
# SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT AUTHORITY

## THEMATIC RESEARCH PLAN

## FOR

## REGIONAL MONITORING

**Last revised May 2017**

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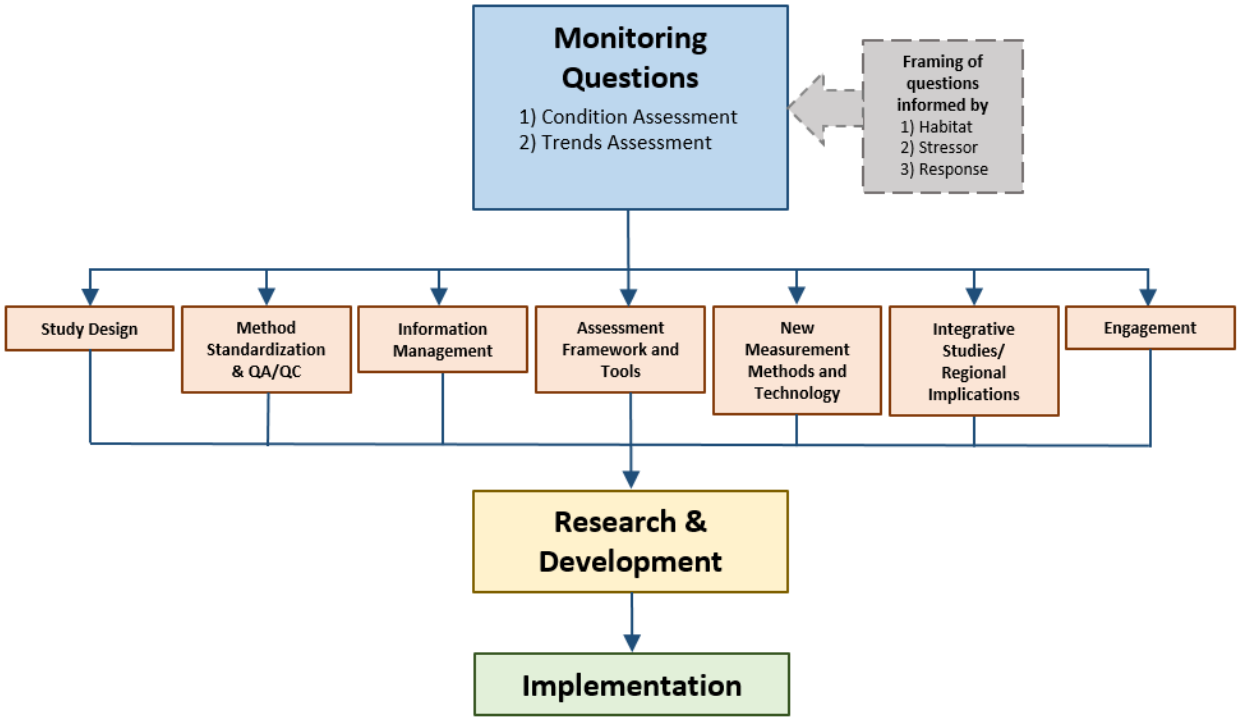
# Introduction

Southern California environmental managers and scientists spend an estimated $50 million every year on monitoring the condition of aquatic systems, but have struggled to answer the big-picture questions being asked by the public: “Is it safe to swim in the ocean?” “Are locally caught fish safe to eat?” and “Are we harming our local ecosystems?” The National Research Council (1990) used southern California as a case study of why there has been such a struggle to answer these most basic of Clean Water Act questions. Fundamentally, the challenge is that most monitoring occurs in the relatively compact areas that surround wastewater outfalls, storm drain outlets and other discharge zones – monitoring that is required for compliance with state and federal laws. Consequently, when researchers attempt to compile compliance-based monitoring data, the resulting regional picture of holistic ecosystem condition can become skewed. Recognizing this challenge, SCCWRP has coordinated and facilitated regional-scale monitoring programs across a variety of habitats, including streams, wetlands, estuaries, offshore pelagic, rocky reefs and soft-bottom marine environments. Somewhat unique to southern California, SCCWRP works with dozens of local and regional agencies to coalesce common management information needs, then standardize data collection and coordinate analysis efforts, leveraging the limited resources of many to obtain comprehensive data on some of the region’s most pressing environmental challenges. SCCWRP’s best-known monitoring program is the ongoing Southern California Bight Regional Monitoring Program (Bight), conducted every five years since the mid-1990s to monitor the region’s coastal areas. The Bight program’s freshwater counterpart is the Southern California Stormwater Monitoring Coalition (SMC) Regional Watershed Monitoring Program, which launched in 2009 and also runs on rolling five-year cycles. The programs are among the top regional monitoring programs in the nation and have served as models for developing similar programs internationally.

