Southern California Bight
2008 Regional Marine Monitoring Survey
(Bight'08)

Offshore Water Quality Workplan

Prepared by:
Bight'08 Water Quality Committee

Prepared for:
Commission of Southern California Coastal Water Research Project
3535 Harbor Boulevard, Suite 100
Costa Mesa, CA 92626

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I. INTRODUCTION

A. Setting

The Southern California Bight (SCB; Figure 1) is an open embayment in the coast between Point Conception and Cape Colnett (south of Ensenada), Baja California. Complex bathymetry and currents have resulted in a diversity of habitats and marine organisms, including more than 500 species of fish and several thousand species of invertebrates. The SCB is a major migration route for marine bird and mammal populations and is ranked among the most diverse ecosystems in north temperate waters. In addition to its ecological value, the coastal zone of the SCB is a substantial economic resource. The Los Angeles/Long Beach Harbor complex is the largest commercial port in the United States, while San Diego Harbor is home to one of the largest US Naval facilities in the country. In addition to being the home to more than 20 million people (NRC, 1990), southern California receives over 100 million visitors to its beaches and coastal areas annually. The combination of resident and transient population has resulted in highly developed urban environment that has greatly altered the natural landscape. The conversion of open land into impervious surfaces has included dredging and filling over 75% of bays and estuaries (Horn and Allen 1985) and extensive alternations of coastal streams and rivers (Brownlie and Taylor 1981; NRC 1990). This "hardening of the coast" changes both the timing and rate of runoff releases to coastal waters and can affect water quality through addition of sediment, toxic chemicals, pathogens, and nutrients. Besides input of urban runoff via storm drains and channelized rivers and streams, numerous municipal wastewater treatment facilities, power-generating stations, industrial treatment facilities, and oil platforms discharge to the SCB.

B. History of Bight Regional Surveys

To understand the cumulative impacts of these discharges to the SCB a cooperative, multi-agency regional monitoring program has been established that looks at coastal ecology, water quality, and microbiology. To date three surveys have evaluated the environmental status and trends of the SCB. In 1994, the Southern California Bight Pilot Project (SCBPP) included 12 agencies that sampled sites along the continental shelf between Point Conception and the United States/Mexico border. In 1998, 64 agencies undertook the Southern California Bight 1998 Regional Monitoring Project (Bight'98) and sampled sites between Point Conception and Punta Banda, Mexico that included new habitats such as ports, bays, and marinas. Finally, in 2003, the Southern California Bight 2003 Regional Monitoring Project (Bight'03), was comprised of 65 agencies that sampled between Point Conception and the United States/Mexico border, and again expanded the number of habitats to include estuaries and deep ocean basins. The increase in the number of sites and habitat types is a reflection of the value of this type of monitoring approach and positive interactions among organizations. Benefits derived from the previous surveys included the development of new useful technical tools and increased comparability in field and laboratory methods that could only be developed with regional data sets and participation by multiple organizations.

C. Context for Bight '08 Offshore Water Quality Study

The 1994 SCBPP water quality survey provided an evaluation of SCB coastal waters at over 260 sites. Findings showed natural latitudinal differences (e.g., colder water in the Northern strata) and that over 99% of the coastal waters met California Ocean Plan objectives for dissolved oxygen and light transmittance. Since sampling in 1994 occurred during dry weather, the Bight'98 water quality survey looked at both dry and wet weather water quality and the relative inputs of offshore ocean outfalls versus urban stormwater runoff at over 500 stations. Results showed that plumes from most major land-based sources were not measurable during dry weather but that after a rain event, stormwater flows were detectable for at least 3-5 days and extended 10-20 km offshore. Associated with these lower salinity stormwater flows were elevated chlorophyll fluorescence and a coincident pattern of surface phytoplankton. To better characterize stormwater flows, the Bight'03 water quality survey sampled four major SCB river systems at nearly 200 stations. Sampling occurred over multiple days (3-5) after a rainfall event and collected discrete samples for bacteria, toxicity, chlorophyll and phytoplankton both at the source and within the stormwater plumes with the goal of correlating these measures with standard satellite imagery (e.g., ocean color). While the offshore turbidity plumes observed by satellites were found to be extensive in time and space there, the measured water quality impact (e.g., toxicity and indicator bacteria exceeding recreational standards) was typically <10% of this area, and declined rapidly within 1-3 days following the rainfall event. Phytoplankton identifications on water samples collected at a subset of stations during Bight'03 determined that *Pseudo-nitzschia*, a potentially harmful alga that can produce the neurotoxin domoic acid, was significantly more abundant than previously reported in the SCB.

While algal blooms occur along the coast in response to a variety of environmental conditions, nutrients, in particular, are considered critical to the development and/or maintenance of algal blooms. The frequency of algal blooms in the Southern California Bight (SCB) and the level of chlorophyll concentration appears to have gradually increased over the last 10+ years as shown by a preliminary analysis of SeaWiFS satellite ocean color data from 1997-2007 (Nezlin, personal communication). Results showed that most blooms were associated with seasonal upwelling events with the highest frequency in semi-enclosed regions such as the Santa Barbara Channel, Santa Monica Bay, and on the San Pedro Shelf. In proximity to river outlets (Santa Clara, Los Angeles/San Gabriel, Santa Ana and Tijuana Rivers), blooms were observed all year round.

California has a number of phytoplankton species capable of releasing toxins during periods of rapid growth, but from a management perspective, *Pseudo-nitzschia* and *Alexandrium* are the species that raise the most concern. These species can produce the potent neurotoxins domoic acid and saxitoxin, respectively. Domoic acid poisoning can cause memory loss, brain damage and fatalities; saxitoxin poisoning can lead to numbness, respiratory failure and fatalities. Due to the public health implications of these toxins, the California Department of Public Health (CDPH) monitors toxin levels in shellfish and will close both commercial and recreational harvesting when specific alert levels are exceeded to avoid outbreaks of shellfish poisoning. In addition to human health impacts, bioaccumulation of algal toxins through the food web (via contaminated fish and shellfish) has been linked to erratic behavior in birds and marine mammals, as well as marine animal mortality events.

The geographic distribution and the frequency of domoic acid and paralytic shellfish toxin (PSP; saxitoxin being one of the PSP toxins) alert levels between 1981 through 2007 are summarized in Figure 2 below. The left panel shows the number of samples that exceeded the regulatory alert levels of domoic acid of 20 µg/g (20ppm) by county and the right panel shows the same information for the regulatory limit of 80 µg/100g tissue (0.4ppm) for saxitoxin by county. These figures show that southern California has a large number of toxic events of domoic acid yet a relatively low number for saxitoxin. Domoic acid is considered to be the toxin of highest frequency in recent years in the SCB and therefore of the most concern for research, monitoring and management.

