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Regional monitoring programs in the United States: Synthesis of four case studies from Pacific, Atlantic, and Gulf Coasts

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HIGHLIGHTS

- Successful regional monitoring programs from this special issue reveal key insights.
- Each program has dramatically influenced management actions within its region.
- The management influence is tied directly to collaboration and shared governance.
- Linking monitoring questions to management actions is fundamental.
- Benefits include developing management priorities, decision tools, and thresholds.

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ABSTRACT

Water quality monitoring is a cornerstone of environmental protection and ambient monitoring provides managers with the critical data they need to take informed action. Unlike site-specific monitoring that is at the heart of regulatory permit compliance, regional monitoring can provide an integrated, holistic view of the environment, allowing managers to obtain a more complete picture of natural variability and cumulative impacts, and more effectively prioritize management actions. By reviewing four long-standing regional monitoring programs that cover portions of all three coasts in the United States – Chesapeake Bay, Tampa Bay, Southern California Bight, and San Francisco Bay – important insights can be gleaned about the benefits that regional monitoring provides to managers. These insights include the underlying reasons that make regional monitoring programs successful, the challenges to maintain relevance and viability in the face of ever-changing technology, competing demands and shifting management priorities. The lessons learned can help other managers achieve similar successes as they seek to establish and reinvigorate their own monitoring programs.

1. Introduction

Monitoring has been the foundation of water quality management for more than a century. The US Geological Survey has been monitoring national waterways since the 1870s (Stets et al., 2012). The Public Health Service Act of 1912 directed the federal government to study pollution to US navigable waters, acknowledging the effect of untreated sewage on water quality and links to disease outbreaks that can be regional-scale issues (Cumming et al., 1916). Regulatory-based monitoring programs were firmly established with the passage of the Federal Water Pollution Control Act (Clean Water Act) in 1972. Originally, this regulatory-based monitoring focused on pollutant discharges, specifically comparing effluent concentrations to National Pollutant Discharge Elimination System (NPDES) permit limits. However, it soon became apparent to environmental managers – which we define in this manuscript as both regulated and regulatory agencies – that determining not just what was being discharged, but if the discharges were manifesting environmental changes in receiving waters was crucial information (US EPA, 1982). Receiving water monitoring addresses the "so what" questions that ultimately prompt management action in response to deleterious ecosystem effects and fuel public reaction when beneficial uses are impaired.

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Receiving water monitoring provides the insight environmental managers often need to take action and to track the success of these actions. Valuable examples of receiving water monitoring include identifying and reversing the spread of "dead zones" in Chesapeake Bay. Wastewater treatment plant upgrades and a ban on phosphate detergents upstream of the Bay improved surface water dissolved oxygen conditions and submerged aquatic vegetation populations in the Potomac River tributary to Chesapeake Bay (Jaworski et al., 2007; Ruhl and Rybicki, 2010). In Tampa Bay, managers have been using monitoring to track reductions in nutrient loading and subsequent improvements in water clarity, spurring achievement of long-established restoration goals for submerged aquatic vegetation (Sherwood et al., this volume). In the Southern California Bight, monitoring identified precipitous declines in California brown pelican (*Pelecanus occidentalis*) and sea lion (*Zalophus californianus*) populations, attributed to the pesticide dichlorodiphenyltrichloroethane (DDT) (DeLong et al., 1973). Ultimately, these data contributed to a federal ban on DDT production and use in the United States, and it was similar monitoring efforts that illustrated the rebound of these populations and their eventual removal from the list of endangered species.

The value of monitoring is often characterized via success stories such as improved aquatic habitat and recovering populations, but the true value of monitoring is realized at the expense of not monitoring. Environmental managers who do not invest in monitoring are unable to recognize problems until they become acute and/or widespread. In turn, this constrains remediation strategies leaving managers with a limited number of options to deal with problems of larger magnitude and spatial scales. Moreover, when remediation strategies are short-term reactions, instead of pre-planned and well thought-out with available monitoring data, environmental managers miss precious opportunities for cost-effective, multi-benefit strategies and possibly end up implementing management actions that have unintended consequences (i.e., attempting to remediate one problem while exacerbating another). Finally, failure to monitor prevents comparisons to a previous state, often times prior to the problematic condition further complicating the development of realistic targets for remediation strategies. Altogether, the lack of ongoing environmental intelligence inhibits the effective assessment of any management action, potentially leaving the public with the perception of wasted public funds.

