Southern California Bight
2013 Regional Marine Monitoring Survey
(Bight'13)

Nutrients Workplan

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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. These regional monitoring programs have increased the number of sites, analytes and habitat types that are sampled as part of regular monitoring programs in order to provide a regional assessment. Other 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.

To date, four 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 over 260 sites along the continental shelf between Point Conception and the United States/Mexico border. 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. 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. The Bight'98 water quality surveys 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. 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. 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 in 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.

Bight '08 there were 61 agencies that sampled the same geographic area as in 2003. Results of Bight '08 Offshore Water Quality Study provided evidence that on small scales relevant to the development of algal blooms, anthropogenic nitrogen loads were equivalent to upwelled nitrogen loads in the heavily urbanized regions of the SCB (Fig. 1 and 2; (Howard et al. 2012). The discharged effluent of Publicly Owned Treatment Works (POTWs) was the main anthropogenic constituent that comprised the anthropogenic nitrogen loads, whereas riverine runoff and atmospheric deposition were determined to be 1-3 orders of magnitude smaller (Figure 2) (Howard et al. 2012). The POTW effluent was also shown to alter the natural composition of the nitrogen pool, which has implications for algal community composition. Additionally, the results indicated that the extent of surface algal blooms has increased over the last decade, with chronic blooms documented in areas of the SCB co-located with major inputs of anthropogenic nutrients as well as longer residence times of coastal waters. The Bight'08 study also provided new insights into algal bloom development in that upwelling was documented to transport a subsurface algal bloom closer to shore and into surface waters, resulting in bloom intensification.

The Bight'13 Survey is organized into six technical components: 1) Contaminant Impact Assessment (formerly Coastal ecology); 2) Shoreline microbiology; 3) Nutrients; 4) Marine Protected Areas, and; 5) Trash and debris.

Table 1 provides a list of the participating organizations in the Bight'13 Nutrients Study.

C. Context for Bight '13 Nutrients Study

Eutrophication of coastal waters is a global environmental issue, with demonstrated links between anthropogenic nutrient inputs and the global increase in frequency and occurrence of algal blooms, including harmful algal blooms (Anderson et al. 2002, Howarth et al. 2002, Glibert 2005, Glibert et al. 2006, Glibert et al. 2008), and associated effects such as hypoxia and coastal acidification (Howarth et al. 2002, Bograd et al. 2008, Rabalais et al. 2009, Rabalais et al. 2010, Cai et al. 2011, Feely 2012). However, in upwelling-dominated ecosystems, untangling the relative influence of natural (i.e. upwelling) versus anthropogenic (wastewater discharge, urban runoff and atmospheric deposition) nutrient sources on coastal waters has proved to be more complex. In these ecosystems, there has been a perception that anthropogenic nutrient inputs are small relative to upwelling, and thus, can have little effect on these processes (nearshore productivity, hypoxia and coastal acidification). However, the results from several recent studies contradict this perception and provide multiple lines of evidence that anthropogenic nutrients are altering the ecological conditions in the SCB.

First, the results from the Bight '08 Offshore Water Quality study quantified anthropogenic and natural nutrient contributions and showed that in the heavily urbanized regions of the SCB, the anthropogenic nitrogen sources were equivalent to natural nutrient sources (Figure 2). Additionally, algal bloom intensity was shown to have significantly increased over the last decade and algal bloom 'hotspots' were shown to be co-located with major anthropogenic sources and extended water residence times.