Since the first recorded domoic acid poisoning event in California in 1991, *Pseudo-nitzschia* has been observed as a common and often dominant genus in the phytoplankton composition and there have been an increased number of toxic blooms recently recorded throughout southern California, most notably in Santa Barbara (Venrick 1998, Trainer et al., 2000, Anderson et al., 2006, Mengelt, 2006), Los Angeles Harbor and San Pedro Channel (Busse et al., 2006, Schnetzer et al., 2007, David Caron, unpublished data), Newport Beach (Villac, et al., 1993, Busse et al., 2006) and San Diego (Lange et al., 1994, Busse et al., 2006). Toxic blooms of *Pseudo-nitzschia* in the Los Angeles Harbor and San Pedro Channel have been particularly toxic, with some of the highest domoic acid concentrations recorded for the U.S. west coast (David Caron, unpublished data). The increase in toxic events in southern California parallels the increase in frequency and intensity of harmful algal blooms observed globally (Smayda 1990, Hallegraeff, 1993, Anderson et al., 2002 and Glibert et al., 2005).

Table 1 provides a list of the participating organizations in the Bight'08 Offshore Water Quality Study.

Figure 1. Map of the Southern California Bight.

Figure 2. The geographic distribution and frequency of domoic acid (top panel) and saxitoxin (bottom panel) levels in mussel samples above the regulatory limits of 20 µg/g (20ppm) and 80 µg/100g tissue (0.4ppm) respectively. The counties to the right of the red dashed lines represent the Bight'08 study area. (Gregg Langlois, California Department of Public Health, www.cdph.ca.gov)

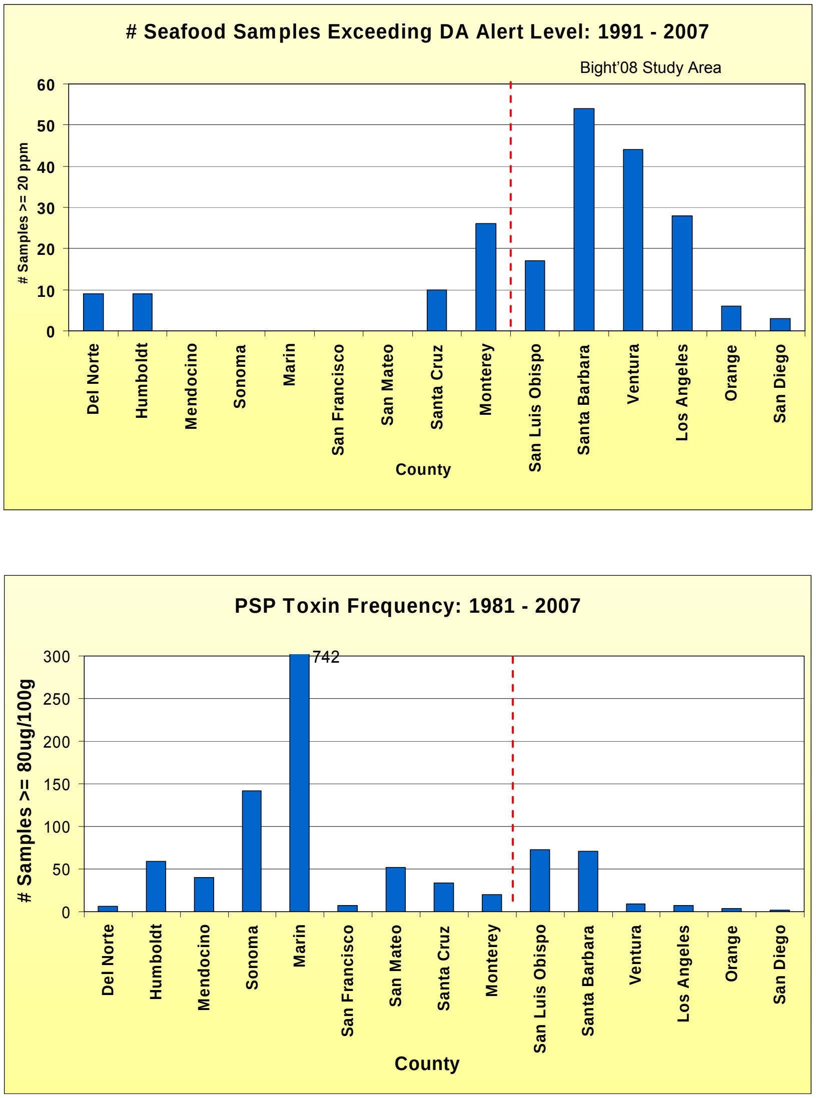

Table 1. Participating organizations in the Bight'08 Offshore Water Quality Regional Monitoring Program.

Aquatic Bioassay and Consulting Laboratories, Inc.
California Department of Public Health
California State Polytechnic University
City of Long Beach
City of Los Angeles
City of Oxnard
City of San Diego
Jet Propulsion Laboratory
Los Angeles County Sanitation Districts (LACSD)
Los Angeles Co DPW
Los Angeles Regional Water Quality Board
National Oceanic and Atmospheric Administration (NOAA)
Orange County Sanitation District (OCSD)
Orange County Resources and Development Management Department
Riverside County FCD
San Bernardino FCD
San Diego Co DEH
San Diego Regional Water Quality Control Board
Santa Ana Regional Water Quality Control Board
Scripps Institution of Oceanography
State Water Resources Control Board
Southern California Coastal Water Research Project
University of Southern California
University of California at Santa Barbara
University of California at Los Angeles
Ventura Co WPD

II. STUDY DESIGN

A. Study Objectives

The overall goal of the offshore water quality study of Bight'08 is to characterize the extent, magnitude, and ecology of harmful algal blooms and to identify the major nutrient sources to the SCB that may fuel those blooms. To accomplish this goal, the study will focus on three primary objectives:

1) Establish the relative nutrient contributions of four major sources to the SCB (upwelling, POTW discharge, atmospheric deposition, terrestrial coastal runoff)
2) Characterize the spatial and temporal patterns of algal blooms, as well as the effects of these blooms, with an emphasis on *Pseudo-nitzschia* and domoic acid.
3) Identify the specific water quality conditions associated with bloom events.

The first objective will establish the relative nutrient (nitrogen, phosphorus, silica) contributions of four major sources to the SCB (upwelling, POTW discharge, atmospheric deposition, and terrestrial runoff). This data will be used to identify the major sources and investigate the timing and magnitude of nutrient delivery to the coastal ocean relative to remotely-sensed and field observations of algal blooms in the SCB.

The second objective will characterize the spatial and temporal patterns of algal blooms, as well as the effects of these blooms, with an emphasis on the occurrence of *Pseudo-nitzschia* and the toxin domoic acid. Historic patterns in algal bloom frequency and biomass will be assessed using remote sensing, CTD data and modeled estimates of historic nutrient loads from the four sources to understand trends over time. The temporal and spatial occurrence of *Pseudo-nitzchia* and associated concentrations of domoic acid, nutrient and other physiochemical parameters will be characterized with a combination of remote sensing, gliders, pier-based and ship-based sampling during January – June 2009. Additional questions to be addressed include where algal blooms originate, how frequently they occur and if this frequency has increased over the last 10 years. Are blooms originating nearshore where terrestrial runoff and POTW discharges are present or are they originating offshore where the main nutrient source is upwelling?

