SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

FY 2013/2014
RESEARCH PLAN

Approved by SCCWRP Commission

June 2013

CONTENTS

INTRODUCTION

The Southern California Coastal Water Research Project Authority (SCCWRP) is a research institute studying the coastal ecosystems of southern California, from watersheds to the ocean. SCCWRP’s primary mission is to enhance scientific understanding of linkages among human activities, natural events, and the health of the Southern California coastal environment; to communicate this understanding to decision makers and other stakeholders; and to suggest strategies for protecting the coastal environment for this and future generations.

Each year, SCCWRP prepares a Research Plan describing anticipated research activities for the upcoming fiscal year. The Plan provides an overview of SCCWRP’s research foci, as well as details of specific projects. SCCWRP's quarterly Director’s Report provides updates on research objectives and reports project benchmarks as related to the Research Plan. Both the Research Plan and the Director’s Reports can be accessed year-round on the SCCWRP website (www.sccwrp.org).

The Research Plan is organized by project purpose, with research activities falling into three main areas: development of new environmental assessment methodologies and tools, science to support management or regulatory programs, and regional monitoring programs to assess status and trends in ecosystem conditions. Projects are next grouped by scientific disciplines or habitats. Although some projects may be representative of more than one category, reflecting the interdisciplinary nature of SCCWRP research, each appears only once. Project descriptions detail goals, current status, collaborators, funders, and lead investigator contact information for each project. Readers are encouraged to contact lead investigators for additional project information and research insights.

A. ENVIRONMENTAL ASSESSMENT METHOD/TOOL DEVELOPMENT

One of the main functions of SCCWRP's research is to investigate, test, refine, validate, and transfer new environmental assessment technologies to California's water quality management community. SCCWRP is consistently on the leading edge of environmental assessment method and/or tool development for southern California, and in some cases, for the state, national, and international scientific community. Method/tool development is often initiated in response to a particular problem or need, morphing novel scientific techniques into usable and reliable applications. SCCWRP's emphasis is not only on discovering new ways of understanding the environment, but on leveraging its linkage to the management community to transition new methods and tools into real-world applications.

In support of this function, many of SCCWRP's current research activities take advantage of recent advances in molecular biology and genetic technology, which offer a new way of examining the diversity of aquatic life and how chemicals interact with biological systems. These methods offer potential advantages in time, cost, accuracy, reproducibility, and detection ranges. Additionally, new methods and tools are being developed to more fully understand previously unstudied contaminant classes and needs specific to California's ecosystems.

1. Chemistry Assessment

a. Analytical Methods for Toxaphene

Traditional analytical methods determine the bulk amount of a particular target chemical in an environmental sample. Approved measurement methods have been developed for most historic environmental contaminants of concern. However, many of these contaminants are analyzed in the laboratory in groups (e.g., organic compounds, metals) using a single, non-specific method. The results are pertinent for well-known compounds such as DDTs, but are inadequate for accurately quantifying difficult-to-detect complex mixtures such as toxaphene.

This project involves development of analytical methods for quantifying toxaphene residue in environmental sample extracts using a relatively new technique known as negative ion mass spectrometry. Toxaphene is the generic name of a complex organochlorine pesticide mixture that was used extensively during the last half of the 20th century. Banned in the 1980s, toxaphene residue raises concern due to its persistence, bioaccumulation, and potential for toxic effects. Method development associated with this project is in late stages, and efforts this year will focus on coordinating laboratory intercalibration exercises for the newly developed toxaphene sample processing protocols.

Lead Investigator: Dr. Keith Maruya (keithm@sccwrp.org)

Collaborators: Ashland Chemical (Tim Hassett), CSU Long Beach (Richard Gossett), National Institute of Standards and Technology (Dr. John Kucklick), Test America (Betsy Beauchamp)

External Funding Support: Ashland Chemical

b. Non-targeted Analysis

Approved measurement methods have been developed for many historic environmental contaminants, but these methods are inadequate for investigating chemical constituents of recent concern, impeding monitoring and management. This project seeks to develop analytical methods for contaminants of emerging concern (CECs). CECs are a large group of chemicals not commonly monitored or regulated in the environment. CECs number in the thousands and include pharmaceuticals and personal care products, current-use pesticides, natural and/or synthetic hormones, and industrial and commercial chemicals.

This project uses two dimensional gas chromatography and time-of-flight-mass spectrometry (GCxGC-TOF-MS) to identify, in a non-targeted manner, multiple classes of CECs in tissue, sediment, and water samples from selected receiving water environments. Non-targeted analysis may serve as a useful periodic screening tool for directing the targeted analytical methods used in regional monitoring projects. Also, the comparison of non-targeted "fingerprints" may be useful in distinguishing the suite of source contaminants, such as treated wastewater effluent and storm water, from naturally occurring contaminants. Work this year will focus on refining the analytical method, complete chemical identifications from marine mammal and bird egg tissue samples, and building a mass spectral library for use in future analyses.

Lead Investigator: Dr. Nathan Dodder (nathand@sccwrp.org)

Collaborators: CSU San Diego (Dr. Euhna Hoh), National Institute of Standards and Technology (Dr. John Kucklick), Orange County Sanitation District (Dr. Jeff Armstrong)

External Funding Support: None at this time.

c. Passive Samplers

Multiple line of evidence approaches to assess contaminated sediments typically measure total (bulk) contaminants. However, in many instances, bulk sediment chemistry does not reflect the pool of contaminants available to organisms, resulting in a lack of concordance between observed chemistry and biological impact data. Attempts to improve contaminant partitioning estimates by modifying conventional measurements and/or parameters (e.g., total organic carbon normalization or toxic unit estimation) have met with limited success. In contrast, passive sampling methods (PSMs), including solid phase microextraction and polyethylene sediment porewater samplers previously developed at SCCWRP, have shown great promise in quantifying the bioavailable contaminant pool for both sediment-associated organic constituents and metals. Further testing is needed to determine if PSMs can predict the amount of uptake and bioaccumulation by sentinel test species, such as fish and benthic invertebrates, and thus the contaminants' potential toxic impacts.

The purpose of this project is to evaluate whether PSMs can be used to better predict bioaccumulation and observed sediment toxicity in sediments from coastal water bodies. Experiments and field studies will be performed using PSMs to quantify the bioavailable fraction of high priority sediment contaminants (e.g., pyrethroids, fipronil, PBDEs) in conjunction with efforts to characterize toxicity parameters (i.e., LC_{50}) and bioaccumulation profiles for the same model compounds. The extent of equilibrium for passive samplers will also be determined using preloaded performance reference compounds.

Lead Investigator: Dr. Keith Maruya (keithm@sccwrp.org)

External Collaborators: Chinese Academy of Sciences (Dr. Jing You), Exxon-Mobil (Dr. Tom Parkerton), National Oceanic and Atmospheric Administration (Dr. Peter Landrum, ret.), State Water Resources Control Board (Chris Beegan), Loyola Marymount University (Dr. Rachel Adams), USC (Dr. Jim Haw), US Environmental Protection Agency (Dr. Robert Burgess)

External Funding Support: USC Sea Grant

New Project

d. Emerging Contaminant Prioritization

Contaminants of emerging concern (CECs) encompass a vast number of largely unregulated compounds that lack data on occurrence and potential toxicity in the environment. A wide variety of substances including pharmaceuticals, flame retardants, contemporary pesticides, and even food additives are considered CECs. Many CECs have been present in the environment for years or even decades but were not previously detectable using available analytical methods. Recent technological advances have improved capabilities for CEC detection and quantification in environmental media, leading to increased attention on determining their potential hazards. Traditionally, identifying CECs with the highest risk to ecological and human health requires knowledge of their fate once discharged into the environment, as well as high quality exposure (occurrence) and toxicological data to support threshold development. The State of California previously sponsored an expert Science Advisory Panel for CECs to develop a prioritization approach to help guide permit monitoring programs. However, the expert panel was challenged by the limited amount of occurrence data available.

The purpose of this project is to enhance the availability of CEC occurrence data. This data will enable the state and advisory panel to continue prioritizing the CECs of greatest concern. SCCWRP will collect occurrence data in sediments at regional scales utilizing the Bight Regional Monitoring Program (see project C1a). A more spatially-focused effort will also target potential CEC sources near Los Angeles. Tissue screening for CECs will be accomplished utilizing NOAA's Mussel Watch program. Finally, SCCWRP will help develop a statewide monitoring study design and associated implementation plan for incorporating CECs into the state's Surface Water Ambient Monitoring Program.

Lead Investigator: Dr. Keith Maruya (keithm@sccwrp.org)

Collaborators: Los Angeles Regional Water Quality Board, Los Angeles County Sanitation Districts, participants in the Bight '13 Regional Monitoring Program, Colorado School of Mines (Dr. Jorg Drewes), National Oceanic and Atmospheric Administration, State Water Resources Control Board.

External Funding Support: State Water Resources Control Board, Los Angeles Regional Water Quality Control Board.

e. Bioanalytical Screening Tools

While new chemical methods and environmental occurrence data can help prioritize monitoring and assessment efforts in the short term, the sheer number of potential CECs (in the tens of thousands of chemicals) makes it impractical to implement a traditional chemical-specific monitoring approach. This is particularly true since hundreds of new CECs are produced each year. The State of California's Science Advisory Panel for CECs encouraged development of bioanalytical screening techniques to meet this challenge. Bioanalytical screening techniques elicit cellular responses such as estrogenicity, androgenicity, or carcinogenicity after exposure to toxic compounds. Successful screening techniques will account for unknown chemicals, integrate multiple chemicals, and elucidate the cumulative potency of complex chemical mixtures.

