Inventory of ocean monitoring in the Southern California Bight

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ABSTRACT

Monitoring of the ocean environment in southern California has been conducted by a diverse array of public and private organizations with different motivations, working on a variety of spatial and temporal scales. To create a basis from which to integrate information from these diverse programs, we conducted an inventory of ocean monitoring activities in the Southern California Bight to address the following questions: (1) How many dollars are being expended annually on marine monitoring programs? (2) Which organizations are conducting the most monitoring effort? and (3) How are resources allocated among the different types of monitoring programs? This inventory focused on existing programs, or those expected to be in existence, for at least 10 years and that were active at any time between 1994 and 1997. For each program identified for inclusion in this study, information was collected on the number of sites, sampling intensity, parameters measured, and methods used. Levels of effort were translated into cost estimates based upon a market survey of local consulting firms. One hundred and fourteen marine monitoring programs, conducted by 65 organizations and costing $31 million annually, were identified. Most of the effort (81 programs, 65% of samples, 70% of costs) was expended by ocean dischargers as part of their compliance with National Pollutant Discharge Elimination System (NPDES) permit requirements. Federal programs (11 programs, 25% of samples, 10% of total expenditures) expended more than state or local government programs. More than one-quarter of monitoring expenditures were conducted to measure concentrations and mass of effluent inputs to the ocean. The largest effort expended on receiving water monitoring was for measuring bacteria, followed by sediments, fish/shellfish, water quality, and intertidal habitats.

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INTRODUCTION

Monitoring provides the foundation upon which managers base their decisions about the marine environment (NRC 1990a). Effluent monitoring is used to evaluate potential effects on the marine environment, with discharge concentrations compared to the water quality thresholds that trigger impacts to human health or aquatic life. Mass emission estimates are also derived from effluent monitoring to determine the largest contributors of contaminants to the marine habitat. Ambient monitoring is used to define the magnitude or extent of ecological impacts, such as habitat degradation or impairments to natural biotic communities. Additionally, each of these monitoring types is used to evaluate trends, allowing managers to assess whether environmental conditions are declining or whether previous management actions have been effective in improving conditions.

Numerous organizations conduct monitoring, but often on different spatial and temporal scales. State and federal government programs typically monitor environmental conditions to assess the overall health of large regions. In contrast, most municipal and industrial dischargers monitor to understand the effects their individual facility has on the local environment. Universities often monitor for yet a third goal, to understand the temporal cycles of natural phenomenon, such as oceanographic temperature or biological recruitment processes. These different types of monitoring programs are rarely coordinated.

Several national reviews of monitoring activities in the United States have called for the integration of monitoring programs to enhance their cost effectiveness (NRC 1990a; NSTC 1995, 1997). The first step in coordinating programs is to inventory the existing effort and identify areas that can achieve synergy through combined resources or shared data. The National Science and Technology Council (NSTC 1997) conducted such an inventory for that purpose, but it was limited to the effort expended by federal programs. An inventory that incorporates federal, state, local university, and private programs has not been conducted previously.

The Southern California Bight (SCB), a 500 km section of coastline from Point Conception, California, to the United States-Mexico international border, has one of highest coastal population densities in the country, and also has numerous coastal monitoring programs to assess the effects of this large population. The NRC (1990b) evaluated the monitoring programs being conducted in this area and found that few groups collaborated to enhance the effectiveness of their individual program, nor were data routinely shared among programs. The investigators found that, as a result, environmental managers were unable to develop an integrated assessment of the health of the southern California marine ecosystem or to produce the integrated information required to make informed decisions.

In this article, we present an inventory of monitoring activities in the SCB and address the following questions: (1) How many dollars are being spent annually on marine monitoring programs? (2) Which organizations are conducting the most monitoring effort? and (3) How are resources allocated among the different types of monitoring programs? The objective of this inventory and assessment is to quantify and define the monitoring programs of multiple organizations so that the information generated by each can be integrated into a sustainable monitoring program that is needed by local, regional, and national-level environmental managers.