The third objective will identify the specific water quality conditions and nutrient sources associated with bloom events. Data collected synoptically on ambient nutrient concentrations and loads from the various sources, upwelling patterns, and other remote sensing data will be used to investigate factors associated with bloom events. A special study using natural isotope ratios found in the four major sources of nutrients will be used as tracers to identify relative contributions in ambient surface waters associated with bloom events.

B. Sampling Design

The water quality sampling design for Bight'08 will be divided into three components. These include: 1) nutrient sources; 2) spatial and temporal patterns of algal blooms and 3) nutrient source tracking.

Nutrient Sources

Estimation the four principal nutrient sources to the Bight (atmospheric deposition, terrestrial runoff, upwelling, and POTW discharge) will involve a combination of field measurements and modeling targeted over a one-year period from November 2008 to October 2009. Where possible, the same suite of constituents will be measured in each of the sources to provide maximum comparability among sources (Table 2). Methods of estimation of loads from each of the sources are summarized below.

Atmospheric Deposition

Atmospheric deposition of nutrients will be measured during three climatic conditions intended to capture the range of expected variability in rates: 1) wet deposition during rain events, 2) quarterly sampling of dry deposition, and 3) dry deposition during a Santa Ana wind event. Rates of wet deposition and dry deposition will be measured at three coastal stations and one station based on Catalina Island. Measurement of dry deposition during a Santa Ana wind event will be made at one of the coastal stations. Wet deposition will be measured with rain water collectors. Dry deposition will be measured with a static water bath surrogate surface sampler.

Upwelling

To estimate the upwelling contributions of nitrate to the nutrient budget, the Regional Oceanic Modeling System (ROMS), a three-dimensional ocean circulation model, will be used to generate a reanalysis of the ocean environment from November 2008 to October 2009. This model integration will result in highly time-resolved output of the three dimensional physical and biogeochemical parameters, one of which is nitrate. From this detailed output, periods of upwelling will be determined using vertical velocity and temperature fields, and then the mass of nitrate upwelled to the euphotic zone will be calculated. Comparison of this quantity of upwelled nitrate will be made to the amount of nitrate from the other studied sources (POTWs, atmospheric deposition, and terrestrial runoff) over a range of spatial scales, from the entire Bight to smaller volumes, such as just Santa Monica Bay. In addition to vertical velocity, horizontal velocities will be examined to determine if lateral advection plays a large role in the transport of upwelled nitrate. Other expected end products include the time-varying concentration of surface nitrate within, for example, 20 km of the coastline. From this distribution, locations that contain elevated levels of nitrate will be identified and their correlation to phytoplankton blooms, as detected from either satellite or ship-board measurements will be calculated and analyzed. The annual mean distribution of surface nitrate will also be computed, which would then enable quantification of the potential impact or other nitrate sources on the local ocean environment, for instance, near a river mouth.

Large POTW Effluent
Nutrient concentrations in the effluent will be measured monthly at each of the following large POTWs:

- Hyperion Treatment Plant (HTP) operated by City of Los Angeles
- Joint Water Pollution Control Plant (JWPCP) operated by Los Angeles County Sanitation District
- Treatment Plant No. 2 operated by Orange County Sanitation District
- Point Loma Wastewater Treatment Plant (PLWTP) operated by City of San Diego

Table 2 provides a complete list of constituents being measured for this nutrient source from November 2008 to October 2009. These concentrations will be multiplied by measured effluent discharge rates to produce monthly loads to the SCB.

Terrestrial Sources
Watershed-based sources of nutrients will be estimated from a combination of measured and modeled wet weather and dry weather loads from all coastal watersheds that drain to the SCB. Watershed loading models will use a Rational Method approach to quantify wet weather loads. Dry weather loads will use measured flows where possible and where not, relationships will be developed between watershed size, land use, and measured flows for the non-gaged watersheds. Watershed wet and dry weather models will be calibrated using data on nutrient concentrations and loads measured at 38 mass emission stations collected by Storm Water Monitoring Coalition (SMC) agencies during the period of November 2008 to October 2009 (Table 3). Existing data on wet weather runoff from various land uses and wet and dry weather loads from mass emission stations will be compiled from SMC agencies to provide supporting data for model development. Table 2 provides a list of the analytes that will be measured in wet and dry weather runoff from the mass emission stations.

Spatial and Temporal Patterns of Algal Blooms

Remote Sensing
Satellite remote sensing will be used to illustrate the spatial and temporal patterns of surface algal blooms as well as the physical factors working as “triggers” of blooms with special focus on coastal upwelling and advection into the Bight. Spatial and temporal patterns of algal blooms can be assessed based on satellite imagery (SeaWiFS since 1997; MODIS-Aqua since 2002; and, probably, MODIS-Terra since 2000). The relationship between the chance of a bloom and environmental factors (e.g., season, upwelling, wind, stormwater discharge, aeolian (dust) fertilization, etc.) will be explored. The criterion that will be used to characterize a “bloom” will be high phytoplankton biomass determined by chlorophyll values exceeding a certain threshold as well as an abrupt increase in chlorophyll (using the method suggested by Stumpf @ NOAA). Physical factors stimulating phytoplankton blooms will be assessed based on data measured by satellites and contact methods (e.g., NDBC buoys). These factors include:

- SST measured by National Data Buoy Center (NDBC) buoys;
- SST measured by satellites (AVHRR and MODIS);

– Stormwater discharge (USGS data and/or model estimations);
– Photosynthetically available radiation (SeaWiFS and MODIS);
– Atmospheric deposition (estimated from aerosol characteristics measured by SeaWiFS and MODIS);

Upwelling in SCB can also be assessed from the maps of SST. We can use modified methodology of Stumpf, estimating the anomalies (i.e., the differences between daily SST and SST averaged over a certain preceding period) indicating dramatic SST decreases.

Real-time chlorophyll and sea surface imagery available from the Southern California Coastal Ocean Observing System (SCCOOS) and Coast Watch will be analyzed before ship-based sampling resulting in optimal coverage of the bloom area.
The Jet Propulsion Laboratory (JPL) has incorporated real-time data (e.g., high-frequency surface currents) to its version to create daily "nowcast" data products as part of the ROMS model. Daily model predictions of temperature, salinity, and currents will be evaluated in conjunction with satellites for additional evidence of Bight-wide upwelling, transport and advection of phytoplankton from offshore to the coast.