Second, there were three relevant findings from the results from the OCSD Diversion in 2012. First, there is evidence of effluent nutrients in two trophic levels of the food webs (primary producers and zooplankton) indicating that effluent is being utilized by primary producers for growth. Second, POTW effluent was a distinguishable nutrient source and significantly contributes to the total nitrogen (dissolved and particulate fractions) pools in Orange County. Third, high rates of nitrification (the biological transformation of ammonia, the dominant nitrogen form in effluent, to nitrate) were documented and provide a source of nitrate from effluent ammonia, thereby altering the natural composition of nitrogen forms in the ecosystem. These nitrification rates are sufficiently high to potentially transform a significant fraction of effluent ammonia to dissolved nitrate. The results also showed that 90% of the dissolved total nitrate was derived from effluent (as opposed to other sources) and the results from particulate matter indicated that nitrogen from effluent comprised up to half of the total nitrogen in bacteria, phytoplankton, and zooplankton located proximal to the OCSD ocean outfall. However, a similar study conducted in the spring of 2008 indicated that effluent nitrate comprised less than 10% of the total dissolved nitrate, suggesting that the effects of effluent nitrogen on the nearshore environment may have strong seasonality. The results of these findings are consistent with the Bight '08 results which indicated that effluent provides an equivalent contribution of nitrogen on annual time scales and has significantly increased the extent of algal blooms over the last decade (Howard et al. 2012, Nezlin et al. 2012). Furthermore, respiration of this organic matter can lead to reductions in dissolved oxygen and increases in carbon dioxide, thereby exacerbating coastal hypoxia and acidification.

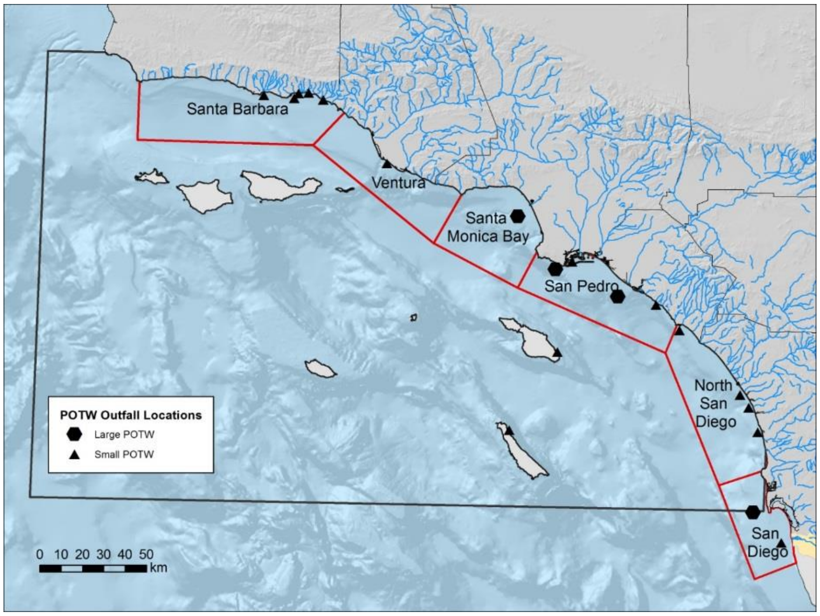
Third, the recent historical analysis of dissolved oxygen concentrations in the SCB compared data collected in the nearshore areas (Central Bight Water Quality Group) with CalCOFI data collected farther offshore (Booth et al., submitted). The results from this study show that dissolved oxygen concentrations have declined in all areas, however, the rates of decline in the nearshore areas are up to four times faster than for the offshore waters (Figure 3). While ~30% of these declines are accounted for by large scale climate variability, it is unclear whether the remaining declines documented are a result of upwelled or anthropogenic nutrient inputs. Additionally, expansion of the oxygen minimum layer and shoaling of the hypoxic zone have also been documented in the SCB (Bograd et al. 2008).

Primary productivity and nutrient cycling (including oxygen demanding processes like nitrification) can have direct and indirect effects on ecological condition of coastal waters. The California Ocean Plan establishes criteria for the amount of influence that anthropogenic wastewater dischargers are permitted to have on the ecological condition of coastal waters. These include criteria for nutrients ("shall not cause objectionable growth or degrade indigenous biota"), dissolved oxygen ("shall not be depressed by more than 10% of that which would occur naturally"), and pH ("shall not be changed more than 0.2 pH units"). However, how anthropogenic nutrients influences each of these is not well understood. In particular, for pH, existing monitoring procedures do not adequately measure pH in a way that a 0.2 pH unit change could even be resolved.