METHODS

The inventory focused on long-term monitoring programs that met all of the following criteria: (1) programs that had been in existence (or were expected to have been in existence) for at least 10 years, (2) programs that collected samples at any time between 1994 and 1997, and (3) programs with data or reports that were publicly accessible. In addition, only those monitoring efforts within a selected program that were conducted in the following geographical areas were included in the inventory: (1) south of Pt. Conception, California, and north of the U.S./ Mexico international border; and (2) no farther inland than the head of tide and no farther offshore than the continental shelf (ca. 200 m depth).

Both effluent and receiving water monitoring programs were included in the inventory. Effluent monitoring included quantity and quality measures of discharges from municipal wastewater, industrial wastewater, power generating station wastewater, and municipal stormwater. Receiving water monitoring elements included water quality (primarily nutrients and plankton), physical water column structure (primarily conductivity temperature depth [CTD] casts), bacteria, sediments (chemistry and biota), rocky subtidal biota and kelp beds, intertidal habitats, and fish/shellfish programs (fish assemblage and bioaccumulation). Bird, mammal, and wetland monitoring programs were not included.

For each program, the number of stations sampled, frequency of sampling, number of replicates, analytical parameters and media, sampling methods, and analytical methods were documented. Information about discharger monitoring programs was obtained from the Regional Water Quality Control Board that issued the permit to the permittee, or from the permittee directly. Information about other programs was gathered through the examination of data sets and/or project reports, and was often augmented with interviews of the project managers.

Each program was classified according to whether it was conducted by a federal agency, state agency, local agency, university, or private sector or non-profit environmental organization. Some programs were difficult to categorize, particularly when a government agency funded the effort and a university or private contractor conducted the work. In these cases, the effort was classified based upon which organization was the final repository for the data obtained from the program.

Program effort was translated into annual cost estimates by multiplying the number of samples of each type by their unit cost for sample collection and analysis. Unit costs were obtained as the median value of at least three price quotes for each parameter obtained from local contractors. The field/laboratory costs were then doubled to account for program planning, database activities, data analysis, and report preparation. This approach compared costs across organizations and considered the large discrepancies in the ways that different organizations, particularly public organizations, accounted for their costs. For programs in which the number of sites, number of replicates, or frequency of sampling were not evenly distributed over multiple years, the effort expended in the years between 1994 and 1997 was averaged to obtain a representative single-year estimate. To assess the accuracy of the study methods, these cost estimates were compared with a few public agencies that use private contractors to implement their programs. In each case, the study cost estimate was within +/- 20% of the actual costs.

RESULTS

The study identified 114 marine monitoring programs conducted by 65 organizations in the SCB. These numbers included 81 programs conducted by ocean dischargers as part of their NPDES permit requirements, 11 federal programs, 4 state programs, 5 local government programs, 12 university programs, and 1 private program. These programs collect 244,917 samples annually (Table 1). More than 65% of these samples were collected by NPDES permittees while nearly 25% of the samples were collected by federal programs. State, local, university, and private programs combined collected 10% of the samples.

The largest number of samples (36%) was collected to assess bacteria concentrations, particularly along the shoreline (Table 1). Effluent (26%) and kelp bed/rocky subtidal (22%) samples were the next most frequent measurement types surveyed. None of the remaining types of monitoring programs accounted for as much as 5% of the total sampling effort.

There was an estimated $31.3 million spent annually on monitoring in the SCB (Table 2). The differences in cost among program types were even more disproportionate than differences in sampling effort. Nearly 70% of the cumulative annual budget allotted for monitoring was expended by NPDES permittees. Federal agencies contributed 10% and universities contributed 6% of the cumulative annual budget. Local and state governmental agencies combined spent less than 6% of the estimated total SCB monitoring budget.