Modeling

ROMS is an ocean circulation model capable of computing three-dimensional variability in physical and biogeochemical parameters with fine spatial resolution using the North American and South American West Coast regions as primary testbeds (Marchesiello et al. 2003, Shchepetkin and McWilliams 2003, Shchepetkin and McWilliams 2005). The ROMS model will be used in this study to estimate the magnitude of upwelling to the SCB. The ROMS configuration for the Southern California Bight has the following elements: a uniform grid scale of 1 km over the entire Bight, surface forcing from regional meteorological simulations based on National Centers for Environmental Prediction (NCEP) operational analyses, lateral boundary conditions from a U.S. West Coast ROMS simulation with 6 km horizontal grid resolution and a global tidal analysis, surface gravity wave fields from regional wave models, empirically specified river inflow of water and material concentrations, circulation dynamics, material concentration dynamics, plankton ecosystem dynamics, and sediment resuspension and transport dynamics. Simulations of physical variables have been performed for a multi-year period from 1996-2003. The ROMS model is currently being used by SCCOOS at a horizontal grid scale of 1 km to assimilate available observations, especially HF radar measurements of surface currents, as well as satellite sea surface temperature (SST) and sea surface height (SSH) measurements.

The coastal nitrogen cycle will be described using a state-of-the-art ecosystem model, The Biogeochemical Elemental Cycling (BEC) model, which includes both phytoplankton and zooplankton, as well as dissolved, suspended, and sinking particulates (Moore et al., 2002). The model includes four phytoplankton "functional groups" (picoplankton, diatoms, coccolithophores, diazotrophs) characterized by distinct biogeochemical functions (nutrient recycling, silicification, calcification, and N_2 fixation, respectively) and limited by four different nutrients (nitrogen, silicic acid, phosphate, and iron). The ecosystem is linked to an ocean biogeochemistry module based on an expanded version of the Ocean-Carbon Cycle Model Intercomparison Project (OCMIP) biotic model (Doney et al., 2004). Prognostic variables are added for carbon, alkalinity, iron, and dissolved O_2. The model has been augmented with atmospheric iron deposition, iron scavenging, and continental margin iron sources (Jin et al., 2008). A mineral ballast/organic matter parameterization is used to predict the fate of particulate matter. At UCLA, the BEC model has been fully implemented within ROMS and used to study the Pacific basin carbon cycle (at coarser resolution) and the consequences of iron open-ocean fertilization (Jin et al., 2008).

Field Measurements

Pier-based Sampling

SCCOOS has implemented a new HAB pier-based sampling program that started in July 2008. This program will be part of the Bight'08 Water Quality study design through the collaboration of Burt Jones (USC), David Caron (USC) and Meredith Howard (USC and SCCWRP). Sampling will occur at five piers located in San Luis Obispo, Santa Barbara, Santa Monica Bay, Newport Beach and La Jolla (Table 4, Figure 2). The piers will have mounted sensors for continuous time-series data of temperature, salinity and chlorophyll fluorescence. These samples will be used as a trigger to evaluate if an algal bloom is developing in the SCB. Discrete water samples will be collected weekly and analyzed for the constituents listed in Table 5.

Offshore vessel surveys

There will be three event surveys following the onset of a "bloom" event from February to May 2009 (Figure 3). The onset (trigger) of an event will be determined by sampling at five piers located along the coast (Figure 2) and the data from the SCCOOS gliders (see section below). Two additional surveys will be conducted by the Central Bight Water Quality (CBWQ) group and City of San Diego (SD) as part of their permit monitoring programs (Figure 4). These offshore field surveys will consist of CTD (conductivity, temperature, depth) and bio-optical (transmissivity; chlorophyll, and CDOM fluorometry) vertical profiles and discrete water samples collected at the surface and at the subsurface chlorophyll *a* maximum for measurements of domoic acid, chlorophyll *a*, nutrients, and phytoplankton toxins. The ship-based indicators to be sampled are listed in Table 6.

Regions and Station Selection

Sampling will take place along a series of preselected transects located at input sources to the SCB. Along each transect, 5-6 CTD profiles will be collected with three of those stations including the collection of discrete samples. The timing of the discrete sampling during the CBWQ/SD group cruises will be adjusted to sample algal bloom events while still meeting the permit requirements (e.g., winter and spring sampling) of the agencies involved. The number of stations per group is listed in Tables 7 and 8 and the station locations are shown in Figures 3 and 4.

Event and temporal selection
The three bloom events will be sampled coincidently throughout the SCB (±2 days). If the primary triggers are weak (e.g., little upwelling) or if there are low concentrations of algal biomass, then the CBWQ/SD sampling will occur no later than the second week of March to insure meeting permit requirements. Subsequent sampling will be conducted either by the onset of a trigger or algal bloom or on a set temporal pattern (e.g., every two weeks) determined by consultation between the Bight'08 water quality committee or its designees.

CTD profiles and discrete water sampling
At each station, CTD profiles will include the measurements of temperature, salinity, dissolved oxygen, turbidity, chlorophyll fluorescence and CDOM fluorescence in the water column. Profiles will extend from the surface (≤ 1 m) to within 2-3 meters of the bottom, except in water depths greater than 75 meters, where only the upper 75 meters of the water column will be sampled.

Discrete samples will be obtained at two depths (the surface and at the maximum chlorophyll-fluorescence) from three of the CTD sites along each transect to assess the relationship between HAB species, nutrients, chlorophyll concentration, and domoic acid. Discrete chlorophyll *a* measurements will be used to calibrate CTD-based fluorescence measurements to chlorophyll *a*. Table 6 summarizes the indicators that will be sampled through ship-based sampling

Gliders
The USC Webb Research gliders are equipped to measure temperature, salinity, chlorophyll fluorescence, CDOM fluorescence, phycoerythrin fluorescence and optical backscatter at three minimally absorbing wavelengths (550, 650 and 880 nm). The slope of the multi-wavelength optical backscatter spectrum provides an index of particle size. By using two gliders, exchanged about every three weeks, it will be possible to maintain a nearly continuous presence for this period. Near real-time telemetering of the glider data will provide information about the timing and location of blooms. This data will be used for initiating additional pier and boat sampling should a bloom event occur. The glider data also feeds directly into data assimilating numerical models (i.e., ROMS) that can be used for nowcasting and forecasting of coastal conditions. If run with a biogeochemical model, the model can predict formation, location, and transport of blooms.

Glider mapping along several sentinel lines will be used to monitor for the development of blooms and/or precursor events such upwelling or stormwater runoff events. The region of observation will be San Pedro Bay between Los Angeles Harbor and the Newport Pier. This is an area where additional fixed site monitoring is occurring through a project funded through NOAA's Monitoring and Event Response for Harmful Algal Blooms (MERHAB) program. The glider mapping will occur during a five-month period that spans the primary period of concern for domoic acid toxicity from *Pseudo-nitzschia* spp. This period is typically between February and June of each year. Figure 5 shows a map of the SCCOOS glider coverage on the San Pedro Shelf.

High-Frequency Radar

High frequency (HF) radar is used to measure surface current velocity fields near the coast. Depending on the number and frequency of HF radar used, these systems can detect up to 70 km offshore. The resulting surface plots provide a high-resolution representation (e.g., vector plots) of currents. These vector plots allow mesoscale features, like coastal eddies, to be resolved with a great degree of accuracy. Daily (25-hour averaged) vector plots will be evaluated in conjunction with satellite and ROMS model output.