In summary, these studies have provided multiple lines of evidence that anthropogenic nutrients are altering the ecological conditions in the SCB. However, the extent of the role of anthropogenic nutrients in these natural biological and chemical processes has not been determined. To insure compliance with Ocean Plan standards, the relative influence of anthropogenic nutrients on primary production and nutrient cycling in the SCB must be resolved, and is therefore the focus for the Bight '13 Nutrients Study.

Figure 1. Map of the Southern California Bight.

Figure 2. Results from the Bight '08 Offshore Water Quality Study.
The map shows the locations of large and small POTWs and the regional area (black lines) and sub-regional area (red lines) used for annual nitrogen fluxes. The lower panel is the annual nitrogen flux for upwelling, effluent, riverine runoff, and atmospheric deposition by sub-region (area shown by red lines) (Howard et al., 2012).



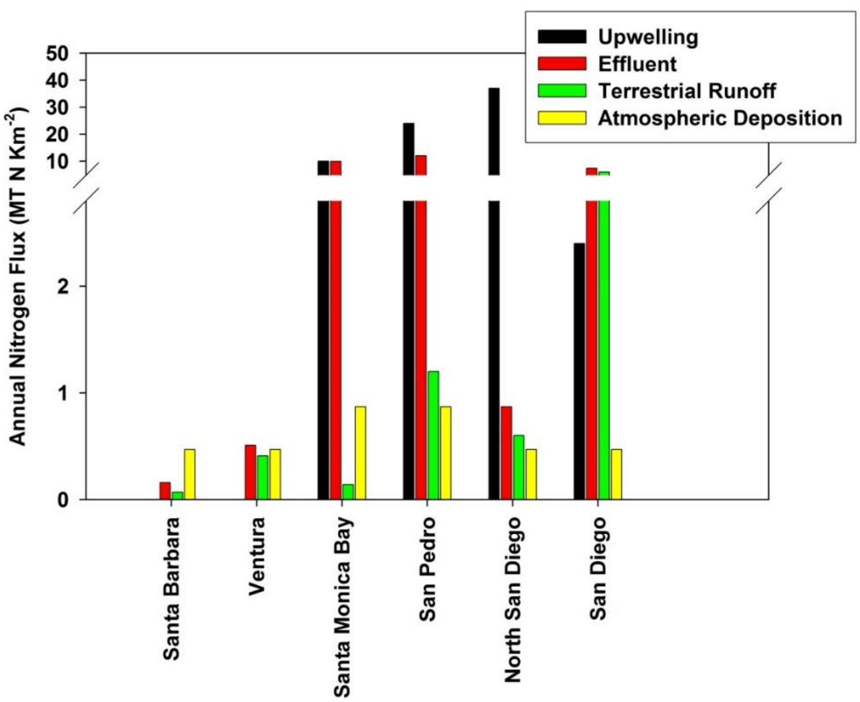


Figure 3. Historical Analysis of dissolved oxygen concentrations in the SCB.
Oxygen concentrations are declining over time, at higher rates in the nearshore areas.
Change in oxygen per year (µmol kg-1 yr-1) from August 1998 to May 2011 by density (σθ) averaged across all stations. POTW regional monitoring areas are shown by colored lines and the solid black line with open circles is all POTW data combined. Nearshore (<175 km) CalCOFI stations are illustrated with black asterisks and offshore (>175 km) station in grey (Booth et al., submitted).