Although NPDES programs spent the most money on monitoring in the SCB, large differences were found in expenditures between the different types of NPDES programs (Table 3). For example, $17.1 million was spent on monitoring by publicly owned treatment works (POTWs), with 60% of these monies spent by the four largest POTWs. Thermal dischargers were the only other group that accounted for more than 10% of the NPDES monitoring expenditures.

The amount of money expended on monitoring in the SCB differed among monitoring types (Table 2). The most money (28%) was spent on monitoring effluent. The second and third largest expenditures were for bacteria (24%) and sediment chemistry and infauna (13%) monitoring, respectively. Fish and shellfish monitoring accounted for 12% of the annual monitoring expenditures. All other monitoring types accounted for $\leq$ 6% of the annual budget.

Monitoring agencies invested their dollars differently among monitoring types (Table 2). For example, NPDES programs, which expended an estimated $24 million annually, invested most of their funds in monitoring effluents, bacteria, and sediments (37, 27, and 16% of total NPDES expenditures, respectively). The federal government, which expended $3.1 million annually, invested most of its funds in monitoring water quality, intertidal habitats, and kelp bed/rocky subtidal habitats (40, 23, and 22% of total federal expenditures, respectively). Universities and state governmental agencies invested the bulk (69%) of their combined $1.2 million in fish and shellfish monitoring. Local government invested the majority (78%) of their $0.6 million in bacteria monitoring.

TABLE 1. Number of annual samples collected in the Southern California Bight by the various types of monitoring agencies.

	Bacteria	CTD	Effluent	Eutrophication	Fish and Shellfish	Intake Screen	Intertidal	Kelp Beds/ Rocky Subtidal	Sediments	Water Quality	Total
Federal Government		36			4,296		1,696	53,728		205	59,961
Local Government	15,136	216		228	14				328	864	16,786
NPDES	71,895	3,367	62,744	2,808	3,714	84	48	382	7,059	8,831	160,933
Private Party								360			360
State Government					2,134				13	768	2,915
University	40	32		1,468	1,556		516	18		332	3,962
Total	87,071	3,651	62,744	4,504	11,714	84	2,260	54,488	7,400	11,000	244,917

CTD = Conductivity temperature depth.
NPDES = National Pollutant Discharge Elimination System

TABLE 2. Estimated annual costs for monitoring in the Southern California Bight by the various types of agencies.

	Cost ($1,000s)										
	Bacteria	CTD	Effluent	Eutrophi-cation	Fish and Shellfish	Intake Screen	Intertidal	Kelp Beds/ Rocky Subtidal	Sediments	Water Quality	Total
Federal Government		9			444		718	694	34	1,248	3,148
Local Government	995	63		49	17				85	65	1,274
NPDES	6,415	958	8,828	570	1,724	147	24	876	3,962	530	24,034
Private Party								394			394
State Government					505			19	7	15	547
University	4	8		277	1,183		291	106		13	1,883
Total	7,415	1,038	8,828	896	3,873	147	1,033	2,089	4,089	1,872	31,279

DISCUSSION

Although the amount of marine monitoring conducted in southern California is large, the estimates should be placed in perspective. Southern California is the most densely populated coastal area in the country, with 17 million people living within 50 miles of the ocean; thus, the $31 million annual monitoring expenditures estimated in the present study equate to less than $2 per person/year. Moreover, the annual estimate of monitoring costs is small in context of the operating budgets of the dischargers and of the regulatory agencies that oversee the dischargers. The annual operating budget of wastewater dischargers alone in southern California exceeds $1 billion.

TABLE 3. Cost of effluent and receiving water monitoring for various National Pollutant Discharge Elimination System (NPDES) permittees in the Southern California Bight.