Figure 6 shows the HF installations for the SCB.

Special Study on Nutrient Source Tracking

Isotopes offer a direct means of source identification because different sources of nitrogen (*e.g.* soil nitrogen, atmospheric nitrogen, chemical fertilizers, manure, and sewage) often have distinct isotopic compositions. In addition, biological cycling of nitrogen often changes isotopic ratios in predictable and recognizable directions that can be reconstructed from the isotopic compositions. Thus utilizing the isotopic composition of nitrate in the SCB could potentially be used to identify point and non-point sources of nitrate to the bight and/or the biological transformation of nitrate. In addition, estimates the amount of primary productivity due to biological recycling and nitrification in surface waters, and loss of nitrogen from the surface waters due to denitrification is critical information to interpret data from the nutrient sources to the SCB.

This component will serve as a pilot study for the utilization of nitrate nitrogen and oxygen isotope ratios as indicators of sources and cycling of nitrate in the SCB. The study involves two parts: 1) determination of nitrate nitrogen and oxygen isotope ratios in specific sources (POTW effluent, river discharge, and upwelled water); and 2) field measurements to determine if source signatures are maintained in the SCB or if they are over-written by biological transformations. For the source signature identification part, water will be collected from LACSD and OCSD during three consecutive months, from the mouths and upstream (freshwater) areas of the Los Angeles River, the San Gabriel River, the Santa Ana River, and the San Diego Creek, and mid-depth and deep water from the SCB representing the upwelling end-member. Samples of wet and dry atmospheric deposition will be analyzed to obtain their isotopic source value. The utility of nitrate isotopic measurements depends on each of these sources having a unique, and identifiable paired oxygen and nitrogen isotopic composition.

The second part of the study will determine if isotopic source tracking is possible in the SCB or if the isotopic composition points to the extent of biological cycling. Water will be collected from the SCB on LACSD and OCSD cruises along vertical and horizontal profiles from the POTW effluent pipes offshore and along transects from the San Gabriel and Santa Ana Rivers (Table 9). Salinity measurements from CTD casts will be used to direct sampling into these freshwater plumes. These measurements will be used to assess whether the river source and POTW source signatures are altered as organisms utilize and recycle nitrate in surface waters. If so, nitrate isotope measurements can still be used to identify key biological source and loss terms for the SCB, but cannot be used for source tracking.

C. Methods and Indicators

The Bight'08 Water Quality study will measure a suite of indicators in order to relate nutrient sources and oceanic hydrodynamic and physiochemical conditions to algal blooms, especially the growth of *Pseudo-nitzschia* and the production of domoic acid. Carefully designed collection of these indicators will allow investigators to identify and statistically model associations between nutrient loads, associated environmental factors and biological response in the SCB. A design principle of Bight'08 is that these indicators will be measured using uniform sampling methods throughout the Bight; the validity of such an assessment depends on ensuring that all the data that contribute to it are comparable. Below, we present a short description of the methods used to measure the Bight'08 indicators; more detailed descriptions of the methods can be found in the accompanying Field Methods and Quality Assurance Manuals for the project.

Nutrients

Water samples from wet weather and dry weather runoff, atmospheric deposition, POTW effluent, and offshore sampling will be analyzed for a suite of total, total dissolved, and dissolved inorganic nitrogen and phosphorus. Silicate, dissolved organic carbon, and urea will also be measured on all samples. Nutrient and silicate samples will be analyzed by autoanalyzer. Urea will be measured by wet chemical methods. Dissolved organic carbon will be measured by high temperature combustion.

Biological Response

Domoic Acid: Particulate domoic acid samples will be collected in the field and frozen until analysis. Rapid analysis of domoic acid concentrations will be made using a new Enzyme Linked Immunosorbent Assay (ELISA) method. The analysis (developed and now offered commercially by Mercury Science, Inc.) is based on a competitive binding assay and is highly specific for domoic acid.

HAB Species Counts: Approximately 100 mL of water will be preserved in lugol's fixative and stored in the lab for future analysis and counts of *Pseudo-nitzschia.*

CTD Profiles: CTD surveys will be conducted using SeaBird CTDs equipped with auxiliary sensors to measure dissolved oxygen, pH, beam transmission (turbidity), chlorophyll fluorescence, and CDOM fluorescence and follow established regional pre- and post-cruise calibrations and deployment procedures.

SCCOOS gliders: The gliders will be deployed on the San Pedro Shelf and will collect measurements of temperature, salinity, chlorophyll fluorescence, CDOM fluorescence and optical backscatter.

Special Studies: Stable Nutrient Isotopes

Nitrogen and oxygen isotope ratios of dissolved nitrate will be measured to identify the sources and cycling of nitrate in the SCB. In addition, the oxygen isotopic composition of water will be analyzed as a tracer for water sources (freshwater sources have lower water oxygen isotope ratios compared to seawater); water oxygen can also be used to extrapolate expected nitrate oxygen isotope values if denitrification is present. Nitrate will be isolated from water samples via reduction of nitrate to nitrous oxide, which will be analyzed on a continuous flow isotope ratio mass spectrometer (CF-IRMS). The oxygen isotopic composition of water will be measured on whole water samples by laser-absorption spectroscopy.

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Figure 3. Map of the study area. The HAB surveillance piers are represented by the blue balloons and the white box shows the San Pedro Shelf, the location of intensive studies using SCCOOS gliders.

Figure 4. Map of the Bight'08 offshore water quality stations for the three event surveys.