# Conceptual Model

SCCWRP’s conceptual model for regional monitoring is driven by the development of monitoring questions that seek to assess condition and/or trends. The monitoring questions are framed by coming to agreement on which habitat(s), which stressor(s) and which response(s) should become the focus of the regional monitoring assessment. To articulate the scope and scale of each regional monitoring assessment, participants focus on fleshing out the following seven areas: study design, method standardization and QA/QC, information management, an assessment framework and tools, new measurement methods and technology, integrative studies/regional implications and engagement. Each of these seven areas typically begins with a research and development phase, during which novel ideas and plans are tested, vetted and refined. As these ideas and plans become more fleshed out, they can be transitioned to routine implementation.

Figure 1. SCCWRP's bioassessment research is driven by the need to achieve beneficial-use goals for waterbodies. SCCWRP works across three main areas – condition assessment, causal assessment, and management application – to design managerially relevant approaches and tools that help achieve these beneficial-use goals.




**Monitoring Questions**: Because regional monitoring programs are typically designed around insights into the condition and/or trends of any number of habitats, stressors, and responses, the first step is to decide on specific habitats, stressors, and responses of mutual interest to program participants. This is accomplished through the development of monitoring questions. The questions, which are mutually agreed to at the outset, become the guiding force of the program; all subsequent decisions and actions regarding the scope and scale of the program revolve around getting answers to the monitoring questions and what actions managers will take once they get an answer.

**Facets of Monitoring Program**: After the regional monitoring questions have been developed and agreed upon, the details of the regional monitoring program need to be fleshed out. The mechanics of defining these details falls into seven main areas: study design, method standardization and QA/QC, information management, an assessment framework and tools, new measurement methods and technology, integrative studies/regional implications, and engagement:

1) **Study Design**: Many lessons learned from regional monitoring programs are universally transferrable; however, the design of every program is unique, involving a different set of habitats, stressors and responses. Some designs require lots of repetition to answer questions about trends over time. Others focus on lots of sites to answer questions about spatial extent or to create maps of condition. Some regional monitoring questions focus on environmental processes that require mechanistic designs. In southern California, where there are a myriad of well-informed managers, all three basic study designs are sometimes commingled, presenting challenges for design optimization.
2) **Method Standardization & QA/QC**: A regional monitoring program, particularly one that relies on multiple participants, is only as good as its ability to obtain high quality, comparable data. In southern California, a performance-based approach is often used, allowing participants to use their chosen methods while maintaining minimum standards for sensitivity, accuracy, precision and bias. The performance-based approach enables innovation, while at the same time guaranteeing comparability. This is then supplemented with training, audits and laboratory intercalibrations to ensure comparability. The key to the performance-based approach is to not drop data quality objectives to the lowest common denominator. Rather, it is to lift all participants up to the necessary shared level of rigor and data quality to answer the monitoring questions.
3) **Information Management**: While creating a rigorous data set is important, the inability to successfully and reliably compile, store and retrieve data for analysis can equally hamstring any monitoring program. This issue gets compounded with the large number of data generators and data users in southern California regional surveys. Information Management has taken on new roles in recent years as modern technology generates more and different data types, and at a higher rate than in previous years. This challenge is compounded with the advent of newer, more powerful data analysis and visualization tools to answer the ever-increasingly complex monitoring questions.
4) **Assessment Framework and Tools**: One challenge faced by all monitoring programs, large or small, is how to determine the condition of each monitoring site. Managers, many of whom are not scientists, rely on assessment frameworks and tools to simplify the complex environmental data that monitoring programs generate into easy-to-understand assessments of whether a site is in "good" or "bad" condition. Not only do program participants rely on these frameworks and tools to efficiently reach consensus conclusions about regional condition, but they often become the primary tools for evaluating conditions in their local monitoring programs.
5) **New Measurement Methods and Technology**: Regional monitoring provides an unparalleled platform for developing and validating new methods and technologies. In a regional program, new technologies can be tested alongside existing methods, quantifying comparability and identifying the advantages/disadvantages of these new measurement tools. Besides efficiently leveraging resources, the regional monitoring platform exposes the prototype methods and technologies to the broad range of natural variability and human impacts for robust validation prior to its widespread use in local programs. Finally, the regional monitoring platform is a perfect vehicle for technology transfer since each agency will be responsible for its deployment. Ultimately, side-by-side testing with existing technology, calibration and validation and technology transfer all lead to confidence in the new technology enabling more rapid acceptance and transfer to other applications, including applications that are independent of regional monitoring.