Regional monitoring programs are unique in that they can be designed to provide a holistic, integrated view of the ambient environment that might challenge local site-specific monitoring. Regional monitoring can consider the cumulative effects of multiple sources of pollution entering the environment from a multitude of sectors: air, land, groundwater, and bottom sediments. Consequently, regional monitoring is better able to answer "so what" questions at scales of public concern: Is it safe to swim and recreate? Is it safe to eat the fish? Can we drink the water? Is the ecosystem protected and sustainable? The ability to answer these questions influences public and stakeholder perceptions of their environment and of the managers tasked with protecting it. Conversely, site-specific monitoring is often times limited in scope to addressing local issues and needs—most importantly, for assessing compliance of individual NPDES discharges, the traditional approach to managing point-source pollution. When managers attempt to knit together a series of site-specific, NPDES compliance-based monitoring programs, they can end up with a skewed overall picture. Even if a manager could overcome site-specific differences in study design, incongruent sampling frequencies, incompatible analyte lists or laboratory methods, dissimilar data quality objectives, and challenges in data compilation, the best end product they could achieve would be an environmental snapshot of a region's NPDES discharge locations, not a snapshot of the region itself (US EPA, 2000).

Regional monitoring provides at least three pieces of scientific information that site-specific monitoring programs cannot. First, regional monitoring programs provide a more complete picture of natural variability than local compliance monitoring. Most coastal regions have documented substantial biogeographic variability based on climate, depth, substrate type, circulation patterns, local climatology, hydrology, and temperature, amongst other variables (i.e., Bergen et al., 2001, Day et al., 2013). Since several potential pollutants occur in nature such as sediments, nutrients, and trace metals, it is critical to understand this natural variability to determine the background against which anthropogenic alterations are assessed. A good example is sediment chemistry, where naturally occurring trace metals can be differentiated from anthropogenic additions using reference elements (Schiff and Weisberg, 1999; Karlen et al., 2015). With sufficient, consistent, long-term water quality and river flow monitoring records, the anthropogenic contribution to nutrient and sediment concentrations or loads can be distinguished from changes in hydrology (Hirsch et al., 2010).

Second, regional monitoring can assess cumulative impacts from many individual discharges to a common water body, which is necessary to generate holistic, integrated data sets capable of answering big-picture environmental questions. Understanding cumulative impacts has been especially valuable in San Francisco Bay, which receives runoff from nearly two-thirds of the State of California, including the Central Valley that contains one of the most intensive agricultural areas in the country. In addition, San Francisco Bay receives direct discharges from 35 municipal wastewater discharges, nine industrial facilities, one once-through-cooling water discharge, and stormwater runoff from more than 100 local municipal agencies (Trowbridge et al. this issue).

Third, regional monitoring gives managers the tools and data they need to rank and prioritize the actions they take. Through regional monitoring, managers can decide which habitats (or areas within habitats) to target, which pollutants are most problematic, and which pollutant sources to most effectively manage. Tampa Bay used regional monitoring to identify sea grass beds as being the most sensitive habitats to nutrient pollution. Management actions focused on restoring these sentinel habitats have improved overall Bay ecosystems (Sherwood et al. this issue, Greening et al., 2014). In San Francisco Bay, regional monitoring of sport fish tissue for public health and ecosystem health protection is used as a primary indicator of beneficial use attainment (SFBRWQCB, 2006, 2008).

The goal of this special issue of *Regional Studies in Marine Science* is to present management insights derived from four effective, long-term US regional coastal water quality and biological resource monitoring programs: Chesapeake Bay, Tampa Bay, Southern California Bight, and San Francisco Bay. The four articles that follow this synthesis article provide the details of each of these four regional monitoring programs, highlight each program's most salient findings, and describe the effects each has had on management actions in the region. For environmental managers struggling with how to implement a regional monitoring program, or with how to design an effective regional monitoring strategy, these four case studies provide a wealth of perspective and insight.

This synthesis article provides an overview of the management benefits derived from regional monitoring, the underlying, shared reasons these four regional monitoring programs have been successful, and the ongoing challenges these programs face in continuing to provide viable, relevant monitoring approaches for managers and the public. Although the four programs vary dramatically in scale, study design, constituents of concern, and ecological setting, the roadblocks they have overcome to aid in effective management have been remarkably similar. From this synthesis article, the managers of any region and at any spatial scale should be able to take away valuable lessons learned and tools needed to overcome similar obstacles within their respective regions.