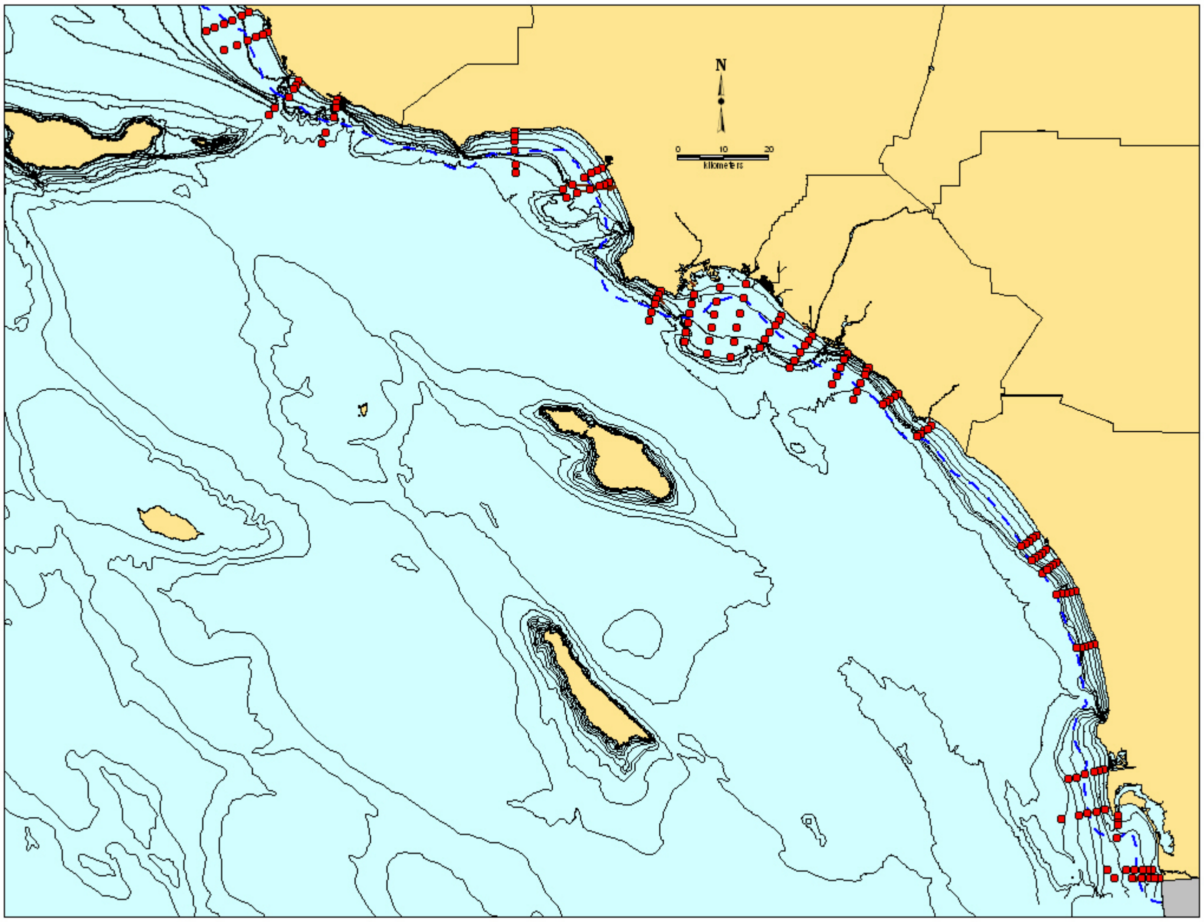

Figure 5. Map of the Bight'08 offshore sampling stations for the two Central Bight Water Quality surveys conducted as part of their permit monitoring programs.

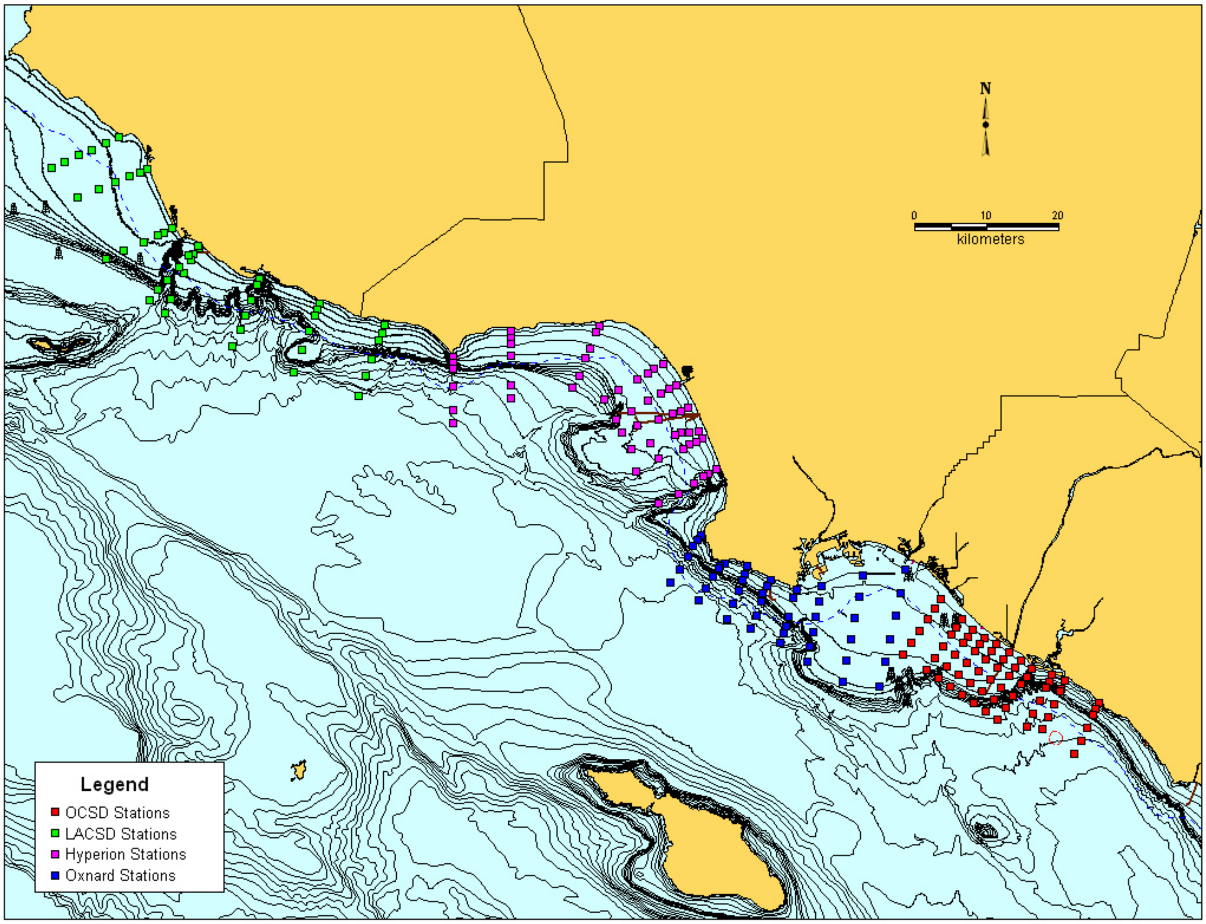

Figure 6. Map of the Bight'08 glider sampling area off the San Pedro Shelf. Black box outlines the intensive region. Red lines are the Spray glider lines and the yellow box is the Webb glider operational area. Hydrographic profiles will be taken along the two Spray lines.