The purpose of this study is to evaluate whether selected bioanalytical methods can be used as monitoring tools for recycled water and ambient waters receiving treated wastewater effluent and stormwater discharge. Many bioanalytical screening tools are adaptations of methods recently developed by the US Environmental Protection Agency and National Institute of Environmental Health Sciences. This project will test and evaluate these various methods for the best performing bioanalytical screening tools for the new applications for recycled water and ecosystem health. The best performing assays will be applied in the Regional Marine Monitoring Program (see project C1a) to evaluate their relevance to ecosystem protection where stressors (i.e., contaminant chemistry) and biological response (i.e., sediment toxicity tests and biological communities) are being synoptically measured.

Lead Investigator: Dr. Keith Maruya (keithm@sccwrp.org)

Collaborators: BDS-Calux (Dr. Peter Benisch), Griffith University (Dr. Fred Leusch), Life Technologies Inc. (Dr. Kun Bi), , UC Riverside (Dr. Daniel Schlenk), University of Arizona (Dr. Shane Snyder), University of Florida (Dr. Nancy Denslow), University of Queensland (Dr. Beate Escher), University of South Florida (Dr. Sandy Westerheide)

External Funding Support: State Water Resources Control Board, Water Reuse Research Foundation

2. Toxicity Assessment

a. Traditional Toxicity Identification Evaluation Methods

Identifying the specific constituents responsible for positive sediment toxicity tests is a complex task, but important to supporting management actions such as site remediation, Sediment Quality Objective compliance, and Total Maximum Daily Load establishment. Most environmental samples contain mixtures of contaminants, and conventional chemical analyses are rarely sufficient to identify individual constituents. A more effective approach to contaminant assessment involves use of Toxicity Identification Evaluation (TIE), which is a sequence of laboratory investigations that first characterize the general classes of toxicants present (e.g., metals) and then confirm the specific constituents (e.g., copper) causing environmental effects. Standardized characterization and identification methods are available for water samples, but fewer methods are available for sediments. Moreover, reliability and specificity of the sediment methods are poorly understood.

The goal of this project is to develop and refine toxicity identification methods for current-use pesticides in marine sediments. This will involve method development studies with spiked samples and application to field sites, refining sediment TIE thresholds for pyrethroids (commonly found in household insecticides), and developing TIE methods for additional current use pesticides (e.g., fipronil). This year will also focus on following up on recommendations from a 2012 workshop to address uncertainties in determining the causes of sediment toxicity in California bays and estuaries. Retrospective data analyses will be used to investigate the influence of clay particles on test results and the role of seasonal changes in test animal condition.

Lead Investigator: Steve Bay (steveb@sccwrp.org)

Collaborators: San Francisco Estuary Institute (Sarah Lowe), UC Davis Marine Pollution Studies Laboratory (Bryn Phillips)

External Funding Support: City of Los Angeles

b. Molecular Tools for Toxicity Identification Evaluation

The Toxicity Identification Evaluation (TIE) process uses a variety of chemical/physical separation methods and treatments to remove one or more toxicant class, coupled with toxicity testing following each manipulation. Although helpful in identifying contaminant classes of greatest concern, traditional TIE methods have several drawbacks including cost, chemical specificity, and omission of low-level sublethal toxic effects and synergistic or antagonistic effects associated with contaminant mixtures. Recent advances in molecular biotechnology may allow development and application of improved methods based on genomics (e.g., analysis of gene expression or protein production). Gene microarrays, particularly when linked to higher level effects on the test organism (e.g., growth, reproduction), have the potential to simultaneously measure effects on multiple physiological systems, providing a sensitive measure of a contaminant's or sample's toxicological effects.

The goal of this project is to develop a new suite of TIE tools. This will involve microarray development for sentinel organisms (including marine and freshwater fish and invertebrates), documentation of gene expression profiles for target contaminants, and comparison of the microarray results to conventional toxicity test and TIE methods. Research this year will include refining the amphipod gene microarray based on the results from an interlaboratory comparison, sequencing RNA from hornyhead turbot tissue samples to develop an improved gene microarray for marine fish, and examining linkages between microarray findings and higher order effects (protein production, histopathology, reproductive effects) in freshwater fish exposed to endocrine disrupting compounds.

Lead Investigator: Steve Bay (steveb@sccwrp.org)

Collaborators: CSU Long Beach (Dr. Kevin Kelley), Environment Canada (Graham Van Agglen), Los Angeles County Sanitation Districts, UC Berkeley (Dr. Chris Vulpe), UC Davis Marine Pollution Studies Laboratory (Brian Anderson), UC Riverside (Dr. Daniel Schlenk), University of Southern California (Dr. Andrew Gracey)

External Funding Support: Environment Canada, Los Angeles County Sanitation Districts, Los Angeles Regional Water Quality Control Board, San Francisco Estuary Institute

3. Biological Assessment

a. Rocky Reefs

Rocky reefs, most easily identified by their forests of giant kelp (*Macrocystis*), are among the most productive marine ecosystems on earth. Rocky reef habitats span at least one-quarter of the southern California coastline, but are sensitive to water quality stress, suffer from fishing pressure, and respond dynamically to natural fluctuations such as temperature and wave climate. There are a number of programs that manage these habitats and their associated biota, but lack standardized assessment tools that can be used to score sites, define status, and evaluate trends. This lack of standardization has limited communication of the complex biological information to environmental managers in a simple, straightforward manner.

The goal of this project is to begin developing a rocky reef assessment index. Workshops held in 2012 built consensus among the state's rocky reef ecology experts about attributes used for ranking biological condition. This information will be used to implement status assessments and stressor responses in the southern California Regional Monitoring Program (see project C1a) and the region's brand new Marine Protected Areas promulgated in 2011.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: Occidental College (Dr. Dan Pondella), UC Santa Barbara (Dr. Jenn Casselle), MPA Monitoring Enterprise

External Funding Support: South Orange County Water District

b. DNA Barcoding

Species assemblages are often used as indicators of environmental condition; however, traditional methods for identifying and quantifying organisms can be time-consuming and labor-intensive. This project explores the efficacy of DNA barcoding, in which a short gene sequence from a standardized position in the genome is measured as an alternative tool for rapidly identifying species. The first step to barcoding is building a library of sequences from known reference specimens. After that, unknown specimens can be identified by looking up their sequences in the reference library. Species composition can then be translated to correspond with existing indices of biological integrity. Additionally, barcode speciation data could reveal instances where reassessment of taxonomy is warranted.

The goal of this project is to assess the efficacy of barcoding for rapidly identifying benthic invertebrate and algal species in marine and freshwater samples from southern California.

Aspects to this project include: a) establishing a DNA barcode reference library of voucher specimens identified both using traditional taxonomic methods and genetically sequenced unique DNA barcode; b) developing protocols for sample processing, including suitable fixatives that do not degrade genetic material; c) determining how to correlate barcode data with existing quantitative indices; and d) working toward next-generation sequencing methods to analyze composite DNA samples. This year's efforts will focus on leveraging the Bight Regional Monitoring Program (see project C1a) to enhance the barcoding library for the marine environment, evaluate alternatives for sample preservation, and differentiate cryptic organisms important for use in marine benthic indices.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: Canadian Centre for DNA Barcoding (Dr. Peter Miller), SCCWRP member agencies, Stroud Water Research Center (Dr. Bernard Sweeney), US Environmental Protection Agency (Dr. Erik Pilgrim).

External Funding Support: None at this time

c. Cyanobacteria

Cyanobacteria blooms are a global problem and have been found throughout California in freshwater and brackish habitats. Cyanobacteria produce toxins that can cause wildlife mortality and are associated with liver cancer and tumors in humans. Cyanotoxins transported in coastal runoff can also affect marine ecosystems, causing mortality in California sea otters. Despite the health risks associated with cyanotoxins, insufficient data is available on the prevalence of cyanobacterial blooms and cyanotoxin concentrations in southern California water bodies. A better understanding of the temporal patterns and environmental drivers for bloom occurrence and toxin production is needed before effective regulatory or remediation actions can be implemented.

The goals of this project are to: a) document the prevalence of cyanobacterial blooms and toxin concentrations in a variety of fresh and brackish water habitats in southern California, b) document temporal patterns of bloom occurrence and toxin concentrations by pilot-testing novel cyanotoxin monitoring methods, c) increase understanding of environmental drivers for cyanobacterial bloom occurrence and toxin production, and d) recommend ways to optimize monitoring. Habitats for cyanobacteria prevalence measurements will include depressional wetlands (see project C1a) and reference streams in the San Diego region (see project C3b).

Lead Investigators: Dr. Betty Fetscher (bettyf@sccwrp.org), Dr. Meredith Howard (merdithh@sccwrp.org)

Collaborators: UC Santa Cruz (Dr. Raphael Kudela)

External Funding Support: None at this time

New Project

d. Non-perennial Streams

More than 100 samples are collected from perennial wadeable streams each year in an effort to assess biological condition. The State Water Resources Control Board is developing biological objectives to create a regulatory framework for protecting highly functional streams and restoring impacted streams. However, only about one-third of the stream-miles in southern California coastal watersheds are perennial (have year-round flow). The majority of stream miles are non-perennial, and most of these are located in lightly-developed watersheds which are susceptible to future urban growth. Ecosystem management and protection efforts for non-perennial streams will require development or adaptation of monitoring tools and assessment mechanisms.