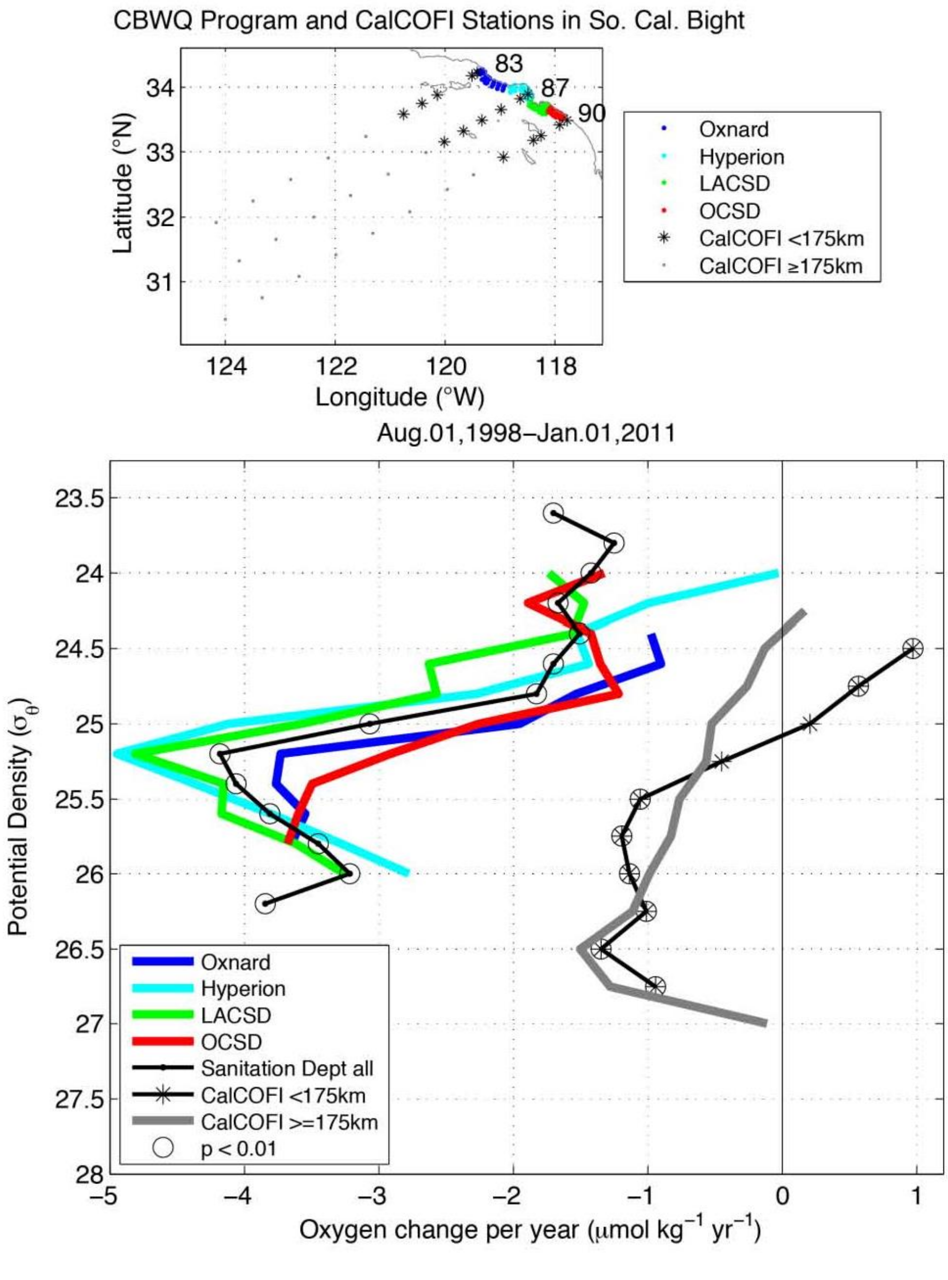


Table 1. Participating organizations in the Bight'13 Nutrients Regional Monitoring Program.

Aquatic Bioassay and Consulting Laboratories, Inc.
Chevron
City of Escondido
City of Los Angeles
City of Oxnard
City of San Diego
Los Angeles County Sanitation Districts (LACSD)
Orange County Sanitation District (OCSD)
Santa Ana Regional Water Quality Control Board
State Water Resources Control Board
Southern California Coastal Water Research Project
University of Southern California
University of California, Santa Barbara
University of California, Los Angeles
University of California, Irvine

II. STUDY DESIGN

A. Study Objectives

The overall goal of the Bight'13 Nutrients Study is to determine the extent to which anthropogenic nutrients are altering ecological conditions in the SCB. There are three main areas of interest that will be the focus of the Bight '13 Nutrient study, (1) algal blooms, (2) acidification and low pH (aragonite saturation state), and (3) ecological processes (biological productivity, concentrations of dissolved oxygen and nutrient cycling). Previous studies have documented some effects to primary production however, the specific role of anthropogenic or local nutrients in the decline in dissolved oxygen concentrations and low pH have not been examined in the SCB. Primary productivity and nutrient cycling can have direct and indirect effects on dissolved oxygen and pH measurements at local scales and it is unclear the extent to which these processes are influenced by anthropogenic nutrients. The Bight '13 Nutrients Program is designed to focus on these aspects.