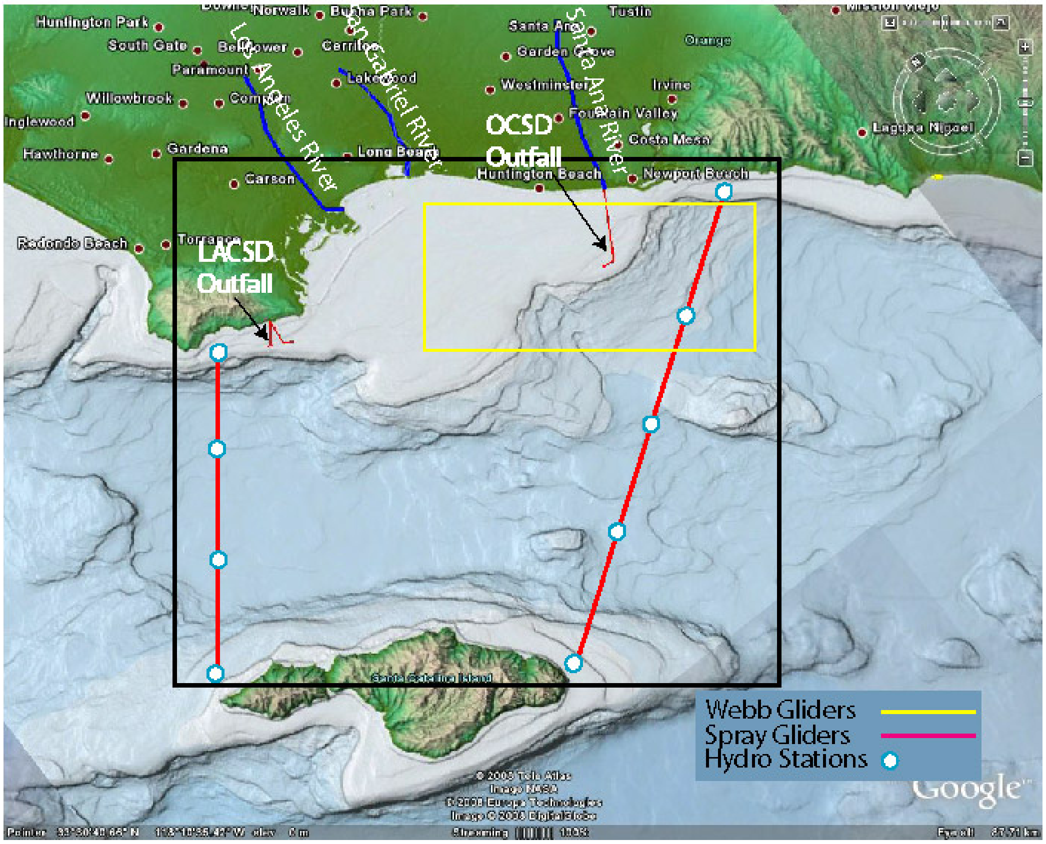

Figure 7. Map of the Bight'08 water quality study area with high-frequency (HF) radar sites.

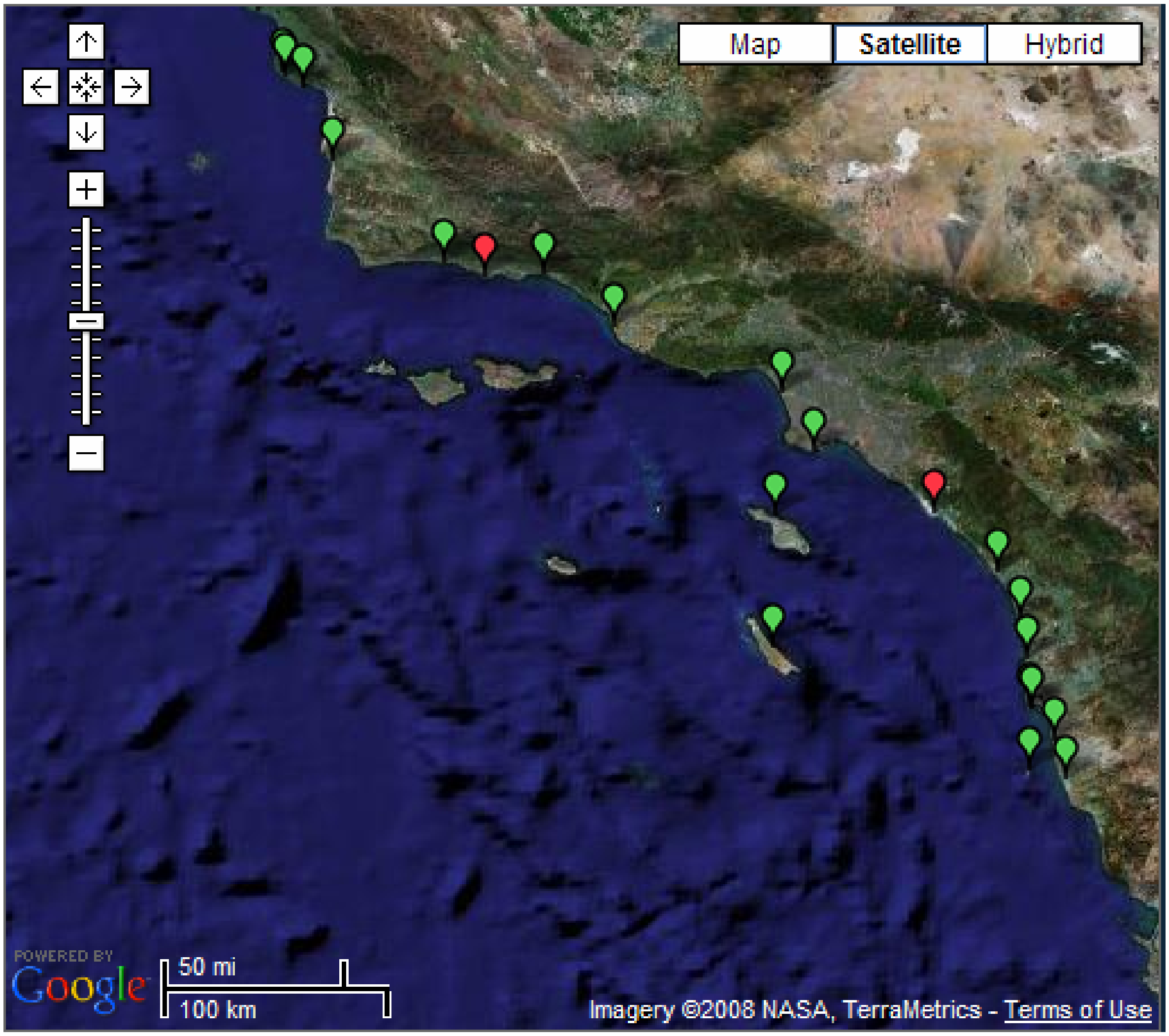

Table 2. List of constituents to be sampled and analyzed for each nutrient source.

Constituent	Watershed Loading	Atmospheric Deposition		POTW Effluent	Upwelling
		Wet	Dry		
Nitrate+Nitrate	X			X	
Nitrate		X	X		X
Ammonia	X	X	X	X	
Phosphate	X	X	X	X	X
Silicate	X			X	X
Urea	X			X	
Total Dissolved Nitrogen	X	X	X	X	
Total Nitrogen	X	X	X	X	
Total Dissolved Phosphorus	X	X	X	X	
Total Phosphorus	X	X	X	X	

Table 3. List of mass emission stations where nutrient concentrations and loads will be measured under Bight'08 water quality study.