The goal of this project is to evaluate applicability of current biological assessment tools, originally created for perennial streams, in non-perennial systems. This project has four components including: a) identifying reference sites with a range of non-perennial flow characteristics; b) sampling flow, biology, and a variety of physical and chemical parameters throughout wetting and drying cycles; c) calculating biological objective scores to identify critical flow conditions for biological communities; and d) comparing results across a host of non-perennial and perennial sites with a range of anthropogenic stress exposure. If existing scoring tools prove untenable, new scoring tools that better reflect the natural variability of non-perennial ecosystems must be evaluated.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: California Department of Fish and Wildlife (Dr. Peter Ode), Sand Diego Regional Water Quality Control Board (Dr. Lilian Busse)

External Funding Support: State Water Resources Control Board

4. Microbiological Assessment

a. Rapid Water Quality Indicators

Traditional growth-based methods used to enumerate indicator bacteria (i.e., multiple tube fermentation, membrane filtration, and chromogenic substrate) are too slow to effectively evaluate risk of swimmers' exposure to waterborne pathogens. These methods require 18- to 24-hour sample incubation periods, during which the public may be exposed to contaminated water. Correspondingly, beaches may have posted warnings or advisories for a day longer than necessary simply because of methodological lags in obtaining results. In 2010 and 2011, pilot projects were conducted at Orange County and LA County beaches demonstrating how a rapid bacterial indicator measurement method (quantitative polymerase chain reaction or qPCR) could be used for beach monitoring with same-day results. Several logistic and technological challenges remain, including method modification to address inhibition of the rapid reaction that occurs when inhibitory substances are present in water samples. Such interference poses a concern because it can cause underestimation of pathogen levels. In addition, opportunities remain for speeding the monitoring process through assay automation.

The goal of this project is to continue development of rapid methods that can augment or replace existing methods for indicator bacteria at high risk beaches. This year, SCCWRP will work to resolve inhibition issues, support technology transition in southern California, and share findings with the US Environmental Protection Agency as they move toward approving a rapid beach monitoring method nationally. Researchers are also working to develop automated sample processing technology, including an automated environmental sample processor for deployment on piers or moorings, to analyze indicator bacteria *in situ* and then telemeter data back to shore.

Lead Investigator: Dr. John Griffith (johng@sccwrp.org)

Collaborators: Stanford University (Dr. Ali Boehm), Monterey Bay Aquarium Research Institute (Dr. Chris Scholin), US Environmental Protection Agency (Dr. Richard Hoagland), City of Los Angeles, NOAA (Dr. Kelly Goodwin)

External Funding Support: None at this time

b. Microbial Source Tracking and Identification

The State of California enacted the Clean Beaches Initiative (CBI) Grant Program in 2001 with the aim of restoring and protecting coastal beach water quality. The CBI has helped to improve water quality at many beaches by funding nearly $100 million in management measures, such as diverting storm drains to reduce runoff flows, repairing aging sewer lines, and creating natural filtration areas. Despite these successes, a number of beaches with poor water quality remain, primarily because the source of contamination is unknown. A variety of molecular methods designed to distinguish among fecal sources have been developed over the last several years, but the last comprehensive examination of such source-tracking methods was conducted nearly a decade ago. Thus, water quality managers are unsure about which methods are most reliable for their specific application, forestalling mitigation efforts.

The goal of this project is to create a source identification manual, implement selected protocols at several beaches of high interest to the State, and transition source identification capabilities to local laboratories to ensure their continuing use. In addition, SCCWRP research aims to understand the relationship among fecal indicator bacteria (FIB), source identification markers, and pathogen presence to ensure monitoring and tracking mechanisms are relevant to human health concerns. Ultimately, this research seeks to develop a field deployable instrument capable of measuring both FIB and source identification markers, thus enabling near real-time for tracking intermittent sources.

Lead Investigator: Dr. John Griffith (johng@sccwrp.org)

Collaborators: Stanford University (Dr. Ali Boehm), UC Santa Barbara (Dr. Patricia Holden), UCLA (Dr. Jennifer Jay), Virginia Tech (Dr. Charles Hagedorn)

External Funding Support: State of California Water Resources Control Board, County of San Diego

c. Quantitative Microbial Risk Assessment

Current fecal indicator bacteria (FIB) criteria are based on epidemiological studies that tied swimmer health risk to FIB concentrations. These studies were largely conducted at beaches dominated by human sources of fecal inputs (sewage pollution), but many beaches, including those in southern California, are subject to fecal pollution inputs from non-human sources. Because of differences in associated pathogen loading, health risks associated with non-human FIB levels may differ from that associated with human fecal inputs. To address situations where non-human fecal sources predominate, the EPA is considering the use of quantitative microbial risk assessment (QMRA) to determine site-specific objectives. QMRA models human health risks associated with non-human sources of fecal pollution based on source strength and pathogen load. However, very few QMRAs have been conducted globally, and none have been conducted at marine beaches in the US.

The goal of this project is to conduct a QMRA demonstration project at a southern California marine beach and will involve: a) identifying sources in detail to ensure no or few human pathogen inputs exist; b) sampling fresh fecal material from identified non-human sources for pathogen analysis; c) characterizing swimmer exposure by modeling transport and fate of non-human source inputs, and; d) quantifying the level of illness in the swimming population. This project will test the QMRA framework, evaluate assumptions associated with the modeling, and identify data gaps where research can improve QMRA as a future management tool.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: Soller Environmental (Dr. Jeffrey Soller), US Environmental Protection Agency (Dr. Nick Ashbolt, John Ravenscroft)

External Funding Support: State Water Resources Control Board, US Environmental Protection Agency

5. Biogeochemical Cycling Assessment

a. Harmful Algal Blooms

Harmful algal blooms (HABS) have increased in frequency and severity along the US West Coast in recent years, linked to detrimental effects on commercial fisheries, tourism, and marine animals. In other parts of the world, anthropogenic nutrient inputs overwhelm most natural sources and are often a significant factor contributing to the increase in HABs. In contrast, large quantities of nutrients from the deep ocean rise to the surface of the nearshore zone in upwelling-dominated ecosystems such as the California Current, and the relative influence of nutrients from local anthropogenic discharges on HAB development is less clear. Scientists lack understanding about how bloom dynamics change in response to shifting environmental conditions and why certain "hot spots" are frequently impacted by harmful or toxic blooms.

The goal of this project is to understand the ecophysiological factors driving HABs in order to support improved monitoring, predictive modeling, and management approaches. This research will: a) evaluate existing data to characterize trends in HABs, and related phenomenon (hypoxia and acidification); b) conduct studies to understand the fate of anthropogenic nutrients in the SCB and the linkage between anthropogenic nutrients and algal bloom development, and; c) continue our partnership with the California Harmful Algal Bloom Monitoring and Alert Program (HABMAP).

Lead Investigator: Dr. Meredith Howard (meredithh@sccwrp.org)

Collaborators: Monterey Bay Aquarium Research Institute (Dr. Chris Scholin), Moss Landing Marine Laboratories (Dr. Jason Smith), National Oceanic and Atmospheric

Administration (Dr. Greg Doucette), UCLA (Dr. Yi Chao), UC Santa Cruz (Dr. Raphael Kudela), University of Southern California (Dr. David Caron)

External Funding Support: National Oceanic and Atmospheric Administration

b. Coastal Hypoxia

Hypoxia is an increasing threat to global coastal waters, with several time-series studies highlighting recent declines in ocean dissolved oxygen (DO) concentrations. In addition to this large-scale trend, short-term acute hypoxic events in shallow, coastal locations are of special concern because they impact the coastal ecosystems that support important economic sectors like fishing, shellfish hatcheries, and tourism. Determining the causes of hypoxia in upwelling-dominated ecosystems is fundamentally difficult. Traditionally, hypoxia has been thought to result from nutrient runoff fueling increased productivity. However, more recent work suggests that some coastal hypoxic events on the west coast result from shoaling of deeper oceanic water that is becoming increasingly hypoxic due to a climate-change induced strengthening of the thermocline layer. Untangling the cause(s) of hypoxia in the near shore environment, be it from respiration of algal blooms generated from nutrient over enrichment, global changes in deep ocean oxygen concentrations, or a combination of the two, will require a both *in situ* monitoring and ecological modeling.

SCCWRP is working to characterize the episodic nature of algal blooms and hypoxia in the SCB. Hypoxia research at SCCWRP has three main components: a) synthesis of existing data and analysis of trends; b) determination of data gaps and feasibility of filling data gaps with new monitoring efforts, and; c) continuing partnerships in understanding the effects of hypoxia on the nearshore environment.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: Center for Ocean Solutions (Dr. Fio Micheli)

External Funding Support: None at this time.