There are three specific objectives of the program:

1. Determine the frequency, spatial extent and seasonality of algal blooms (high chlorophyll features), in the SCB.
2. Determine the spatial patterns and seasonality of pH and aragonite saturation state in the SCB.
3. Determine how anthropogenic nutrient inputs affect ecological processes and rates that drive biological productivity, concentrations of dissolved oxygen, and aragonite saturation state.

Objective 1 will be accomplished by analyzing historical chlorophyll data collected as part of routine monitoring by the POTWs, CalCOFI and SPOTs programs. This analysis will focus on the trends of algal blooms with respect to the (1) frequency, (2) spatial extent and (3) seasonality.

Objective 2 will develop new monitoring protocols that will improve the collection of pH data during POTW ocean monitoring programs. The collection of discrete samples of pH and alkalinity at a subset of stations during the POTW NPDES monitoring programs will be used to develop these protocols and to determine the spatial patterns and seasonality over 2 years in the SCB.

Objective 3 will be accomplished by conducting biogeochemical field experiments to determine key rates of primary production and respiration processes and nitrogen and carbon cycling. The use of stable isotopes to trace nitrogen sources in dissolved seawater as well as in algal and bacterial biomass will also be utilized. These chemical and biological rates will be used to populate, refine and validate models used by University of California, Los Angeles collaborators. These models will be used to determine if anthropogenic nutrients are having significant effects on primary production, hypoxia and acidification on a regional scale.

B. Sampling Design

The sampling design for Bight'13 Nutrients program will be divided into three main components focused on the following: 1) temporal and spatial trends of algal blooms, 2) spatial patterns of pH and aragonite saturation, and 3) biogeochemical process studies and nutrient source tracking.

Temporal and Spatial Trends of Algal Blooms

The historical analysis of the temporal and spatial trends of algal blooms will be determined from analysis of existing CTD (conductivity, temperature, depth) vertical profiles chlorophyll fluorescence. Existing datasets that will be used in the analysis include the following: POTWs Ocean Monitoring, (2) CalCOFI, and (3) SPOTS (Wrigley and USC). Additionally, when available, discrete chlorophyll a samples collected during previous programs will be used to create a calibration coefficient that will be used to correct the chlorophyll fluorescence datasets.

Table 2 summarizes the number of stations in each sub-region for which CTD data exists from the NPDES permit monitoring program.

Spatial Patterns of pH and Aragonite Saturation State

The spatial patterns of pH and aragonite saturation state will be determined from new data collected over 2 years that will be used to develop new monitoring protocols to improve the collection of pH data during POTW ocean monitoring programs. The collection of discrete samples of pH and alkalinity at a subset of stations during the POTW NPDES monitoring programs will be used to develop these protocols.

Discrete samples will be collected at a minimum of 25% of stations and a minimum of 2 depths at each station for alkalinity and pH, coincident with pH profiles collected using glass electrodes mounted on the water column profiling package. The ship-based indicators to be sampled are listed in Table 3. These samples will be analyzed either by the agency or an outside contract laboratory. There will be an intercalibration before sampling starts to determine interlaboratory comparability for alkalinity and pH amongst the laboratories participating in the sample analysis.

Table 2 summarizes the number of stations for sample collection and total number of discrete samples that will be collected.