County	Location	Number of Wet and Dry Weather Events
Los Angeles	Ballona Creek at Sawtelle	3 storms + 2 dry
Los Angeles	Coyote Creek at Spring Street	3 storms + 2 dry
Los Angeles	Dominguez Channel at Artesia Blvd	3 storms + 2 dry
Los Angeles	Los Angeles River at Wardlow	3 storms + 2 dry
Los Angeles	Malibu Creek at Piuma Road	3 storms + 2 dry
Los Angeles	San Gabriel River at SGR Parkway	3 storms + 2 dry
Los Angeles	Santa Clara River at The Old Road	3 storms + 2 dry
Orange	San Diego Creek at Campus	3 storms + ≥ 3 dry
Orange	Bolsa Chica at Westminster	3 storms + 2 dry
Orange	Bonita Cyn Wash u/s University	3 storms + ≥ 3 dry
Orange	Costa Mesa Channel at Highland	3 storms + ≥ 3 dry
Orange	Garden Grove Wintersburg at Gothard	3 storms + 2 dry
Orange	Santa Ana Delhi at Irvine Ave	3 storms + ≥ 3 dry
Orange	Aliso Creek at Aliso/Woods Cyn Park	3 storms + 2 dry
Orange	Laguna Canyon at Woodland	3 storms + 2 dry
Orange	Prima Deschecha at Calla Grande Vista	3 storms + 2 dry
Orange	Segunda Deschecha at El Camino Real	3 storms + 2 dry
Orange	San Juan Creek at La Novia	3 storms + 2 dry
Orange	Trabuco Creek at Del Obispo Road	3 storms + 2 dry
San Diego	Santa Margarita River	1 storm
San Diego	San Luis Rey River	1 storm
San Diego	Agua Hedionda Creek	1 storm
San Diego	Escondido Creek	1 storm
San Diego	San Dieguito River	1 storm
San Diego	Penasquitos	1 storm
San Diego	Tecolote Creek	1 storm
San Diego	San Diego River	1 storm
San Diego	Chollas Creek	1 storm
San Diego	Sweetwater River	1 storm
San Diego	Tijuana River	1 storm
Ventura	Calleguas Creek at CSUCI Bridge	4 storms + 2 dry
Ventura	Freeman Diversion, Saticoy	4 storms + 2 dry
Ventura	Ojai Valley Sanitation District	4 storms + 2 dry
Ventura	La Vista Drain	1st storm
Ventura	Revolon Slough	1st storm

Table 4. The SCCOOS HAB pier sampling locations and research groups.

Pier	City	Laboratory	Researcher/PI	Institution
California State Polytechnic Pier	San Luis Obispo	Moline Laboratory	Mark Moline	California State Polytechnic University
Stearn's Wharf	Santa Barbara	Brzezinski laboratory	Mark Brzezinski	University of California Santa Barbara
Santa Monica Pier	Santa Monica	Shipe Laboratory	Rebecca Shipe	University of California, Los Angeles
Newport Pier	Newport Beach	Jones and Caron Laboratories	Burt Jones and David Caron	University of Southern California
Scripps Pier	La Jolla	McGowan laboratory	John A. McGowan	University of California, San Diego - Scripps Institution of Oceanography

Table 5. List of pier-based indicators to be sampled in the Bight'08 study.

Component	**Indicator/Analyte**
Continuous sensor	temperature
	salinity
	fluorescence
Discrete water samples	chlorophyll *a*
	nitrate
	ammonia
	phosphate
	silicate
	domoic acid
	temperature
	HAB species counts
	Pseudo-nitzschia
	Alexandrium
	Lingulodinium polyedrum
	Prorocentrum
	Dinophysis
	Akashiwo sanguineum
	Cochlodinium
	Phaeocystis

Table 6. List of ship-based indicators to be sampled in the Bight'08 study.

Component	Indicator/Analyte
CTD profile	Temperature Salinity dissolved oxygen turbidity fluorescence (for chlorophyll a and CDOM)
Discrete water samples	chlorophyll *a* nitrate nitrite phosphate silicate urea total dissolved nitrogen total dissolved phosphorus total nitrogen total phosphorus *Pseudo-nitzschia* cell counts

Table 7. Bight'08 offshore water quality station counts for the three event surveys.

Area	Responsible Agency	Number of Stations
North	Contractor	10
Central	Oxnard (ABC Labs)	24
Central	Hyperion	18
Central	LACSD	24
Central	OCSD	24
Central	Contractor	10
South	Contractor	25
South	San Diego	28

Table 8. Bight'08 offshore water quality station counts for the two Central Bight Water Quality surveys as part of their permit monitoring programs.

Area	Responsible Agency	Number of Stations
North	Oxnard	48
Central	Hyperion	54
Central	LACSD	48
Central	OCSD	66

Table 9. Selected sites for Isotope Pilot Study

Site #	Depth	Purpose
LACSD 2903	surface	effluent plume source tracking
LACSD 2903	34 m	effluent plume source tracking
LACSD 2903	45 m	effluent plume source tracking
LACSD 2904	surface	effluent plume source tracking
LACSD 2904	45 m	effluent plume source tracking
LACSD 2904	50 m	effluent plume source tracking
OCSD 2205	surface	effluent plume source tracking
OCSD 2205	30 m	effluent plume source tracking
OCSD 2205	54 m	effluent plume source tracking
OCSD 2206	surface	effluent plume source tracking
OCSD 2206	30 m	effluent plume source tracking
OCSD 2206	45 m	effluent plume source tracking
OCSD POTW	effluent	effluent plume source tracking
LACSD POTW	effluent	effluent plume source tracking
San Gabriel River mouth at Marina Drive	surface	river source tracking
San Gabriel River at 2nd Street/Westminster Blvd (freshwater)	surface	river source tracking
LACSD 2501 - San Gabriel River	surface	river source tracking
LACSD 2502 - San Gabriel River	surface	river source tracking
LACSD 2503 - San Gabriel River	surface	river source tracking
LACSD 2504 - San Gabriel River	surface	river source tracking
PCH and Santa Ana River (river mouth)	surface	river source tracking
Hamilton Ave and Santa Ana River (freshwater)	surface	river source tracking
OCSD 2201 - Santa Ana River	surface	river source tracking
OCSD 2202 - Santa Ana River	surface	river source tracking
OCSD 2203 - Santa Ana River	surface	river source tracking
OCSD 2204 - Santa Ana River	surface	river source tracking
LA River at boat launch near Queens Way Bridge/Bay (river mouth)	surface	river source tracking
LA River at West Wardlow Rd. (freshwater)	surface	river source tracking
San Diego Creek (Upper Newport Bay) Fish and Game Dock at Shellmaker Island (freshwater/saltwater mixing)	surface	river source tracking
San Diego Creek near Campus Drive and University Drive (freshwater)	surface	river source tracking
LACSD 2505	45 m	upwelling source tracking
LACSD 3056	45 m	upwelling source tracking
OCSD 1906	75 m	upwelling source tracking

OCSD 2354	30 m	upwelling source tracking