6) **Integrative Studies/Regional Implications**: Between regional monitoring cycles, there are opportunities to conduct studies and projects that address issues identified by regional monitoring. These spin-off, integrative studies include more intensive site-specific monitoring, adaptive studies that ask new but related questions and causal assessment projects that go beyond the assessment phase to identify specific remediation actions. Integrative studies can also consist of linking separate regional monitoring programs that generate complimentary data sets, which can enhance regional assessments. Thus, integrative studies have the potential to significantly expand the scope and breadth of the monitoring questions that can be answered.
7) **Engagement**: The success of any regional monitoring program – especially the multi-agency southern California regional monitoring programs – is wholly dependent on good communication amongst its many participants and with the managers it intends to inform. Thus, it is crucial to develop effective ways to engage a broad range of participants that influence or have decision-making authority across the region. This is more than program governance, it is ensuring that there is a driving force that coordinates the many activities that glue a program together, from program kick-off meetings to the leadership of Steering and Technical Committees, to facilitating consensus about the messages synthesized in the final report.

**Stages of Monitoring Program**: Each of the seven facets of a regional monitoring program typically spans two distinct phases: research and development (R&D) and implementation. However, by its inherent nature, the engagement facet of regional monitoring typically only encompasses the implementation phase.

- **Research & Development**: Since regional monitoring is focused on answering new questions, oftentimes many of the monitoring activities have never been attempted previously. So, initially, some R&D is required to inform the optimal execution of one or more of the main program areas. Thus, the goal of R&D is to provide the scientific underpinnings that create the most effective and efficient implementation phase to answering the new monitoring questions.
- **Implementation**: Once an initial round of R&D is completed for each of the program areas, technical transfer to the program participants moves the new knowledge into the implementation phase. Whereas R&D typically is short-term with a defined endpoint or goal, implementation can be a long-term endeavor. Since all successful monitoring programs are constantly evolving and asking new monitoring questions, subsequent rounds of R&D followed by new implementation (typically with reducing the old implementation) are commonly required.

# Research Directions

Regional monitoring programs play an essential role in answering big-picture environmental questions being asked by managers and the public, and SCCWRP is committed to seeing these programs flourish. SCCWRP will continue to facilitate R&D initiatives that broaden the reach and utility of these programs. SCCWRP is also committed to long-term implementation ensuring that these innovative regional monitoring programs are fully responsive to management needs and questions.

# Facets of Regional Monitoring Program

## Study Design

### *Accomplishments*

The Southern California Bight Regional Monitoring Program, which began as a pilot project in 1994, pioneered the use of a probabilistic study design that nests different habitats (i.e,, strata) to generate statistically representative, bias-free assessments of environmental condition across the Bight (Stevens 1997). These nested probabilistic study designs continue to serve as the underlying framework supporting the study design of the Bight, SMC, and other regional monitoring programs (Lackey and Stein 2014).

### *Ongoing Research*

***Project*: Estimating the spatial representativeness of bioassessment samples**

Managers faced with assessing stream condition typically receive data from samples collected in 150m reaches. However, stream monitoring sites may be many km apart, and it is uncertain how far to extrapolate the stream condition that remains unsampled in between sites. This is particularly problematic for managers addressing the extent of biological impact for NPDES stormwater programs or 303(d) listings. This project uses recently developed statistical network models to estimate how far up-and down-stream bioassessment results can be extrapolated with varying levels of confidence, and to estimate the optimal distance apart sample sites should be placed.