New Project

C. Ocean Acidification

Ocean acidification (OA) is the reduction of seawater pH associated with increasing global oceanic uptake of atmospheric carbon dioxide (CO_2). When CO_2 dissolves in seawater, the concentration of carbonate ions is reduced, and waters under-saturated with carbonate become corrosive to organisms that produce carbonate exoskeletons (such as shellfish, corals, and some species of plankton). Ocean monitoring programs have measured significant OA-related changes in ocean chemistry at a rate much faster than predicted and with continuing acceleration. The West Coast is particularly susceptible to OA due to seasonal upwelling, which brings waters high in nutrients, low in dissolved oxygen, and low in pH onto the coastal shelf. In response to this knowledge, scientists, managers, regulators, and industries affected by OA began meeting in 2010 and are collaborating to develop a coordinated OA measurement network through the West Coast-wide California Current Acidification Network (C-CAN).

Initial goals of this research are to: a) take a leadership role in C-CAN; b) assist the West Coast Governors Alliance for Ocean Health (WCGA) in developing a West Coast-wide strategy for addressing OA issues, and; c) work with member agencies to determine the feasibility of upgrading existing monitoring programs to incorporate OA measurements into routine surveys. C-CAN is currently developing explicit guidance on monitoring program development (parameters, technology development, quality assurance, information management). Work in collaboration with the WCGA will include: a) inventorying existing and potential assets and a plan to incorporate them into a West Coast-wide OA monitoring network; b) defining the science and policy questions most relevant to addressing stakeholder needs, and; c) developing a prioritized research agenda based on these collective policy questions.

Lead Investigator: Dr. Karen McLaughlin (karenm@sccwrp.org)

Collaborators: C-CAN Steering Committee, SCCWRP member agencies

External Funding Support: West Coast Governor's Alliance for Ocean Health

New Project

d. Causal Modeling

Many of the documented hypoxic and acidification events on the West Coast result from shoaling of deep nutrient-rich ocean waters. However, local nutrient additions (e.g., from municipal treated wastewater plumes) have the potential to exacerbate hypoxia and acidification by stimulating algal growth, which affects the carbon cycle through rapid blooming and senescence. The relative contribution of local anthropogenic inputs to these processes is presently unknown, but is vital to understanding the potential benefits of management controls on local inputs. Calculating the relative importance of local anthropogenic nutrient inputs in hypoxic and acidification events requires a complex coupling of biogeochemical models. These models describe nutrient uptake and biological processing in conjunction with physical circulation models to determine whether those processes occur rapidly enough for the local inputs to generate effects while waters from land-based sources remain in the coastal zone.

The goal of this project is to facilitate development of complex causal models. To begin, SCCWRP will host a modeling workshop convening coastal managers, scientists and modelers to: a) distill the critical, unanswered questions and potential management scenarios the models should address; b) define the relevant temporal and spatial scales in which the models need to operate; c) determine which models should be used, and; d) identify the data required for model calibration and validation. SCCWRP will also conduct field and laboratory studies recommended by workshop participants to generate key data sets necessary to parameterize and validate the model, including: a) nutrient inputs (stormwater, treated wastewater, and atmospheric deposition); b) rate processes (productivity, respiration, nutrient uptake and nutrient transformation) and how they change as a function of time and proximity to anthropogenic inputs, and; c) validation data sets (CTDs, ocean moorings, gliders). Modeling results will be distilled into regional budgets to help discern the major causes of hypoxia and acidification changes over time.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: Center for Ocean Solutions (Dr. Fio Micheli), UCLA (Dr. Mark Gold, Dr. Curtis Deutsch, Dr. Jim McWilliams), University of Georgia (Dr. Brock Woodson), SCCWRP member agencies

External Funding Support: West Coast Governor's Alliance on Ocean Health

B. TECHNICAL SUPPORT FOR MANAGEMENT/REGULATORY PROGRAMS

A second major function of SCCWRP's research is to integrate the body of available scientific knowledge and new studies to build a technical foundation for effective management and regulatory programs. California's environmental management programs often shape the development of national programs, and SCCWRP is uniquely positioned at the interface of science and management on both levels. As a result, SCCWRP is often called upon to serve as one of a handful of organizations offering expertise to discern the best scientific approaches for achieving environmental policy goals. This type of service is usually requested when environmental issues are widely acknowledged and well documented, but support is needed to develop effective, practicable management.

SCCWRP's research activities in this area are intended to guide the unbiased development of the best available methods for tracking progress and for ultimately achieving environmental management goals. While the goals themselves are set by policy and management agencies, SCCWRP helps to interpret and transition scientific methods to support program implementation.

1. Nutrient Objectives

Many areas in California are experiencing accelerated accumulation of organic matter and overgrowth of aquatic plants as a result of nutrient enrichment. Effects of this overgrowth may include harmful algal blooms, hypoxia, altered aquatic food webs, or degradation of critical habitat. The California State Water Resources Control Board (SWRCB) is working to develop scientifically-based statewide water quality objectives that relate these endpoints to management controls. These nutrient objectives will be narrative, with numeric guidance otherwise referred to as the nutrient numeric endpoint (NNE) framework. The NNE framework consists of two components: a) response indicators and their regulatory endpoints that specify how to assess water body condition, and; b) nutrient-response models that can be used to link response indicators to nutrients and other management controls (e.g., hydrology) on a water body-specific basis.

The goal of this project is to provide a scientific foundation for NNEs. This research is occurring in streams, lakes, and estuaries and consists of four types of activities: a) documentation of appropriate response indicators; b) documentation of the natural background levels of those indicators in "reference" California water bodies; c) establishment of dose-response relationships between response indicators and metrics of aquatic life use, and; d) development of nutrient-response models ranging from statistical stress-response to mechanistic computer simulation models.

a. Nutrient Objectives in Streams

For streams, proposed algal biomass regulatory endpoints were chosen by best professional judgment consensus as determined among a team of national and international experts. This approach presents several challenges. For example, no work has been done to explicitly identify tipping points for increased nutrients and algal biomass related to indicators of aquatic life use (e.g., community structure of algae and benthic macroinvertebrates). In addition, there is a need to continue research on alternative or complimentary algal indicators (e.g., percent cover) and optimize monitoring protocols. As a preliminary alternative, the SWRCB is offering “benthic biomass spreadsheet models” as scoping tools that relate ambient nutrient concentrations to algal biomass while accounting for physical factors such as stream flow velocity and canopy cover. However, early validation efforts indicate these spreadsheet tools require refinement. Finally, because assessment endpoints are biological yet management is based on nutrients, stakeholders need technical assistance in working through issues of implementing the NNE in management programs such as Total Maximum Daily Loads, 303(d) listing, and discharge permits.

Addressing these needs involves five tasks: a) document statistical thresholds in the dose-response relationships between proposed NNE indicators and metrics of aquatic life use in streams (algae and benthic macroinvertebrate indices of biological integrity); b) document “reference levels” of proposed NNE indicators and the percent of stream miles exceeding statistical or proposed regulatory thresholds; c) validate stream NNE spreadsheet models, identify sources of error, and propose refinements to NNE scoping tools; d) develop calibrated, site-specific, dynamic models to better understand factors controlling algal response to nutrient; and e) use tools and data to assist with decisions about how to implement the NNE to set watershed-based nutrient targets. This year, researchers will analyze existing statewide stream bioassessment data to support the completion of the first three tasks. In addition, SCCWRP will collect data to support the development of a calibrated, site-specific mechanistic model in Santa Margarita River watershed.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: US Environmental Protection Agency (Dr. Naomi Dettenbeck), Tetra Tech (Dr. Jon Butcher)

External Funding Support: County of San Diego, State Water Resources Control Board, US Environmental Protection Agency

New Project

b. Nutrient Objectives in Lakes

As with streams, nutrient management indicators and regulatory endpoints proposed by the state for lakes offer an algal biomass spreadsheet model as a scoping tool to relate ambient nutrient concentrations to algal biomass. Model validation is needed to better understand its performance; however, given the diversity of lakes in California, model validation requires compilation of a substantial data set reflecting the range of conditions.

The following approach will be taken to address these needs: a) compile existing data on phytoplankton biomass, nutrient concentrations, cyanobacterial dominance and cyanotoxins in California lakes; and b) validate the NNE spreadsheet model for lakes, identify sources of error, and propose refinements. This year, researchers will focus on compiling existing lake data.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: San Francisco Estuary Institute (Dr. Thomas Jabusch), UC Santa Cruz (Dr. Raphael Kudela)

External Funding Support: State Water Resources Control Board

c. Nutrient Objectives in Estuaries

California has a variety of estuarine classes and habitat types (i.e., intertidal flats, seagrass, unvegetated subtidal) for which numeric endpoints and nutrient-algal response models would be expected to differ. Initially, this project inventoried California estuaries, reviewed candidate indicators and science supporting decisions on assessment framework thresholds for algae and dissolved oxygen, developed a work plan to proceed with assessment framework and nutrient-response model development for the state's estuaries, and conducted experiments to document the threshold for effects of macroalgae on intertidal flats in perennially tidal estuaries. Because the San Francisco Bay-Delta encompasses approximately 80% of the state's estuarine habitat, but differs from many small estuaries in other areas of California, a site-specific NNE assessment framework and nutrient algal-response model will be developed for San Francisco Bay and for the Delta.

