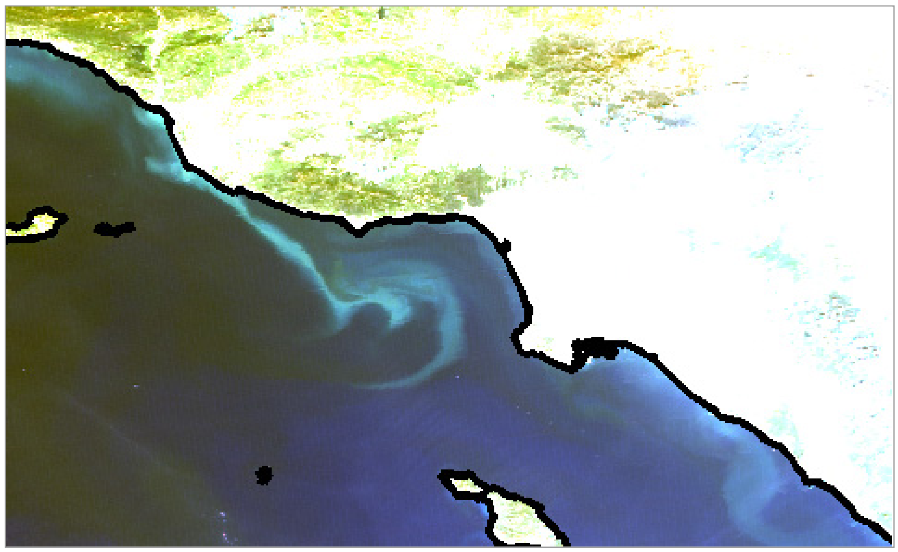

Figure 9. MODIS-Aqua satellite image from March 25, 2005 illustrating stormwater plume from Santa Clara River transported downcoast.

Satellite data provide valuable information on plume dynamics, but cannot replace *in situ* measurements of water quality.

Another goal of the program was to determine whether relationships between environmental indicators derived from satellites are sufficiently robust for remote sensing to become a part of routine water quality monitoring programs. Accurately describing stormwater runoff plumes was found to require a combination of *in situ* and remote sensing assessment tools. Ships provide the opportunity to measure parameters that cannot be measured through remote sensing, but ships move slowly relative to the rate of plume dispersion observed in this study and do not provide a comprehensive assessment on their

Particle Size

Particle size was measured within the offshore runoff plumes in northern Orange County over the course of one storm. Particle size was found to be dynamic, with the size spectra becoming progressively coarse as the storm evolved. Particle size signature also differed between the Santa Ana and San Gabriel river plumes. There was an inverse relationship between fecal indicator bacteria density and particle size, as bacteria were mostly associated with small particles (<53 µm). These findings suggest that understanding how particles are generated in the watershed provides new opportunities for insight into the evolution of the offshore plume and its attendant biological properties.

own. The synoptic perspective provided by satellite remote sensing was valuable in characterizing the spatial and temporal extent of runoff plumes, and also in determining whether the outflow of a particular watershed was impacting water quality in other parts of the SCB coastal ocean far from the source watershed.

INTERCALIBRATION

Intercalibration studies were conducted to ensure consistent data among Bight'03 participants.

Fifty-eight organizations participated in Bight'03, 33 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'03, but also have been the basis for improved data quality by the participants in their ongoing monitoring programs.

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'03. 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. Demonstrations included field audits of onboard activities and analysis of blind samples to assess competency in laboratory sample processing. Laboratory proficiency examinations were conducted for chemistry, toxicology, microbiology and benthic macrofauna identifications. For most parameters, there were only small discrepancies among laboratories, usually requiring minor supplemental training for one or two individual laboratories.

Regional Professional Organizations

Standardization and intercalibration in Bight'03 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'03 are SCAMIT members and SCAMIT directed many of its activities to the needs of the survey. Even after completion of Bight'03, SCAMIT continues working to resolve taxonomic issues in preparation for future surveys. Similar organizations exist within the region for environmental chemists and toxicologists.