### *Priorities for Future Research*

***Future focus area*: Optimizing probabilistic sampling designs for temporal trends**

Probabilistic designs, where an emphasis on sampling more locations is preferred over revisiting existing sites, is most effective for answering questions about spatial extent. Temporal trend designs, where an emphasis on resampling the same site again and again is preferred over going to new sites, is most effective for assessing changes over time. Managers in southern California, after using probabilistic designs for decades, are now asking new, hybrid questions about trends in spatial extent. The goal of this research will be to identify the optimal allocation of sites between new sampling locations and revisiting existing locations to best answer these hybrid questions.

***Future focus area*: Optimization within a dynamic sampling frame**

While a nested probabilistic study design is an established and widely used approach for determining sampling locations, dynamic sampling frames continue to present a challenge in some circumstances. This is particularly problematic for regional stream monitoring in arid environments like southern California, where stream flow between drought years and flood years can alter the sampleable stream network (i.e., study frame) by hundreds of miles. This research will optimize the sample selection approach for dynamic sampling frames such as these.

# Method Standardization & QA/QC

## *Accomplishments*

To ensure that the dozens of laboratories participating in the Southern California Bight Regional Monitoring Program were able to generate high-quality, comparable results, SCCWRP facilitated the design of intercalibration exercises in the 1990s. These comparability studies were done for indicators such as chemistry, toxicity, and infauna components in the Bight Program, and the rigor with which they were completed has withstood the test of time (Ranasinghe et al. 2003, Gossett et al. 2003, Greenstein et al. 2008). For example, infaunal samples from the Bight program now reside at the Los Angeles Museum of Natural History. More recently, as part of the Bight '13 Water Quality element, a method standardization exercise was completed for ocean profiling pH sensor probes known as glass electrodes. The study demonstrated that decades of Bight pH data collected using glass electrode technology – the instrument of choice for profiling – were inaccurate and unable to track changes to pH to the level of precision required under California's Ocean Plan Standard (McLaughlin et al. in review). At the same time, SCCWRP showed that the use of discrete pH bottle measurements could provide an opportunity to perform an *in situ* calibration of the glass electrodes.

## *Ongoing Research*

(none)

## *Priorities for Future Research*

While much of the method standardization and QA/QC for regional monitoring is now implementation, there are some measurements that require further rigor. These include problematic methods that may be inherently variable, new chemicals that are not routinely measured, or new sampling methods that are not optimized. Ideally, many of the intercalibrated methods will also be adopted by the state's Surface Water Ambient Monitoring Program (SWAMP).

> ***Future focus area*: Optimizing sampling methods for trash and debris**
> Trash and debris, particularly plastic, are now nearly ubiquitous in the southern California environment. Trash and debris has become so prevalent, the State Water Resources Control Board recently adopted a statewide trash policy in an attempt to control all trash >5 mm diameter. However, no universal method currently exists for monitoring trash. This research will aim to calibrate and validate the most effective method(s) for monitoring trash and debris, so current baselines can be established and the success of future management actions can be gleaned.

# Information Management

## *Accomplishments*

SCCWRP has facilitated the design and creation of database structures and systems that have enabled comprehensive, efficient data management for the many participants of regional monitoring programs (Hale et al. 2003). This data management process encompasses the development of data checkers to ensure a high level of quality of all inputted data. More recently,

SCCWRP has integrated these databases with internet-connected field devices that have allowed for the input and review of data in real time (B'13 Field and Logistics Committee 2013).

## *Ongoing Research*

Much of SCCWRP's ongoing research focuses on updating and upgrading the information management facet of regional monitoring. Information technology is moving fast, and SCCWRP is overhauling systems implemented five years ago during the previous Bight survey.

> ***Project*: Building online data checkers**
> Because of the dispersed sampling and analysis responsibilities of southern California regional monitoring, dozens of data generators may need to provide data for a single measurement type. Experience has shown that enforcing standardized transfer formats helps ensure data can be integrated seamlessly, but that double-checking the completeness and accuracy of these many data sources *post hoc* is challenging and time consuming. To overcome this obstacle, SCCWRP is creating data checkers, a tool that activates simultaneously with on-line data submission, to verify data completeness and accuracy. These new data checkers can evaluate if all expected data were submitted, ensure data dependencies are complete (i.e., QA/QC data), and calculate on-the-fly whether the submittal met all data quality requirements. Easy to understand error reports ensure data providers can quickly correct any necessary changes before resubmittal. Ultimately, data checkers not only improve the quality of the data set, but also dramatically reduce the time-to-availability for data analysts.