To address the technical needs for nutrient objectives in estuaries, SCCWRP will help develop indicators, conduct dose-response studies, and hold expert workshops to support selection of regulatory endpoints for intertidal flats, seagrass habitats, and unvegetated subtidal habitat across the range of estuarine classes in the state. In addition, SCCWRP will develop nutrient-algal response models including statistical stress-response models, "pilot" mechanistic models for southern California Bight estuaries, calibrated dynamic simulation models for individual estuaries (e.g., Loma Alta Slough, Santa Margarita River estuary), and a conceptual model/modeling strategy for the San Francisco Bay.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: San Francisco Estuary Institute (Dr. Dave Senn), UCLA (Dr. Peggy Fong), UC Santa Cruz (Dr. Raphael Kudela), US Geological Survey (Dr. Jim Cloern), Elkhorn Slough National Estuarine Research Reserve (Dr. Kirsten Wassen), Morro Bay National Estuary Program (Adrienne Harris).

External Funding Support: San Francisco Estuary Institute Regional Monitoring Program, San Francisco Regional Water Quality Control Board, State Water Resources Control Board

2. Sediment Quality Objectives

Sediment quality objectives (SQOs) were recently approved for use in California's enclosed marine bays and estuaries. SCCWRP helped to develop and validate the assessment framework and data analysis tools needed to interpret sediment quality in the context of SQOs. Regulatory agencies are currently in the process of incorporating SQOs into monitoring programs, permitting processes, and cleanup actions, which raises continuing technical questions about study design and data interpretation, applicability in new habitats, and stressor identification. A second phase of SQO is also under development to investigate indirect relationships between sediment contamination and potential impacts on organisms (e.g., marine birds, predatory fish, and humans) through the food chain. Bioaccumulation in organisms consumed by humans and wildlife is often a driving factor in ecological risk assessments, especially with respect to common southern California contaminants like DDTs, PCBs, and mercury. Still, the assessment of indirect effects due to sediment contamination is more complex than direct effects and requires a different conceptual approach. The potential for indirect effects on an organism is influenced by numerous factors, including the fraction of sediment contaminants biologically available to prey species, complexity of the food web, movement of receptor organisms, food consumption rates, and species-specific variations in chemical sensitivity.

The goal of this project is two-fold. For indirect effects, SCCWRP will develop and test an assessment framework for evaluating sediment contamination risks to human and ecosystem health based on multiple indicators. This will include additional data collection to better understand the bioaccumulation pathways in California food webs and quantify/reduce uncertainty in bioaccumulation models. For direct effects, SCCWRP will: a) develop and test toxicity source identification strategies including traditional toxicity-based approaches and biological community approaches (see project A2a); b) develop assessment tools for new habitats such as mesohaline estuaries, and; c) provide technical support to regulatory and regulated agencies for implementing the approved SQO elements.

Lead Investigator: Steve Bay (steveb@sccwrp.org)

Collaborators: San Francisco Estuary Institute, State Water Resources Control Board

External Funding Support: San Diego Regional Water Quality Control Board, San Francisco Estuary Institute, State Water Resources Control Board

New Project

3. Flow Criteria

Southern California is one of the most urbanized regions in the country. The process of urbanization affects stream courses directly through channel engineering, and indirectly through altered watershed hydrology (hydromodification). Hydromodification can have adverse effects on stream habitat, surface water quality, and water supply, while associated stream erosion may threaten infrastructure, homes, and businesses. To address this issue, state and local agencies are developing and implementing standards and policies in an attempt to control and/or mitigate hydromodification effects on natural and semi-natural stream courses. SCCWRP has spent many years developing support tools to assist managers by: a) mapping the streams most at risk from hydromodification; b) estimating the magnitude of hydromodification effects such as erosion, sedimentation, and habitat loss based on increases in impervious land cover, and c) identifying a suite of the most effective management measures to offset hydromodification effects. Although additional work is needed to improve capacity for predicting hydrological and physical effects of hydromodification, some of the biggest unanswered questions relate to the relationships between these physical changes and biological responses, which is a core endpoint of management concern.

The goal of this project is to define the relationship between stream flow and biological community impacts as measured by benthic macroinvertebrate communities. This will be done in a four-step process: a) identify reference sites (defined by lack of human influence), b) develop flow models to estimate hydrologic conditions in unmodified streams, c) establish the natural variation in stream flow vs. biological community relationships at reference sites, and d) compare these reference relationships to stream flow/biological condition relationships in hydromodified streams.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: California Department of Fish and Wildlife (Dr. Peter Ode), Colorado State University (Dr. Brian Bledsoe), US Geological Survey (Dr. Darren Carlisle)

External Funding Support: State Water Resources Control Board, US Geological Survey

4. Modeling

New Project

a. Modeling of Best Management Practices

As watersheds urbanize, stormwater best management practices (BMPs) are increasingly being used to mitigate the adverse effects of hydromodification and contaminant loading. However, the effectiveness of BMPs for achieving stream water quality and biological objectives is rarely tested, despite increasing regulatory requirements for their installation that greatly increase the costs of stormwater management. In particular, a key management need is identifying the optimal placement, type, and numbers of BMPs to achieve sufficient hydraulic detention/capture and desired management endpoints. Because of site-specific variability in BMP effectiveness and the need to integrate effects at a watershed scale, the most efficient means to address this management need is modeling. Models including mechanistic BMP models, watershed hydrology and chemical loading models, and biological stress response models have been developed and used on an individual basis. However, they haven't been coupled on a watershed scale to examine the effects of BMP implementation on the watershed hydrology and receiving water chemical and biological responses. Experimental data have documented the effects of BMPs on a treatment catchment in Melbourne, Australia, monitoring the effects on hydrology, water chemistry and biology over a ten year period and providing a unique opportunity to calibrate linked models.

The goal of this project is to develop a toolkit of linked models that will optimize BMP density, type, and location at a watershed scale. It will include: a) mechanistically modeling BMP performance at a site scale; b) modeling effects of implemented BMPs on watershed hydrology and water quality for wet and dry weather; c) developing mechanistic stress-response models to link BMP performance, watershed hydrology, and water quality to biological endpoints; and d) using the tools in tandem to optimize the placement, type, and density/size of BMPs within the watershed. This year will focus on: a) developing and calibrating mechanistic models of BMP performance as a function of intrinsic factors such as geology, soil type, and slope using existing southern California BMP performance data; and b) developing linked watershed hydrology and stress-biological response models using the experimental data from Australia.

Lead Investigator: Dr. Ashmita Sengupta (ashmitas@sccwrp.org)

Collaborators: UC Irvine (Dr. Stanley Grant, Dr. Brett Sanders, Dr. Jean-Daniel Saphores), University of Melbourne (Dr. Tim Fletcher)

External Funding Support: National Science Foundation

New Project

b. Stressor Response Modeling

The linkage between management actions and the recovery of receiving waterbodies is often obscure. This is most obvious in Southern California estuaries, located at the terminus of urbanized watersheds and subjected to the adverse effects of hydromodification and contaminant loading. Complicating the linkage between management actions in the watershed and downstream changes in the estuary is the high degree of variability in freshwater flow and contaminant concentrations, the large diversity of estuarine ecotypes, temporal and spatial patterns in estuarine hydrology that affects the transport and biological fate of pollutants, and the ultimate interaction between water quality and biology. Because of the complexity of these site-specific factors, scientists turn to mechanistic-based stressor-response models to better understand and predict the linkage between management actions and the fate and effects of contaminants in estuaries. Unfortunately, these mechanistic models are rare in southern California largely due to the large effort required. As a result, managers lack the confidence needed for implementing management actions in the watershed to protect downstream estuarine resources.

The goal of this project is to begin developing linked stressor-response models that managers can routinely use for protecting estuaries. The objective is to streamline the model-building process so that easy-to-find solutions can be readily appraised and effectively evaluated. Developing linked stressor-response models will begin with developing simple hydrodynamic models for various estuarine ecotypes. The base hydrodynamic model will include: a) advection and dispersion; b) interaction of freshwater inflow with saline ocean waters, and; c) residence times in the estuaries. The hydrodynamic model will then be coupled with either a biological response model for nutrients or a chemical fate model for Constituents of Emerging Concern (CECs). The biological response model for nutrients will include eutrophication processes such as predicting biomass and dissolved oxygen concentrations. The fate model for CECs will include contaminant dependent processes such as sorption/desorption and transformation. The simple model will be calibrated and validated with regional data collections (see project C1a) and compared to model output from existing complex 3-Dimensional mechanistic models.

Lead Investigator: Dr. Ashmita Sengupta (ashmitas@sccwrp.org)

Collaborators: Dr. Mi-Hyun Park (University of Massachusetts) Dr. Christopher Kinkaid (University of Rhode Island), Dr. P.F. Wang (SPAWAR), Dr. James Martin (Mississippi State University)

5. Freshwater Biological Objectives

Direct measures of biological condition are increasingly preferred as assessment endpoints because they are most closely linked to the beneficial uses or functions that are the focus of environmental protection and management. In contrast, traditional chemistry- or toxicity-based assessment endpoints require inferences about their relationship with the ecological integrity of natural systems. Biological indicators have the added advantage of integrating condition over space and time, thus providing a more comprehensive assessment than traditional indicators. As a result, the California State Water Resources Control Board is working to develop biological objectives (bio-objectives) for perennial streams and rivers. Currently, the State is focused on benthic macroinvertebrates as their primary stream bioindicator because of their well-studied life histories, comparatively sessile nature, readily available taxonomy, and relative ease of collection. However, there are number of other potential bioindicators that could be used for bio-objectives other than benthic invertebrates, such as upper trophic levels (i.e., fish, amphibians, birds), that represent beneficial uses including wildlife habitat, cold water habitat, warm water habitat, or the ability to support rare species. Ultimately, the State would like to include an approach for integrating multiple biological indicators across many trophic levels for the bio-objectives framework.