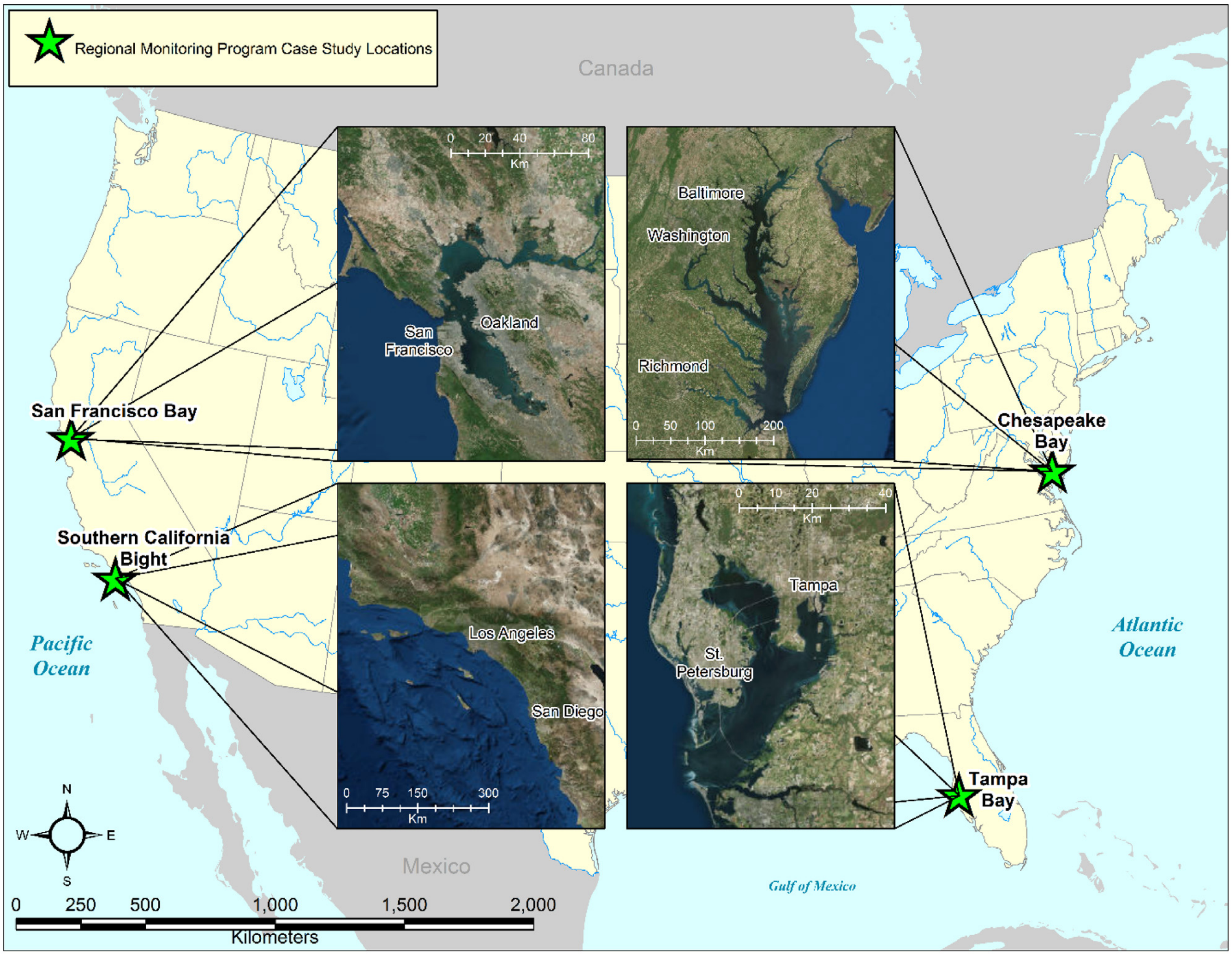

Fig. 1. Map of the United States, with inset locations for each of the regional monitoring programs in this special issue.