## *Priorities for Future Research*

The data visualization aspect of information management, including tools to easily and autonomously convert data into management-friendly maps, charts and other visualizations, is the new frontier for converting regional monitoring results into actionable information. Virtual reality applications, in which users can walk through an environment and interact with it, are also part of the data visualization arena. Data visualization will continue to dominate SCCWRP's information management research portfolio going into the future.

> ***Future focus area*: Development of cross data set visualizations**
> Traditionally, monitoring agencies throughout southern California have conducted sampling in a particular geographical area with little knowledge of how their data compare on a regional basis. Cross-data set visualizations are an important way of looking at, and integrating data from, multi-agency projects such as the Bight or SMC Regional Monitoring Programs. Multiple sources of data from across an entire region, including from web services, could be pulled together to gain a holistic, integrated perspective. These powerful visualizations will allow managers to visually compare their local area to conditions across the region.

# Assessment Framework and Tools

## *Accomplishments*

SCCWRP has been a leader in developing seminal assessment frameworks and tools that have enabled regional monitoring participants to take huge volumes of data, then synthesize and interpret it in meaningful ways that resonate with management audiences. Based largely on the Bight Program's Contaminant Impact Assessment element, SCCWRP co-developed a sediment quality triad scoring tool to quantitatively score sediment condition using a multiple-lines-of-evidence approach (Bay and Weisberg 2012). The sediment quality triad was subsequently adopted by the State Water Board to regulate sediment quality in California embayments (SWRCB 2009). On the freshwater side, SCCWRP co-developed the California Stream Condition Index (CSCI), scoring tool to quantitatively assess the condition of wadeable streams. The CSCI predicts benthic invertebrate community composition and metrics at a site based on natural factors such as gradients in rainfall and temperature, then compares the prediction to what actually exists at that site (Mazor et al. 2016). The CSCI is now the cornerstone of the State's upcoming Biointegrity Plan for streams.

## *Ongoing Research*

***Project:*** **Developing a predictive stream algae index with statewide applicability**

Fundamentally, algae and invertebrates respond to different anthropogenic stressors. So, SCCWRP and collaborators are developing a predictive assessment index for statewide use that is based on benthic algae. Similar to the CSCI assessment tool, the algal predictive index (ACSI) incorporates site-specific natural gradients to determine biological expectations, enabling assessments applications with regional and statewide consistency. That is, assessments with a passing (or failing) score with the ACSI will have equivalent meaning in all habitat types. In tandem with the CSCI, the ACSI will be used for regional monitoring assessment endpoints, and may be used in future statewide management goals or nutrient policies.

## *Priorities for Future Research*

SCCWRP is interested in either expanding the utility of existing assessment tools, creating new assessment tools, or finding ways to combine assessment tools, all in order to provide more robust assessments of environmental condition.

***Future project area*****: Expanding existing assessment tools**

There are a number of existing assessment tools used in regional monitoring that are only calibrated and validated for only a portion of the region. For example, the Bight program uses the Benthic Response Index (BRI) to assess infauna on the continental shelf to 325m depth, but regional monitoring samples are collected to depths of 1,000m. Future research will fill in these habitat gaps based on depth. Additional gaps in assessment tool availability - not just for benthic infauna, but also other organisms such as fish - include habitats such as low salinity estuaries, rocky reefs and eel grass beds.

***Future project area*: Creating new assessment tools**
New measurements are continually introduced during regional monitoring programs (see next section: New Measurement Methods and Technology). Once these methods are vetted and adopted, they require an assessment tool to help interpret their findings for managers. The most recent of these technology improvements is associated with a burgeoning issue – ocean acidification. As new and more measurements are made of the multiple components within the oceanic carbon cycle, and linkages to ecosystem impacts are made, an easy-to-understand framework to interpret the results needs to be developed. Whether the measurements include pH, aragonite saturation, dissolved oxygen, or the numerous other parameters measured by physical and biogeochemical oceanographers, this assessment tool will be one of the primary communication vehicles for letting managers know if they need to take necessary additional steps to protect our environment.