The goal of this project is to continue developing the technical foundation for bio-objectives. SCCWRP is already helping develop this technical foundation for benthic macroinvertebrate indicators, the California Rapid Assessment Method (CRAM), physical habitat assessment and flow. For the upcoming year, technical support will include refining bioassessment tools for a variety of stream types throughout the state (see project A3d) and developing new tools that provide insight into potential stressors, such as physical habitat and flow. New for this year will be evaluating approaches for integrating multiple biological indicators across many trophic levels. This will begin with and assessment of the relationship between benthic macroinvertebrates and higher trophic level organisms such as amphibians, fish, and birds.

Lead Investigators: Eric Stein (erics@sccwrp.org), Ken Schiff (kens@sccwrp.org)

Collaborators: California Coastal Commission (Ross Clark), California Department of Fish and Game (Dr. Peter Ode), Southern California Stormwater Monitoring Coalition, State Water Resources Control Board, US Environmental Protection Agency, US Geological Survey (Dr. Jason May, Dr. Larry Brown, Dr. Robert Fisher, Dr. Daren Carlisle, Dr. Chris Konrad), Colorado State University (Dr. Brian Bledsoe, Dr. LeRoy Poff).

External Funding Support: US Environmental Protection Agency and State Water Resources Control Board

C. Regional Monitoring

Monitoring is a cornerstone of environmental management, providing stakeholders with information about changes in ecosystem condition and the effectiveness of management programs. SCCWRP's research focus on monitoring programs helps guide implementation of problem-driven investigations and sustained tracking. In the early stages, these efforts are focused on defining clear monitoring questions and appropriate sampling designs to answer those questions. Subsequently, there is a need for standardization of approaches and assessment methodologies across multiple monitoring agencies from a regional perspective. At later stages, SCCWRP supports the data management and quality assurance needs of ongoing monitoring efforts.

SCCWRP began conducting regional surveys in the 1970s and continues to be well known for coordinating the Southern California Bight Regional Monitoring Program, which monitors waters from the shoreline to the coastal shelf in five-year cycles. SCCWRP also maintains extensive pollutant emissions data from the many dischargers to the Southern California Bight at periodic intervals dating back to 1971. More recent efforts involve development of monitoring solutions for other habitats, including streams, wetlands, and Areas of Special Biological Significance.

1. Regional Marine Monitoring

a. Southern California Bight Regional Monitoring Program

The Southern California Bight Regional Monitoring Program is currently conducted in five-year cycles and has involved over 100 different stakeholder organizations. This program has been useful in monitoring trends over time, as well as establishing regional reference conditions, developing new environmental assessment tools, standardizing data collection approaches in southern California, and providing a support network for special studies. The next iteration of the regional monitoring is set to occur in 2013 (Bight '13). The Bight '13 survey will examine five major research areas including: Coastal Impact Assessment (sediment condition), Nutrients (water column condition), Beach Quality (microbiological condition), Marine Protected Areas (rocky reef condition), and Trash and Debris (especially plastics).

The goal of this project is to implement the Bight '13 Regional Monitoring Program. Project planning including study design, sampling and analysis preparation, pre-survey quality assurance activities have already occurred. Implementation will involve coordinating dozens of study teams including 10 vessels, 11 analytical laboratories, and an integrated data system for seamlessly sharing results (see project Da). Hundreds of indicators will be measured including sediment chemistry, sediment toxicity, benthic infauna, benthic fish and invertebrates, bioaccumulation in bird eggs, trash and debris, physical water column characteristics, nutrients and algae, and fecal indicator bacteria and human pathogens.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: Numerous participating organizations

External funding support: In-kind contributions from participating organizations

b. Pollutant Sources Data Cataloguing

Mass emission estimates enable comparisons among different pollution sources to assess relative risks and track trends over time. SCCWRP has estimated mass emissions from large publicly owned treatment works (POTWs) annually for the last 38 years, and from other sources (such as small POTWs, industrial dischargers, dredged material disposal, urban runoff, oil platforms, vessel discharges, and aerial deposition) about every five years. Pollutant mass emissions from the four largest southern California POTWs have declined by more than 95% over the last 40 years as a result of increased effluent treatment, source control, industrial pretreatment, and reclamation. At the same time, nonpoint source discharges (such as stormwater runoff) have become a proportionately greater contributor to overall pollutant loading to the ocean. Regulated stormwater agencies have recently begun to standardize monitoring approaches and methods in order to estimate concentrations and loads; however, these agencies still lack an integrated data management system for compiling monitoring data.

The primary goal this year is to estimate mass emissions from stormwater, industrial dischargers, power generating stations, and large POTWs to the southern California Bight. In addition to being used for status and trends tracking, the stormwater data will be transferred to the California Environmental Data Exchange Network for use in statewide water quality assessments.

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: City of Los Angeles, City of San Diego, Los Angeles County Sanitation Districts, Orange County Sanitation District, Southern California Stormwater Monitoring Coalition

External Funding Support: None at this time

c. Areas of Special Biological Significance

Areas of Special Biological Significance (ASBS) are water quality protected areas in California where the waste discharge is prohibited. There are 34 ASBS throughout the state, and about half are located in southern California. Mapping studies conducted in 2003 identified nearly 1,700 outfalls that discharge into ASBS statewide, and in 2006, voters approved a $5.4 million water bond with a portion of the funds dedicated to reducing pollutant inputs into ASBS. To date, 14 grants totaling $1.3 million have been authorized by the State Water Resources Control Board (SWRCB) for ASBS-regulated parties. While the SWRCB requires monitoring for each grant, there is no coordination among grantees with respect to monitoring questions, study designs, measurement indicators, or methods. This makes it difficult to assess the overall effectiveness of the Proposition 84 grant program.

The goal of this project is to provide technical support for coordinating Proposition 84 grantee monitoring. The monitoring program should determine: a) the mass of pollutants removed from ASBS discharges as a result of Proposition 84 grants, and; b) the condition of ASBS receiving waters, especially near grant implementation sites. Earlier work focused on reviewing and improving grantee monitoring plans and quality assurance project plans. This year's activities will focus on data compilation from initial grantee monitoring.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: None at this time

External funding support: State Water Resources Control Board

2. Regional Watershed Monitoring

a. Stormwater Monitoring Coalition Regional Watershed Monitoring

In-stream bioassessment monitoring in southern California is currently conducted by more than a dozen different organizations. In the past, each of these organizations had disparate programs varying in design, frequency, and indicators selected for measurement. Even where designs were similar, field techniques, laboratory methods, and quality assurance requirements often diverged, making cumulative assessments impossible. To address these issues, a comprehensive and integrated monitoring program was designed by the southern California Stormwater Monitoring Coalition (SMC). This program mirrors SCCWRP's Southern California Bight Regional Monitoring Program, wherein each participating group assesses its local geography and contributes a small portion to the whole regional assessment. The SMC program plans to establish comparability in the field and the laboratory, performance-based quality assurance guidelines, and an information management system for sharing data. In this way, it can address large-scale management needs and provide answers to the public about the overall health of southern California's streams and rivers. The SMC program also provides an opportunity to investigate novel issues and/or monitoring parameters.

The goal of this project is to support implementation of the SMC's regional watershed monitoring program for southern California's coastal streams and rivers. This will be the fifth year of sampling in a five-year cycle intended to assess a total of 450 sites. SCCWRP will continue providing support for data compilation and interpretation to guide the future directions of the program including special studies for the 2014 summer sampling season and the next five year cycle to begin in 2015. In addition, SCCWRP will continue developing a methodology for multi-indicator assessment of riparian wetland ecosystem condition in California. This requires integration of existing biological assessment tools, including benthic macroinvertebrate and algal indices of biotic integrity, physical habitat assessment (PHAB), and the California Rapid Assessment Method (CRAM), to provide an overall ecosystem assessment for riverine wetlands.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: Regional Water Quality Control Boards 4, 8, and 9; Southern California Stormwater Monitoring Coalition; State Water Resources Control Board's Surface Water Ambient Monitoring Program

External Funding Support: Southern California Stormwater Monitoring Coalition, State Water Resources Control Board

b. Background Concentrations of Contaminants in San Diego Reference Streams

The streams and rivers in Orange and San Diego County watersheds have become increasingly urbanized, which brings additional wet and dry weather runoff to streams, resulting in increased loads of bacteria, nutrients, heavy metals and other contaminants. Management of these water quality issues in the San Diego Regional Water Quality Control Board's region is currently hampered by the lack of a consistent set of scientifically-defensible numeric targets for streams. Existing standards do not account for natural sources of constituents. One approach to developing numeric targets that account for "natural sources" involves quantifying concentrations in, or loads from, streams in a minimally disturbed or "reference" condition.

The goal of this project is to collect the data necessary to derive reasonable and accurate wet and dry weather numeric targets for bacteria, nutrients, and heavy metals, based on a reference approach. This project also provides an opportunity to demonstrate the use of new bioassessment approaches to identify reference conditions, including: a) establish the biomass, cover, and taxonomic composition of algae associated with reference streams, and; b) investigations of toxicity sources to invertebrates using newly developed molecular Toxicity Identification Evaluations (see project A2b).