2. Regional case studies

The four regional monitoring programs profiled for this special issue reflect collaborations established in four major water body areas of the Atlantic, Pacific and Gulf of Mexico coastlines:

- Chesapeake Bay Program Partnership's long term water quality monitoring program (Tango et al., this volume).
- Tampa Bay Regional Ambient Monitoring Program (Sherwood et al., this volume).
- Southern California Bight Regional Marine Monitoring Program (Schiff et al., this volume).
- San Francisco Bay Regional Monitoring Program (Trowbridge et al., this volume).

Each of these programs is defined by their spatial scale, which is greater than local discharges, but less than the entire coastline (Fig. 1). These programs are all focused on ambient water quality, have been in existence for at least 20 years, and are cooperatively run through coordination of up to 100 different agencies (Table 1). The surface water area covered by each program ranges from 1000 to 12,000 km^2, salinities range from 0 to 33 PSU, and maximum sample depths range from 20 to 1000 m.

The study design of each program is guided by a series of monitoring questions (Table 2). Some of these questions are quite general, while others are more detailed. However, every program has questions to answer, and every program uses a network of engaged managers to generate the questions.

For each program, the monitoring questions that are posed become the foundation of the elements of the study design (Table 1). Some study designs are composed of fixed stations that are revisited at periodic intervals and optimized for trend detection. Other programs utilize probability-based designs in which stations are selected randomly and are optimized for estimates of spatial extent. Some programs contain a mix or hybrid of these two design approaches. The number of stations in each program ranges from 465 to 1700.

The four monitoring programs do not all focus on the same indicator classes; rather, each program focuses on the indicators necessary to answer their monitoring and management questions of concern. As a result, the different programs measure everything from sediment toxics to eutrophication-related water quality indicators. The four articles that follow this synthesis article detail the specific indicator parameters measured by each of the four monitoring programs.

3. Synthesis and discussion

Management benefits from regional monitoring

All four regional monitoring programs have successfully provided at least five main categories of benefits to resource managers and key decision-makers. The first benefit is supporting development of scientifically-defensible regulatory endpoints including water quality criteria, total maximum daily load (TMDL) targets, sediment quality guidelines, and numeric assessment tools.

Table 1
Study design characteristics of four of the most successful regional monitoring programs in the United States.

Region	Regional Scale[a] (sq. km)	Year initiated	Number of partner agencies	Cost ($M/yr)	Study design	Cumulative number of stations	Primary indicators
Southern California Bight	12,000	1994	100	5	Probabilistic	1700	• Sediment toxics • Bioaccumulation • Beach water quality • Eutrophication
San Francisco Estuary	2,000	1993	66	3.5	Probabilistic and fixed station	654	• Sediment toxics • Bioaccumulation • Water column toxics • Eutrophication
Tampa Bay	1,000	1992	5	2	Fixed station (primary) and probabilistic	45 fixed, 420 + Probabilistic	• Eutrophication • Physical water column
Chesapeake Bay	11,600	1987	35	15	Fixed station, rotational, random linear, and probabilistic	285 fixed + 250 probabilistic	• Eutrophication • Physical water column • Benthic infauna • Submerged aquatic vegetation • Plankton • River, stream, and fall-line

[a] Size of coastal receiving water body, not including contributing watershed.

Table 2
Monitoring questions of the four regional monitoring programs in this special issue (see Schiff et al., Trowbridge et al., Sherwood et al., and Tango and Batiuk in this volume for details).

Region	Monitoring question
Southern California Bight	• What is the extent and magnitude of anthropogenic impact in the Southern California Bight? • How does the anthropogenic impact vary among habitats of concern? • Is the extent and magnitude of anthropogenic impact changing over time?
San Francisco Bay	• Are chemical concentrations in the Bay at levels of potential concern? • What are the concentrations and masses of contaminants in the Bay? • What are the sources, pathways, loading, and processes leading to contaminant-related impacts? • Have concentrations, masses, and associated impacts of contaminants in the Bay increased or decreased? • What are the projected concentrations, masses, and associated impacts of contaminants in the Bay?
Tampa Bay	• Are annual Bay segment-specific water quality indicators (chlorophyll-a and effective light penetration, measured as Secchi depths) below management targets to restore seagrasses? • Is the annual Bay segment-specific chlorophyll-a regulatory threshold in attainment? • Did an anomalous event influence non-attainment of the Bay segment-specific chlorophyll-a threshold? • Has the chlorophyll-a threshold been exceeded for >2 successive years? • Has the bay segment achieved a federally recognized TMDL during that time?
Chesapeake Bay	• Are we meeting water quality standards for dissolved oxygen, water clarity/bay grasses and chlorophyll a in the tidal waters of Chesapeake Bay? • Are management actions effectively reducing nutrient and sediment loads entering the Bay from the watershed? • Can we better target our management actions? • How do we best illustrate and explain changes in water quality and living resources in the watershed and bay? • Improve calibration and verification of partners' bay and watershed models that support decision-making.