***Future project area*: Combining assessment tools**
As part of regional assessments, SCCWRP is working to integrate multiple indicators of condition so that managers will have a convenient, meaningful way to synthesize different measures of ecosystem health. Multi-indicator integration has the potential to, among other things, improve robustness, increase responsiveness to different stressor types and enhance diagnostic ability. SCCWRP's previous research integrating multiple indicators focused on the marine sediment quality triad (chemistry, toxicity and benthic invertebrates). However, no such integration is available for regional surveys of stream health (flow, physical habitat, chemistry, benthic invertebrates, algae and riparian wetlands). Multi-indicator integration projects generate several key issues that need to be addressed before managers can use them with confidence, including: How should conflicting indicators be weighed? Does poor condition reflected by one indicator override good condition reflected by others? Should various patterns of pass vs. fail index scores trigger different types of management responses? Once calibrated and validated, this assessment framework will be applied to regional ambient stream surveys.

# New Measurement Methods and Technology

## *Accomplishments*

The regional monitoring platform has enabled multiple breakthroughs regarding new measurement methods and new technologies. Using Bight program data, SCCWRP showed that it is possible to successfully link remote sensing data to ground-level measurements (Reifel et al. 2009) or serve as the foundation for new method approval by the State and EPA (Noble et al. 2003). Most recently, via the Bight '13 Water Quality element, a series of pH profiling sensor prototypes have been evaluated that might one day be adapted to replace glass electrodes that have traditionally been used for ocean pH profiling (McLaughlin et al. in review).

## *Ongoing Research*

***Project*: Employing Quantitative Polymerase Chain Reaction (QPCR) to monitor beach water quality**

For decades, fecal indicator bacteria (FIB) have been used to monitor beach water quality, and the methods have all been based on slow-growing cultures. New technology based on analyzing genetic material, or QPCR, can measure FIB in less than 2 hours enabling same-day notifications to protect public health. An additional advantage of QPCR is its ability to measure more than just generic FIB, and quantify FIB source-specific host markers so managers can assess the magnitude of potential health risk and track FIB to its source for remediation. One challenge for managers, however, is a demonstration of applicability for the new technology at their beach. The Bight program is demonstrating this new technology by helping local laboratories assess the FIB levels – and the levels of human-specific source markers – at nearly three-dozen beaches region-wide during both dry and wet weather.

## *Priorities for Future Research*

Regional monitoring programs will continue to serve as important platforms for capturing the breadth and depth of habitats, and for cross-training member agencies. New measurement methods and technologies include DNA barcoding and bioanalytical screening assays. Both technologies hold promise for improved speed and cost to achieve screening level information, helping managers assess whether additional effort is necessary.

***Future project area*: Using bioanalytical assays to screen for CECs in receiving waters**

Bioanalytical screening assays are *in vitro* tissue cell line-based tests that respond when exposed to various constituents of emerging concern (CEC). The value of the bioanalytical assays is their rapid ability to simultaneously screen for a large number of difficult-to-measure compounds, reducing the need to utilize a long list of expensive chemical methods. Since these *in vitro* assays are inherently lab-based, there are a number of research needs to bring this technology to fruition including developing assays for different modes of action, demonstration in receiving water matrices and linking bioanalytical screening assay responses to environmental effects.

***Future project area*: Adapting DNA barcoding methods for bioassessment**

SCCWRP is developing molecular tools - called DNA barcoding - to aid in difficult to identify organisms such as algae and ichthyoplankton. Both algae and ichthyoplankton have the potential to be sensitive indicators of environmental condition, but their identification in the laboratory is problematic because of challenging taxonomy and lack of trained taxonomists. DNA barcoding utilizes the unique signatures from each species' genetic material as a relatively rapid and inexpensive technique for identifying organisms. Research on method development, evaluating accuracy and precision, and data utilization are all important aspects of transforming DNA barcoding into a valuable monitoring asset. If successful, next generation high-throughput sequencing enables even greater capabilities for the future.

# Integrative Studies/Regional Implications

## *Accomplishments*

Regional monitoring by definition is large and complex, and the many facets require time to implement. However, between regional monitoring cycles are opportunities to conduct studies and projects that address issues identified by regional monitoring. These spin-off, integrative studies include more intensive site-specific monitoring, adaptive studies that ask new but related questions and causal assessment projects that go beyond the assessment phase to identify specific remediation actions. Sometimes, these integrative studies can consist of linking separate regional monitoring programs that generate different data sets, but at the same spatial scales, which can enhance regional assessments. Other times, these integrative studies locally intensify the scope and breadth of the monitoring questions that can be answered.