Lead Investigator: Dr. Martha Sutula (marthas@sccwrp.org)

Collaborators: None at this time

External Funding Support: City of San Diego, Counties of Orange and San Diego and their co-permittees

c. Atmospheric Deposition of Nutrients to Coastal Watersheds

Recent data from the Stormwater Monitoring Coalition Regional Stream Monitoring Program indicate that heavy algal cover (>30%) occurs even at sites with predominantly undisturbed catchments, suggesting that atmospheric deposition may be a significant source of nutrients to streams. Previous SCCWRP research found that atmospheric deposition can be a significant source of trace metals to southern California watersheds, but only limited data exists on atmospheric deposition of nutrients and its contribution to water quality in this region. A lack of standardized techniques for direct measurement of atmospheric nutrient deposition is one reason for such limited data. Inferential methods, which have frequently been used in other regions, are both costly and time-consuming. Surrogate surfaces offer a simple, cost-effective method for direct measurement of atmospheric nutrient deposition, but surrogates have not been tested in the semi-arid conditions of southern California.

The goals of this project are to: a) provide reliable measurement techniques for atmospheric nutrient deposition in southern California, and b) to estimate rates of atmospheric nutrient deposition in selected sites in Southern California. The combination of the most successful methods (static surface samplers versus conventional denuders) and isotope tracking methods will be used to measure rates of wet and dry atmospheric at six regional stream bioassessment reference sites in southern California across an annual cycle, capturing natural gradients in land cover type (forested, chaparral, etc.).

Lead Investigator: Dr. Karen McLaughlin (karenm@sccwrp.org)

Collaborators: US Forest Service (Dr. Pamela Padgett)

External Funding Support: County of San Diego, US Environmental Protection Agency

3. Regional Wetland Monitoring

a. Wetlands Status and Trends

Billions of dollars have been invested over the last 20 years for the protection and restoration of California's wetlands and riparian areas. However, the effectiveness of these investments is uncertain due to a lack of systematic monitoring. At a national level, the US Fish and Wildlife Service National Wetland Inventory program has adopted a probability-based survey approach to assess trends in wetland acreage and produce status and trends plots. The new design was also incorporated into the EPA's National Wetland Condition Assessment (NWCA). Within the state, the California Wetlands Monitoring Workgroup (CWMW) has developed and is working to implement a statewide Wetland and Riparian Area Monitoring Program (WRAMP). The goal of the WRAMP is to produce regular reports on trends in wetland extent and condition, and to relate these trends to management actions, climate change, and other natural and anthropogenic factors, in order to inform future decisions. In addition, new tools to track and evaluate the success of wetland restoration programs are needed, such as performance curves that forecast how beneficial uses and functional capacity of restoration projects should improve over time. These new tools for mitigation and restoration planning will help ensure individual projects contribute to an overall net gain (or no net loss) in wetland extent and condition throughout the state.

The goals of this project are to help build a framework for wetland and riparian monitoring and assessment by participating in the CWMW, supporting implementation of the NWCA and WRAMP, and to develop new technical tools for wetland tracking. The current year will focus on the second phase of this project, including identifying ways to refine the technical approach, reduce sample error, and evaluate proposed change assessment methodologies. SCCWRP will participate in an interagency team to develop a long-term implementation and funding strategy for wetland monitoring. In addition, performance curves based on the California Rapid Assessment Method (CRAM) are being developed for perennial estuarine and coastal riverine wetlands, and regional reference sites will be incorporated to evaluate the curves with respect to best achievable condition.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: California Department of Fish and Game, San Francisco Estuary Institute (Dr. Josh Collins), CSU Northridge (Dr. Shauna Dark), US Environmental Protection Agency, US Fish and Wildlife Service National Wetlands Inventory, California Wetlands Monitoring Workgroup

External Funding Support: US Environmental Protection Agency, California Coastal Conservancy, California Resources Agency via the Coastal Impact Assistance Program

b. Depressional Wetlands

Freshwater depressional wetlands are the state's most diverse wetland class and comprise approximately 45% of California's 3.6 million wetland acres. This class includes vernal pools, freshwater marshes, and wet meadows, and may have near-persistent to intermittent surface water flows that connect them to other surface waters. Depressional wetlands may be natural, actively-maintained manmade features, or abandoned manmade features. While they perform the entire range of functions typically associated with wetlands, depressional wetlands are particularly important as seasonal refuges and breeding areas in dry habitats. Cumulatively, they contribute to groundwater recharge, water purification, and attenuation of surface runoff, thus reducing the impact of excessive flow to streams, lentic water bodies, and coastal environments downstream. To date, the state's Surface Water Ambient Monitoring Program has focused almost entirely on wadeable streams; most monitoring and assessment of depressional wetlands is associated with specific impact or mitigation projects. As a result, the available monitoring data is limited in space and time, and there is little knowledge about the overall extent and condition of depressional wetlands.

The goal of this project is to establish a foundation for a statewide ambient monitoring program for depressional wetlands by: a) developing, modifying, and testing assessment tools; b) creating a monitoring design; and c) demonstrating the monitoring program through pilot implementation at a subset of depressional wetland types in southern California. This year will involve testing the Periphyton Index of Biotic Integrity developed for streams for potential application in depressional wetlands, and repeated measurement of seasonal wetlands to evaluate the influence of drying on invertebrate communities and refine appropriate monitoring time frames.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: CSU San Marcos (Dr. Robert Sheath), UC Berkeley

External Funding Support: California Resources Agency via the Coastal Impact Assistance Program; San Diego, Los Angeles, and Santa Ana Regional Water Quality Control Boards; US Environmental Protection Agency

c. Historical Ecology

Historical ecology (mapping the historical extent and distribution of natural resources) is a valuable environmental management tool. For example, knowledge of the streams and wetlands in southern California's coastal watersheds circa 1870 provides environmental managers, scientists, and the public answers to a range of key questions about the restoration potential of contemporary watersheds, such as where to leave streams accessible to daylight, or how to lay out a landscaping palette of native vegetation for restoration projects. Historical ecology requires the acquisition, georeferencing, digitizing, and interpretation of historic coastal topographic maps (t-sheets). However, much more information is needed to help fill in data gaps, cross-reference facts, and make estimations for interim time periods. Specifically, information about wetland and riparian habitat must be gathered, especially in relation to natural events and management activities within the watershed, such as floods, fires, agriculture, channel modifications, and water diversions and impoundments.

The goals of this project are to develop a framework and infrastructure for compiling sentinel data sets on historic condition, and use these data to evaluate how the distribution of wetlands has changed over time, specifically in response to key changes in land use or stream management efforts. Previously, the project examined distribution of wetland and riparian habitat in the San Gabriel River, lower Ventura River, lower Santa Clara River, and Ballona Creek watersheds. The current focus is historical ecology of several north San Diego lagoons. In addition to creating summary reports, the project has developed several online tools to host products and metadata including digitized coastal t-sheets. New historic coastal maps (t-sheets) will be added using a crosswalk between historical and contemporary classification systems.

Lead Investigator: Dr. Eric Stein (erics@sccwrp.org)

Collaborators: CSU Northridge (Dr. Shauna Dark), San Francisco Estuary Institute (Robin Grossinger), Santa Monica Bay Restoration Commission (Dr. Shelley Luce), University of Southern California (Dr. Travis Longcore)

External Funding Support: California Coastal Conservancy, Santa Monica Bay Restoration Commission, US Fish and Wildlife Service

D. INFORMATION MANAGEMENT AND ANALYSIS

The scale of data collection often grows exponentially as new technologies and techniques become available. Regional data may be obtained via large-scale monitoring programs or instantaneously via satellite or aerial imaging. Large datasets are also being generated via lab analysis for a variety of chemical and biological data types, perhaps most intensively for emerging molecular methods and DNA barcoding. New approaches are needed to collect, store, manage, and analyze these very large datasets in a manner that effectively serves the needs of the scientific community and environmental managers. New technology is evolving for collecting data that by-passes human intervention. Emerging methods for data storage, including cloud databases, require further research to develop effective methods for supporting new data types. In addition, new tools are needed to process data sets for various applications (e.g., index computation, environmental models) and produce information in useful formats like scores, charts, graphs, maps, animations, and other visualizations.

SCCWRP has historically played a primary role in helping member agencies and others produce comparable data products that maximize value and usability among the environmental management community. The essential next step is developing mechanisms to more effectively collect, manage and share data and to deliver analytical results when and where needed.

New Project

1. Mobile Data Acquisition Technologies

Mobile technologies offer vast new opportunities for on-site data collection never before seen in science. SCCWRP is dedicated to developing field data tools that can be implemented on everyday mobile devices such as smart phones and tablet computers. By leveraging built-in capabilities such as GPS receivers, cameras and wireless connectivity, new age mobile devices can capture nearly limitless types of monitoring information. Then, these mobile devices can take advantage of communication networks to record information, either automatically or through human input, and directly transfer that data from the field to the office. Moreover, these mobile applications ensure data is collected and structured consistently with quality checks handled instantaneously, at the point of collection, before scientists leave the site.