Biogeochemical Process Studies and Nutrient Source Tracking

The combination of field observations and experimental studies will be used to characterize the sources and fates of nitrogen in an effluent impacted area as well as a minimally-impacted area. Collectively, these datasets will be used to elucidate the sources and fates of nutrients at times when effluent discharge is anticipated to constitute minor (spring upwelling period) or major (late summer/fall) components of the total nutrient budget. The use of stable nitrogen isotopes offer a direct means of source identification because different sources of nitrogen (*e.g.* effluent, atmospheric nitrogen, chemical fertilizers etc.) often have distinct isotopic compositions or signatures. 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 and ammonia in the SCB can be used to identify point and non-point sources of nitrogen to the bight and/or the biological transformation of nitrate.

Field Work Overview

There are two main components to the field work (1) nitrogen source tracking and (2) process studies to determine rates of nitrification, primary production, respiration, and nitrogen uptake.

Field work will be conducted twice a year during the first two years of the project in order to capture the spring upwelling period (when upwelling is likely the dominant nutrient source) and the fall period (normally characterized by stratified water conditions and very low-to-no precipitation when effluent is likely the dominant nutrient source). Sample collection and experiments will be conducted in the OCSD and LACSD outfall areas (effluent impacted area), in the Camp Pendleton area (non-effluent impacted area) and at one offshore location (in San Pedro area). Table 4 summarizes the indicators that will be collected for this study component and Figure 4 shows the tentative sampling locations.

(1) <u>Nitrogen Source Tracking Analysis:</u> Discrete samples for nitrogen concentrations in different pools (dissolved and particulate), and for stable isotopic composition of the dissolved and particulate fractions will be collected on the ship surveys in order to determine the nutrient sources present in coastal waters as well as which sources are being utilized by phytoplankton and bacteria. These samples will be collected at 8 stations, 5 in the effluent impacted area (LACSD and OCSD monitoring areas), 2 in the non-impacted area (Camp Pendleton), and 1 from an offshore location (San Pedro area). Discrete samples will be collected at a minimum of 4 depths at each station. The relative contribution of nitrogen from effluent and upwelling (the two largest sources in this area as determined by the Bight'08 results) will be assessed by comparing the natural abundance stable isotopic composition of *in situ* waters (i.e. seawater samples) with those of the distinct sources. The source samples of effluent and upwelling will be compared with both dissolved and particulate discrete seawater samples.

(2) <u>Process studies</u>: We will conduct three main types of bottle incubation experiments with seawater collected during each survey cruise, designed to identify the fate of nitrogen in the San Pedro shelf ecosystem.

a. *Nitrification Rates:* Nitrification rates will be determined by measuring the accumulation of ^{15}N in the dissolved nitrate pool following addition of isotopically-enriched ammonium to bottle incubations at 7 stations total, 4 in the effluent impacted area (LACSD and OCSD monitoring areas), 2 in the non-impacted area (Camp Pendleton) and 1 at the offshore station. There will be 4 depths characterized for each station.

b. Primary Production and Respiration: Short-term incubations of natural plankton communities will be conducted to determine rates of primary production and respiration using radioactive ^{14}C labeled compounds. Seawater for experiments will be collected at 3 stations total (the same as the nitrification rate experiments) at 5 depths to determine an integrated water column rate. These experiments will provide rates of primary production and rates of respiration and will be used in conjunction with the nitrogen source tracking results to determine if differences in rates exist between effluent impacted and non-impacted regions.

c. *Nitrogen Uptake Rates:* Short-term incubations of natural plankton communities will be conducted to determine the uptake rates of ^{15}N-labeled nitrogenous compounds (ammonium, nitrate) to characterize the nitrogenous physiology of the biological community as a whole and determine specific rates of uptake of the common nitrogen forms present (nitrate, ammonia). Experiments will be conducted within 24 hours of collection at *in situ* temperatures; one station and depth will be selected in each region in each season for this experiment.