When any monitoring program collects sufficient data at appropriate temporal and spatial scales to inform ambient assessments, the program invariably requires benchmarks to differentiate "good" from "bad", healthy from degraded, compliant from non-compliant. Regional monitoring programs are able to more effectively generate benchmarks than local programs because they collect data that quantifies the range of natural variation over which regional programs can judge anthropogenic alteration. Regional monitoring also captures the range of anthropogenic impacts allowing managers to judge which impacts are meaningful. Moreover, many of the programs collect information on multiple indicators, which serves as a validation for benchmark development and assessment. For example, the data used from the southern California Bight and San Francisco Bay were used to develop sediment quality objectives, the first of its kind in the nation (Bay and Weisberg, 2009; SWRCB, 2008). Similar examples can be found for chlorophyll and dissolved oxygen in Chesapeake Bay (US EPA, 2007; Harding et al., 2013), and nutrients and light attenuation in Tampa Bay (Yates et al., 2011).

The second benefit of a successful regional monitoring program for managers and decision-makers is that it provides support for development, calibration and verification of environmental models and decision-support tools. In Tampa Bay, a simple stop-light graphic easily conveys the annual status of water quality to resource managers, which influences proactive, adaptive strategies for nutrient pollution management in each major bay segment (Sherwood et al., this volume). In Chesapeake Bay, a combination of integrated regional monitoring programs is used to support development, calibration and validation of a suite of environmental models that, in turn, supports collaborative decision-making for pollutant reductions (US EPA, 2010).

The third benefit of regional monitoring for decision-makers is that it improves messaging with stakeholders and the public on key environmental issues. In Chesapeake Bay, the water quality, submerged aquatic vegetation, and benthic infauna components of the larger, integrated regional monitoring network contribute to a collective, annual report card on the condition of the Bay's ecosystem (Williams et al., 2010) and the annual "Bay Barometer" report (http://www.chesapeakebay.net/documents/2014_Bay_Barometer_02.03.2015.pdf, CPB, 2015). The San Francisco Bay annual monitoring report has evolved from a "data-heavy" technical report to a concise "Pulse of the Bay" report (http://www.sfei.org/programs/pulse-bay, SFEI, 2013) that provides an accessible, largely pictorial summary of regional monitoring program information. These examples highlight how regional monitoring products can be distilled to appropriate and palatable assessment levels that are effective in garnering public and political support for regional remediation strategies and investments.

The fourth benefit of regional monitoring for decision-makers is that it can support the basis for Clean Water Act §305(b) waterbody assessment reports and a prioritized §303(d) listing of impaired waterbodies. These two reports, required by the Clean Water Act from states and the US EPA every three years, form the basis of many regulatory actions, including TMDLs. Some regions struggle with uneven water quality monitoring effort among habitats; waterbodies with sufficient data to be evaluated are often placed on the list of impaired waterbodies, even as waterbodies that may be in far worse ambient condition do not get listed because little to no ambient water quality data exist. In contrast, regional monitoring provides a vehicle for consistent quality and effort across all waterbodies of interest. In Chesapeake and Tampa Bays, regional monitoring supports decisions on regional and local allocations of pollutant reduction responsibilities (US EPA, 2010; Sherwood et al., this volume). In Southern California, regional monitoring assessments have been used for delisting decisions of legacy contaminants in sediments, largely due to a lack of biological impacts and commensurate loss of beneficial uses (Schiff et al., this volume).

The fifth benefit of regional monitoring for decision-makers is the ability to proactively focus management action on priority areas, perhaps even before they require significant action by regulators. While TMDLs generate reactive responses, it is far better to take proactive management measures to prevent problems so that significant regulatory action is avoided. In the Southern California Bight, where sediment quality is particularly impacted in marinas, regulators are working with stakeholders to develop non-toxic, anti-fouling boating paints and best management practices to reduce pollutant releases into marinas during hull-cleaning activities (Carson et al., 2009). In San Francisco Bay, managers are working to proactively detect chemicals of emerging concern (CECs), ensuring these chemicals can be managed and their risks understood before they potentially become an environmental problem (Sutton and Kucklick, 2015). In Chesapeake Bay, the integrated analysis of watershed and estuarine model applications have yielded maps of the six-state Chesapeake Bay watershed that guide geographically-targeted implementation of best management practices aimed at generating the greatest benefits to downstream tidal waters (US EPA, 2010).