SCCWRP is exploring this rapidly evolving technology to further extend the capabilities of field sampling programs. These capabilities currently fall into three areas: a) smart phone applications to capture sample event data including location, station occupation observations, on-site descriptions and images, and then transferring these data to cloud-based databases; b) using image capture devices, including cell-phone cameras, as microscopes to optically identify species in the field, and; c) using wireless-based sensors to communicate with mobile devices to aid in data acquisition, sensor testing and maintenance, and real-time adaptive monitoring capabilities.

Lead Investigator: Dr. Steve Steinberg (steves@sccwrp.org)

Collaborators: None at this time

External Funding Support: None at this time

2. Seamless Data Sharing

Data are essential to management and planning on a variety of levels. When data are not readily accessible, many of the decision-making processes dependent upon current, reliable, and high quality data may be impeded. When data sharing is ineffective, there are lost opportunities and the potential for making suboptimal management decisions increases. For example, the benefit of additional information may include context, such as considering data from adjacent areas or a time-series to provide perspective. Modern data sharing tools provide opportunities for effective data sharing that is both rapid and accurate. These data sharing tools enable managers and the public straightforward, understandable, and transparent access to environmental information.

The goal of this research is to: a) facilitate collection and submission of data to a consistently accessible data server, and; b) facilitate access to data and analytical results needed by the scientific and management community. SCCWRP has helped develop and support the California Environmental Data Exchange Network (CEDEN), which is utilized by the State Water Resources Control Board to prepare the 303(d) list of impaired water bodies. SCCWRP has also designed, developed and maintained the Beach Watch database, which serves as the central repository for beach water quality monitoring information statewide. Current efforts are focused on recruiting and training regional data providers, developing data visualization and extraction tools, providing user-friendly web-based data access and documentation, and connecting CEDEN with other state and US Environmental Protection Agency (EPA) data servers. These databases will serve managers and the public through the California Water Quality Monitoring Council's website (see project D3) and a number of other applications which are 'Powered by CEDEN'.

Lead Investigator: Dr. Steve Steinberg (steves@sccwrp.org)

Collaborators: Moss Landing Marine Laboratories (Rusty Fairey), San Francisco Estuary Institute (Meredith Williams), State Water Resources Control Board, Dr. Michael Johnson

External Funding Support: State Water Resources Control Board

3. Dynamic Data Processing and Visualization

Data visualization provides valuable insights into understanding data relationships and interactions. This includes ways to effectively convert data into information and to effectively present this information using visualization techniques such as computation of indices and integrating dynamically generated charts, maps, and animations. With the advent of more sophisticated scientific and spatial modeling tools and capabilities, there are important opportunities to extend capabilities in data modeling and visualization, particularly within a geospatial framework. For data visualization to be useful, however, it must be driven by development and validation of scientifically-appropriate and robust analytical techniques.

SCCWRP's research focus is to enhance options for reporting and presenting real-time statistical data analysis and visualization for data output to the web or mobile device in the field. There are two areas of current research: a) assisting the State in making monitoring data, and easily understandable interpretations of available data, to the public through water quality portals (http://www.waterboards.ca.gov/mywaterquality/), and; b) developing approaches that infer ecosystem services from spatial products or tracking changes over time and under different management scenarios, in order to integrate the past, present, and future management for specific recovery goals in southern California watersheds (i.e., Tijuana River Valley).

Lead Investigator: Dr. Steve Steinberg (steves@sccwrp.org)

Collaborators: California Department of Public Health (Mark Emmerson), Water Education Foundation, Tijuana River National Estuarine Research Reserve (Jeff Crooks), Sacramento State University, Center for Collaborative Policy (David Ceppos), San Francisco Estuary Institute (Robin Grossinger), California Coastal Conservancy (Greg Gauthier)

External Funding Support: State Water Resources Control Board and National Estuarine Research Reserve System Science Collaborative (NERRS)

E. MEMBER AGENCY SUPPORT

SCCWRP research is generally applicable to collective environmental management concerns. However, to ensure scientific resources are communicated to and used by the core network of end users (our 14 member agencies), attention is also devoted to supporting individual member agency activities (and sub-groups of member agencies facing similar questions). SCCWRP provides ongoing on-call support for these organizations.

1. General Support

This project encompasses a variety of forms in which SCCWRP provides periodic assistance to member agencies, such as training, quality-assurance audits, field and laboratory method review, monitoring guidance, administrative support, meeting organization, data processing, technical advice, memo or fact sheet preparation, response to media requests, and communication/presentations to the member agencies' governing boards.

Lead Investigator: Dr. Steve Weisberg (stevew@sccwrp.org)

2. Quality Assurance for Offshore Monitoring

The State Water Resources Control Board recently prepared an amendment to the California Ocean Plan that requires quality assurance (QA) procedures for ocean monitoring paralleling the State's previous efforts to establish QA protocols for freshwater monitoring. Some of the existing QA guidelines for freshwater are directly applicable to ocean monitoring, but others need to be retooled for application within a marine context. One of the most challenging adaptations will involve biological monitoring of benthic infauna, where thousands of organisms comprising hundreds of species can live within one square meter of the seabed.

The goal of this project is to prepare method quality objectives (MQOs) for ocean monitoring that the state can integrate into its Quality Assurance Program Plan. This process will require consideration of several different science-based approaches and facilitation of cooperative decision-making among stakeholders.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: The SCCWRP member agencies, Southern California Association of Marine Invertebrate Taxonomist (SCAMIT), Southern California Association of Ichthyological Taxonomists and Ecologists (SCAITE).

External Funding Support: None at this time

3. Pilot Monitoring with Autonomous Underwater Vehicle

Ocean monitoring surveys are currently conducted several times a year by the municipal wastewater dischargers in southern California. These rely on ship-based data collection using a CTD (conductivity, temperature, and depth) measurement device, supplemented by periodic grab sampling of water for further laboratory analysis. Some water quality tests (e.g., bacterial and nutrient measurements) can only be collected with grab samples, limiting the spatial coverage of this type of data. In addition, ship-based data can only be collected during favorable weather conditions and time periods when agency personnel are available. The National Oceanic and Atmospheric Administration and others are developing automated ocean monitoring technology that would allow pre-programmed continuous monitoring along specified transects. These autonomous underwater vehicles (AUVs) could potentially provide better spatial and temporal coverage while reducing monitoring costs.

The goal of this project is to test application of an AUV (glider) in southern California through a collaborative effort with SCCWRP member agencies. The glider will be deployed at four locations (near the City of Los Angeles, Los Angeles County, Orange County, and City of San Diego outfalls) in conjunction with a comparable traditional survey. Objectives are to identify and address potential logistic challenges, compare data collected using the two methods, and determine if AUV technology offers advantages to local agencies.

Lead Investigator: Dr. Steve Weisberg (stevew@sccwrp.org)

Collaborators: City of Los Angeles, City of San Diego, Los Angeles County Sanitation Districts, National Oceanic and Atmospheric Administration, Orange County Sanitation District, Southern California Coastal Ocean Observing System

External Funding Support: None at this time

4. Effects of Ocean Outfall Diversion on Nutrient Cycling

The relative influence of anthropogenic versus natural factors in regulating nitrogen cycling and primary productivity has not been well established in the Southern California Bight. One challenge is isolating the effect of individual factors, such as wastewater effluent input from the other factors at play. Last fall, the Orange County Sanitation District diverted discharge from its main ocean outfall to a pipe that discharged effluent closer to shore and in shallower water. This diversion presented an opportunity to observe the effect of wastewater on dominant pathways of nitrogen cycling and primary production before and after the area receives effluent input. Similarly, this year the City of Los Angeles Hyperion Treatment Plant will divert their outfall to conduct routine maintenance, providing a further opportunity to continue gathering information.

SCCWRP joined a team of researchers using gliders and ship-based sampling to track the effluent plume during the diversions to monitor for any detrimental environmental impacts, such as increased algal growth. Experiments are also being conducted to a) compare rates of nitrification and denitrification between reference areas and sites near the temporary effluent discharge both before and after the diversion, and b) monitor phytoplankton productivity and species composition changes during the diversion.

Lead Investigator: Dr. Meredith Howard (meredithh@sccwrp.org)

Collaborators: National Oceanic and Atmospheric Administration (Dr. Greg Doucette), Orange County Sanitation District, University of Southern California (Dr. David Caron)

External Funding Support: None at this time

5. Newport Bay Watershed Model Monitoring

The Newport Bay watershed is a valuable natural resource in Orange County, with Upper Newport Bay being one of the region's largest estuaries. The watershed is subject to a complex mix of regulatory requirements resulting in a series of unlinked monitoring programs for wastewater, stormwater, and Total Maximum Daily Load (TMDL) compliance. Like many urban watersheds, the results of independently-developed monitoring programs are not synthesized; consequently, many basic questions about status, trends, and knowledge gaps remain unanswered.

The goal of this project is to facilitate a critical review of (and potentially redesign) current watershed monitoring efforts to improve effectiveness and cost-efficiency, while supporting management decision-making. This effort includes defining and prioritizing monitoring questions, inventorying existing efforts, evaluating current monitoring designs, and recommending design changes for program improvement.

Lead Investigator: Ken Schiff (kens@sccwrp.org)

Collaborators: Orange County Public Works, Santa Ana Regional Water Quality Control Board

External Funding Support: Santa Ana Regional Water Quality Control Board