High quality data production has been institutionalized at each of the participating labs.

Only eight of the more than 100,000 measurements made during Bight'03 were of insufficient quality for use. Much of that success appears to result from successes in previous regional surveys. In Bight'98, several intercalibration efforts and more than 100 person-days were required to achieve comparability in chemical analysis. In Bight'03, however, only a single intercalibration exercise was required to demonstrate comparability in chemistry measurements. This suggests that regional monitoring training has been institutionalized and participating laboratories are achieving high quality data on an ongoing basis.

FUTURE DIRECTIONS

Bight'03 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 assists management by providing a foundation for establishing regional management priorities. It also provides regional context and perspective for assessing the relative severity of local issues.

Beyond its findings, the regional survey also served to identify deficiencies in our knowledge that hamper 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 had been already collected. The organizations that participated in Bight'03 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: Continue to improve the sediment quality assessment tools

A large part of Bight'03 focused on assessment of sediment quality, which relied on sampling for chemical, toxicological and biological community measures. Interpretation of these data is challenging, though. Chemistry data are confounded by uncertainty about which fractions are bioavailable. Benthic data are a complex assemblage of organisms that must be integrated to assess whether they represent a healthy, thriving community. Bight'03 made giant strides in interpretation of such data. New indices were developed for interpreting benthic data in embayments. Bight'03 was also the first study to begin integrating multiple lines of evidence into a regional assessment, an approach the State Water Resources Control Board is proposing for sediment quality objectives. However, there is continued need for improvement in these tools and the regional surveys provide a good opportunity to develop and evaluate such tools. In particular, tools for interpreting benthic data have not yet been developed for the slopes and the basins, and the triad assessment tools that have been a focal point for embayments have not yet been validated for use in offshore waters.

Recommendation 2: The next regional survey should measure new constituents of emerging concern

The chemical constituents measured in Bight'03 reflect the standard monitoring analytes that appear in most NPDES permits. However, there are some constituents of potential concern to marine life that are not measured in routine monitoring and the regional monitoring program represents an appropriate opportunity to evaluate their prevalence. At least four classes of compounds would be appropriate additions to future surveys, one of which is current use pesticides (i.e., pyrethroids). A second class is pharmaceuticals and personal care products, which have been detected in offshore receiving waters. A third class is flame retardants, such as PBDEs, which have been detected in high concentrations in several southern California samples from NOAA's national mussel watch program. A fourth class is DDT metabolites other than DDD and DDE. The Bight surveys have been unable to account for 90% of the historic DDT discharges into the Bight and it is unknown how much resides in unmeasured breakdown products. Measuring such additional compounds may prove challenging because of limited capacity for their measurement among the laboratories participating in the regional monitoring program, but their measurement should be pursued where possible.

Recommendation 3: The next regional monitoring survey should have an increased focus on trend detection

Bight'03 is the third cooperative regional monitoring survey to be conducted in southern California, and all three focused on questions about spatial extent of impact. However, as spatial extent questions are answered and the number of surveys grows, there is increasing opportunity to refocus towards questions about trends in condition. Attempts were made in Bight'03 to examine potential trends over the ten year period since the first regional survey. However, temporal comparisons were confounded by differences in methods and sample frame. The study design for future regional monitoring surveys should be re-evaluated to ensure maximum opportunity for accurately addressing trends questions.

Recommendation 4: The next regional monitoring program should quantify anthropogenic nutrient loadings and assess whether they contribute to phytoplankton blooms.

Pseudo-nitzschia, a diatom that produces the neurotoxin domoic acid, was found to occur in high numbers in Los Angeles Harbor during Bight'03, but its occurrence in other parts of the SCB has not been well assessed. The timing and location of the Bight'03-measured bloom suggests that it was associated with a runoff event, but there are numerous other sources of nutrients to that area, including those from treated wastewater outfalls and from natural upwelling. Bight-wide sampling to develop nutrient budgets from various sources coupled with water column measurements of phytoplankton would provide insight as to the prevalence and dynamics of blooms, and allow assessment of whether they are associated with human inputs.

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