Common keys to success

All regional monitoring programs have the potential to offer a range of benefits to various stakeholders, but not all programs are successful. The four regional monitoring programs chronicled in this special issue share at least three "keys to success". All three of these keys revolve around the ability to effectively translate management concerns into meaningful monitoring questions.

The first key to success is to formulate monitoring questions that are directly driven by management objectives. The concept of formulating a monitoring question – a hypothesis to be tested that drives the design of the monitoring program – is not new. Indeed, it is the basis of all scientific studies; it is just that scientists often underestimate its importance for monitoring (NRC, 1990). In the case of the successful regional monitoring programs in this issue, the scientists responsible for designing the programs uniformly utilized environmental managers to shape their monitoring questions. In fact, the scientists were so integrated with the decision-making process that they associated specific management actions with the specific answers that would be obtained from each monitoring question. In other words, future management decisions were built into the monitoring design and assessment process, hard-wiring the link between science and policy from the outset. Then, scientists use the magnitude and cost of the predefined management actions to make decisions about the size and scope of the monitoring effort necessary to generate sufficient confidence in the monitoring answers.

The second key to success is to ensure the programs were not set up to remain static, but instead to evolve over time. To do this, the evolution and growth of the program must be tied to the evolution and growth of the monitoring questions. As one question is asked and then answered, a new set of questions will arise. When a program is tied to management actions, new areas of concern are automatically explored as old concerns are addressed. Effective monitoring programs also evolved as a result of high-level program reviews by independent and/or regional experts, ensuring that the monitoring design has sufficient scientific rigor to answer the pertinent monitoring questions. Finally, successful monitoring programs evolve by proactively conducting special studies to address and investigate emerging management questions, and testing new monitoring methods and technology for future incorporation into routine monitoring programs.

The third key to success is transparent, collaborative communication and shared governance. All four regional programs are collaborative partnerships among dozens of agencies encompassing hundreds of individuals, ranging from regulated and regulatory agencies to academic and non-governmental organizations. Because these are often agencies with divergent agendas, it is the collective development and interpretation of the monitoring questions that provides a forum for these diverse interests to come together. Also, because participants must decide up-front what information is truly needed for management action, the collaborative process minimizes the potential for contentious or adversarial interactions when data are interpreted after-the-fact or in isolation.

Common challenges

As regional monitoring programs plan for the future, they can expect to face at least four main challenges. The first challenge is that new technology may render old technology obsolete, thereby potentially vexing monitoring consistency and the ability to track long-term trends. Not only does new technology hold the promise of "better, faster, cheaper", but regional monitoring programs also commonly serve as a primary testing ground for advancing cutting-edge assessment tools. New technology developers have a vested interest in maintaining these partnerships because new indicators, or new methods for traditional indicators, can be tested and validated side-by-side with existing methods across a wide spectrum of habitat conditions and environmental stressors. Environmental managers also push for the use of new technology when they feel it is more likely to be readily accepted by a range of agencies. However, changes in methods due to new technology can create problems for detecting long-term trends. For example, using new sensors for pH that are 10 times more sensitive than traditional technology (McLaughlin et al., 2015), or using colored dissolved organic matter (CDOM) instead of ammonia to detect sewage plumes (Nezlin et al. in review), presents real challenges for long-term trends questions addressing spatial extent. As another example, the use of genetic methods for taxonomic identifications of organisms instead of traditional microscopes and a phylogenetic key, holds the promise of providing more accurate identifications at a fraction of the cost and time. Taxonomists, however, are finding that the genetic signatures do not necessarily match the phylogenetic keys, presenting a challenge for ongoing community assessments at both impacted and unimpacted sites.