## *Ongoing Research*

***Project*: Integrating causal assessment into regional monitoring**

It is not enough to identify the extent and magnitude of environmental impacts. Sometimes, scientists must dig deeper into the cause of the impact and provide managers the necessary information for remediation. This has been conducted many times in previous regional monitoring efforts. One example is conducting toxicity identification evaluations (TIEs) to ascertain the specific contaminants causing toxicity. As causal assessment technology advances, so must its integration into regional monitoring responses. These new areas come in the form of isolating the causes of biological community disturbance, molecular TIEs and mechanistic models linking bioaccumulation to sediment contamination and eutrophication impacts.

***Project:* Linking regional monitoring to other monitoring programs**

Regional monitoring programs coordinated by SCCWRP are not the only monitoring programs in southern California. Some monitoring programs measure similar indicators, but occur at larger scales such as EPA's National Coastal Condition Assessment or the State's Perennial Stream Survey. Other monitoring programs occur at smaller spatial scales, including our member agency's NPDES monitoring requirements. And yet others monitor at similar spatial scales, but measure different indicators or habitats such as California Cooperative Oceanic Fisheries Investigations (CalCOFI). Altogether, SCCWRP regional monitoring programs have formed collaborations and linkages with more than 40 different monitoring networks. Integrating the needs (monitoring questions), study design, QA/QC, information management, new technology and assessment tools builds unique foundations for creating enhanced assessments of southern California's environment and leveraging resources for improved cost effectiveness.

## *Priorities for Future Research*

SCCWRP is committed to forging new relationships and continuing to enhance regional monitoring programs, especially by improving integration with related monitoring programs. SCCWRP is interested in linking management actions back to the findings of condition

assessments, data mining to elucidate additional insights, improving the understanding of relationships between condition bioindicators and beneficial-use endpoints and compiling integrated reports on the state of aquatic systems.

# Engagement

Implementation follows R&D and engagement is the process of implementation support. This crucial engagement includes all facets of regional monitoring.

## Study Design

Engagement focuses on recruiting a broad range of participants that influence or have decision-making authority across the region and coalescing them around a series of monitoring questions. This requires program leadership, ultimately creating and guiding program governance. After coordinating a study design that will answer these monitoring questions with specified levels of confidence, implementation support will culminate in program documents such as work plans and guidance documents that serve as the guiding force for the remainder of the survey.

## Method Standardization & QA/QC

Engagement leads technical staff around the region through rigorous QA development to ensure comparability among the dozens of collaborating organizations. This implementation support typically occurs within the numerous Technical Committees organized around each measurement indicator and specialty science organizations that meet between surveys (www.SCAMIT.org, www.SAFIT.org, www.SCAITE.org). The culmination of methods standardization and QA/QC is hands-on training, pre-survey and in-life audits, demonstrated intercalibrations with native sample matrices, verifiable data quality objectives, all captured with the Project Quality Assurance Project Plan. When done well, this implementation support carries over into each participant's local routine monitoring program raising data quality and comparability between regional surveys.

## Information Management

Engagement coordinating information management aims to seamlessly integrate data from multiple sources, support data analysis and map creation, and then serve the finished data set to the public. This implementation support includes creating and updating software for field data collection devices, database updates and structures, programming routine data analysis tools, data portal development and maintenance, training and help desk support, and online data posting.

## Assessment Framework and Tools

Engagement for assessment frameworks and tools focuses primarily on technology transfer for regional monitoring participants. Implementation support includes activities such as education on tool construct and application, creating and maintaining automated assessment tool calculators and data analysis support for building assessment framework outputs.

## Integrative Studies/Regional Implications

Engagement for integrative studies is the culmination of regional monitoring: translating scientific results into answers for the monitoring questions relevant to management decision-making. This implementation support requires working with the collaborating agencies ensuring the data have been analyzed and interpreted adequately and accurately. This interactive and iterative approach to reporting engenders consensus answers, free from bias, that provides managers the confidence they need to take action. Communication and leadership become fundamental tools for accomplishing these support activities.

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