Coordination with Modeling Projects

The integration of ecosystem and biogeochemistry models with the Regional Oceanic Modeling System (ROMS; a three-dimensional ocean circulation model) have been developed and will be used to determine which areas of the U.S. West Coast are most susceptive to acidification and hypoxia, and to determine how local nutrient inputs exacerbate these conditions. While this project spans the U.S. West Coast, the Southern California Bight is the initial focus area. Coupling of biogeochemical and dissolved oxygen models to the ROMS circulation models require additional calibration and validation, with mechanistic studies to help parameterize key processes and rate constants associated with the fate of carbon and nutrients. ***The process study experiments will provide these key rates and will be used in the modeling efforts that are already underway.***

C. Methods and Indicators

The Bight'13 Nutrients study will use existing as well as newly collected CTD and discrete sample data. A design principle of Bight'13 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'13 indicators; more detailed descriptions of the methods can be found in the accompanying Field Methods and Quality Assurance Manuals for the project.

Chlorophyll Fluorescence

Dissolved oxygen and chlorophyll fluorescence will be detected using CTD vertical profiles. CTD data will be conducted using SeaBird CTDs equipped with auxiliary sensors to measure dissolved oxygen, pH, beam transmission (turbidity), chlorophyll fluorescence, and CDOM fluorescence. Table 3 summarizes the indicators that will be collected for this study component.

pH and Depressed Aragonite Saturation State

The pH and aragonite saturation state of waters will be detected using a combination of profiling electrodes and discrete samples. Table 3 summarizes the indicators that will be collected for this study component.

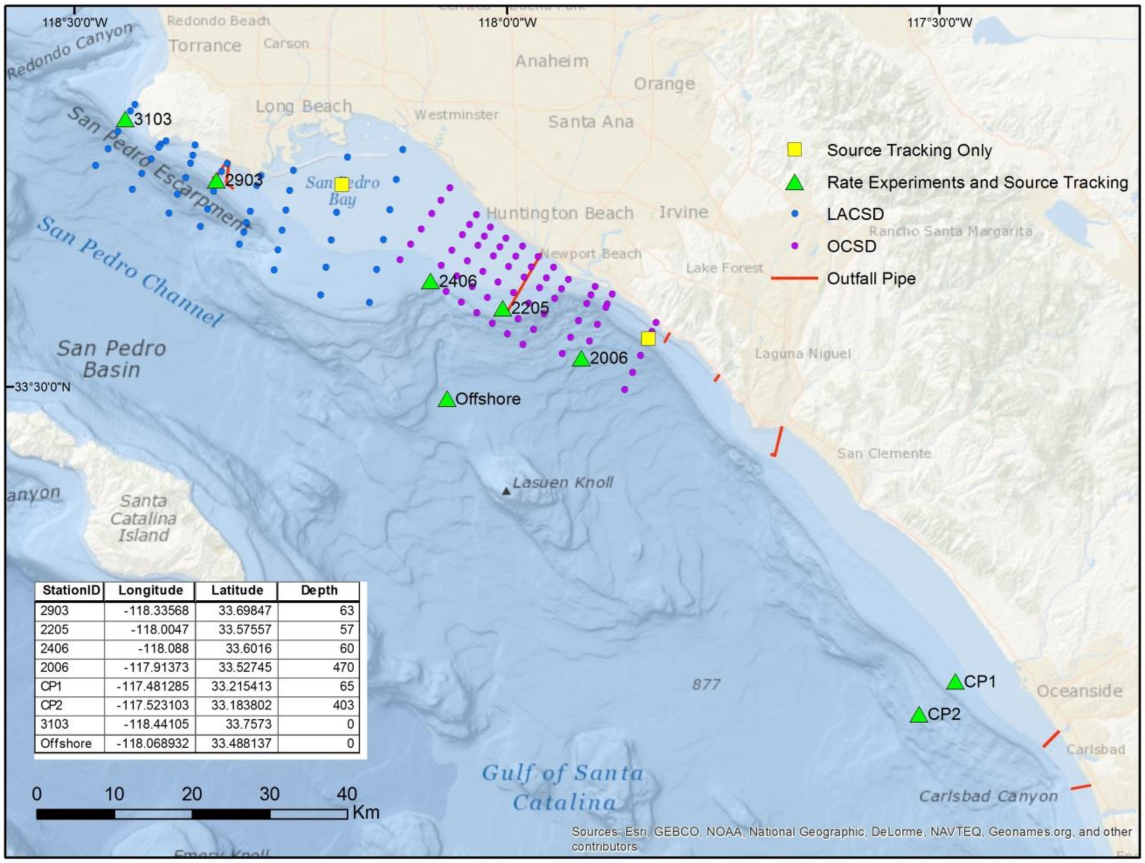
Process Studies and Nutrient Source Tracking

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. Table 4 summarizes the indicators to be collected for this study component.