The second challenge is transforming traditional funding models. Cumulatively, the four monitoring programs spend more than $25 million (US) annually (Table 1). In Chesapeake Bay, funding is primarily provided by federal and state agencies. In San Francisco Bay, funding is primarily from fees paid by the regulated agencies. In the Southern California Bight, funding is primarily from redirected effort of routine compliance monitoring programs. In Tampa Bay, funding comes primarily from local governments. Ideally, a diverse mixture of funding sources is best for a regional monitoring program to buffer the effects of changing federal, state, and local budget priorities. Furthermore, regional monitoring programs have become a victim of their own success, with managers asking more monitoring questions, even as they are unable to keep up with the funding increases necessary to offset inflation for the existing monitoring questions. Since no one wants to reduce technical output (hence the desire for ''faster, better, cheaper''), insufficient funds usually handicaps essential governance duties first. This puts a strain on the key to success that revolves around transparency, communication and the collaborative process that enables participants to reach consensus. New funding models are being evaluated such as pooled-funding collaboratives, user-pay participation or incorporation of supervised volunteer monitoring efforts to enhance existing, long term programs. Each approach has been used successfully to support water quality monitoring programs nationally and globally. Regardless, these approaches force managers to clearly decide which parts of the monitoring program they most need and value.

The third challenge is identifying the proper balance between local monitoring (down-scaling) vs. larger national monitoring programs (up-scaling). The relationship between regional- and local-scale monitoring programs is crucial, as regional remediation strategies are commonly implemented at the local level. Moreover, regional programs have traditionally provided strong support to local programs using regional data to improve local program interpretation, developing regionally calibrated and validated assessment tools for local use, and providing a framework for data collection and management. Indeed, many of the technical staff at local agencies use regional program implementation for technical training and quality assurance evaluations (Gossett et al., 2003). However, as regional programs increasingly focus on the challenges of national initiatives, such as responding to global climate change, their potential for local relevance may wane. It is imperative, therefore, that regional programs continue to downscale their monitoring to local programs and the public they serve, as grassroots support for regional programs originates at the local level.

The fourth, and perhaps most disconcerting, challenge is addressing climate change and related phenomena. Climate change may be the largest environmental issue of the next generation. Increasing water temperature, dramatic changes in precipitation, sea level rise and ocean acidification can all combine to be drivers of potentially powerful changes in regional baseline conditions. Temperature and precipitation are predicted to significantly alter ocean currents, resulting in significant shifts in biological assemblages. Sea level rise will likely result in loss of habitat, especially sensitive estuarine ecosystems (Sherwood and Greening, 2014). Ocean acidification, which is a by-product of increased carbon dioxide, may have profound impacts on shelled organisms (Barton et al., 2015), possibly interfering with normal physiological functions or imparting low-level stress on native fauna and increasing responses to traditional contaminants. Regional monitoring programs can meet this challenge in several significant ways. First, not only will regional programs identify these shifts in baseline conditions, but they will need to update their regional assessment tools to address these new baseline conditions. Second, regional monitoring will need to provide local managers the information they will need to decide if any local actions on their part can resolve, or at least delay, the impacts of climate change. Finally, regional monitoring programs will need to be the intimate link between national and local scale decision-makers, being the focal point for coordination across large marine ecosystems. Good examples are already being developed such as the California Current Acidification Network that spans the entire US West Coast (McLaughlin et al., 2015) or the Gulf of Mexico Alliance (GOMA, 2015). The leadership role that regional monitoring programs can play on national or global issues may represent the next important evolution of these programs, where nested regional monitoring programs integrate into broader coastal programs that help to better inform management actions that cut across these dramatically different spatial scales.

4. Conclusion

A review of four highly successful US regional monitoring programs is able to reveal key insights about the benefits and challenges of establishing sustainable regional monitoring programs. Among its many benefits, regional monitoring paves the way for development of scientifically defensible regulatory endpoints, decision-support tools, improved messaging, more uniform monitoring of waterbodies, and prioritization of competing needs. Regional monitoring also ensures that management concerns are translated into effective, relevant monitoring approaches that are built on collaboration and shared governance responsibilities. Furthermore, the benefits from running regional monitoring programs far outweigh the fiscal investments needed to maintain them, with the products and management decisions developed from them dramatically improving environmental quality and human quality of life. As regional monitoring programs confront the challenges of long-term sustainability and relevance, they must work to balance competing demands from ever-changing technology, shifting management priorities, and growing expectations. Perhaps the greatest test of their long-term survival will be their ability to remain grounded in their local roots, even as they look to tackle global environmental challenges.

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