Nutrients: Discrete samples will be collected on the ship surveys and frozen immediately. Shore-based analyses will use standard protocols for nutrients (nitrate + nitrite, ortho-phosphate, and silica using FIA; total nitrogen (TN) and phosphorus (TP) samples will be analyzed via persulfate digest (Patton and Kryskalla 2003) and analyzed using FIA.

Stable Isotope Source Tracking: The relative contribution of nitrogen from effluent and upwelling in the SCB will be assessed by comparing the natural abundance stable isotopic composition of *in situ* waters with those of the distinct sources. End-member samples will be collected from Orange County Sanitation District and from deep waters offshore using ships of opportunity. End-members will be compared with both discrete *in situ* samples collected coincident with nutrient samples described previously as well as particulate samples collected from whole water samples. Isotope ratios of $^{15}N/^{14}N$ and $^{18}O/^{16}O$ will measured using a ThermoFinnigan GasBench + PreCon trace gas concentration system interfaced to a ThermoScientific Delta V Plus isotope-ratio mass spectrometer at the Stable Isotope Facility at the University of California, Davis. The isotope ratios of $^{15}N/^{14}N$ and $^{13}C/^{12}C$ from particulate matter collected from seawater will be measured using a coupled Costech Elemental Analyzer with a Finnigan Delta Plus Advantage in Continuous Flow Mode at the Marine Science Institute at the University of California, Santa Barbara.

Figure 4. Map of the Bight'13 Nutrient study tentative sampling stations for the biogeochemical process studies.



StationID	Longitude	Latitude	Depth
2903	-118.33568	33.69847	63
2205	-118.0047	33.57557	57
2406	-118.088	33.6016	60
2006	-117.91373	33.52745	470
CP1	-117.481285	33.215413	65
CP2	-117.523103	33.183802	403
3103	-118.44105	33.7573	0
Offshore	-118.068932	33.488137	0

Table 2. Total number of station locations for the Central Bight Water Quality surveys sampled as part of the NPDES permit monitoring program. The number of stations at which discrete samples will be collected for the spatial patterns of pH and aragonite saturation component of the study.

Responsible Agency	Number of CTD Stations for each survey	Number of stations for discrete sample collection	Number of discrete samples per survey (2 depths)	Total number of samples to be collected (2 years)
City of Oxnard/ABC Labs	45	12	24	192
City of Los Angeles	54	14	28	224
LACSD	48	12	24	192
OCSD	66	17	34	272
City of San Diego	76	19	38	304

Table 3. List of ship-based indicators to be collected during the regular NPDES permit monitoring surveys.

Component	Indicator/Analyte
CTD profile	Temperature Salinity dissolved oxygen turbidity fluorescence (for chlorophyll a and CDOM) pH
Discrete water samples	Total Alkalinity pH

Table 4. List of indicators to be collected for the nutrient source tracking and process rate experiments during these ship surveys.

Component	Indicator/Analyte
CTD profile	Temperature Salinity dissolved oxygen turbidity fluorescence (for chlorophyll a and CDOM) pH
Discrete Samples	Dissolved inorganic nutrients (NO_3, NH_4, PO_4) Particulate nitrogen and carbon Total nitrogen and phosphorus Particulate ^{15}N Dissolved $^{15}NO_3$ Dissolved $^{15}NH_3$
Nutrient Source Samples	Effluent (NO_3, NH_4, $^{15}NO_3$, $^{15}NH_3$) Atmospheric samples ($^{15}NO_3$, $^{15}NH_3$) Deep offshore water samples (representative of upwelled water) ($^{15}NO_3$, $^{15}NH_3$)

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