	Cost ($1,000)		
	Effluent	Receiving Water	Total
Power Generating Stations	1,913	1,331	3,244
Industrials	586	157	743
Large POTWs	1,605	8,618	10,223
Platforms	278	0	278
Ship and Boatyards	290	800	1,090
Small POTWs	3,052	3,850	6,902
Stormwater	1,398	156	1,554
Total	9,122	14,912	24,034

The amount of ocean monitoring conducted in the SCB was split almost equally between two types of endpoints: public health and ecological health. However, the expenditures were not evenly apportioned among the indicators for these endpoints. For example, approximately four times more money was spent to address the management question, "Is it safe to swim?" compared to the management question, "Is it safe to eat the seafood?" Similarly, the money allocated to addressing the management question, "Is the ecosystem adequately protected?" was not evenly distributed among habitats or indicators. More than five times the expenditures were spent addressing contaminant levels in sediment compared to eutrophication measures in the water column. Perhaps this level of expenditure is appropriate in the SCB, where historical deposits of threatening pollutants are a greater risk to ecosystem integrity than plankton blooms (Schiff 2000, Conversi and McGowan 1994).

Most of the monitoring in the SCB was conducted by dischargers as requirements of their NPDES permits, but not all dischargers shared equally in the monitoring activity. The POTWs incurred nearly 80% of the ocean monitoring costs expended by NPDES permittees. This finding is consistent with the historical pattern of discharge, in which sewage treatment plants discharged 90% of mass emissions (Raco-Rands 1999). However, increased treatment, pretreatment, reclamation, and source control have considerably reduced the mass emissions from POTWs over the last three decades. Currently, stormwater mass emissions are larger than the mass emissions from POTWs for many constituents (Schiff et *al*. 1999). Despite this trend, NPDES permittees for urban stormwater discharges conducted little or no ocean monitoring for either public health or ecosystem impacts.

In its review of federal programs, the National Science and Technology Council (NSTC 1995) found that more than $200 million is spent annually on marine monitoring and research nationally. In contrast, we found that federal programs spent only an estimated $3.1 million annually on monitoring in the SCB. This low percentage partially reflects our definition of monitoring, which included only sustained programs and precluded many shorter term research activities included in the NSTC estimate. Still, federal expenditures in the SCB were small in comparison to the economic and environmental importance of the southern California coast; 25% of the U.S. population living within 50 miles of the coast resides in southern California (Culliton *et al.* 1990) and more than 50% of the beachgoer-days in the country take place in this area (Schiff *et al.* 2001). Some of this disparity may reflect differences in national versus regional priorities. For example, recent national ecosystem initiatives at the federal level focus on harmful algal blooms (Turgeon *et al.* 1998) and coral reefs, which are not important issues along the southern California coast. In contrast, federal agencies do not participate in bacteria monitoring, which is a high priority at the local level.

The much larger investment of resources in marine monitoring by local agencies suggests the desirability for federal programs to leverage their effort through integration with local programs, a strategy endorsed by the federal Clean Water Action Plan (Coastal Research and Monitoring Strategy Workgroup 2000). In some cases, this goal can be accomplished through cost sharing, although the exchange of funds is not the only means of integration. For example, the National Oceanic and Atmospheric Administration's (NOAA's) Status and Trends Program has developed a national laboratory intercalibration program that has enhanced consistency in sediment and fish tissue chemistry measurements (Cantillo and Lauenstein 1993). The Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program has provided assistance in developing local sampling designs that can be integrated with its national design (Stevens 1997). Neither of these efforts requires a great degree of coordination, but both approaches facilitate integration of data sets for larger scale assessments.

The most significant barrier to the integration of federal and local programs is the difference in their overall missions; local programs are typically conducted on a smaller spatial scale to address site-specific issues. However, significant precedents have been established that could break down this barrier as federal compliance programs are increasingly being redirected towards regional assessment. For example, funding for the Chesapeake Bay Benthic Monitoring Program in Maryland is derived from the integration of the federal baywide program with a state program to monitor the effects of power plants. Another example is the Southern California Bight 1998 Regional Monitoring Program, in which 62 organizations pooled their efforts to achieve a $7 million regional assessment of fish, sediment, and water quality, funded almost entirely through redirection of local compliance monitoring (Hashimoto and Weisberg 1998). Moreover, almost all compliance monitoring programs measure trends at unimpacted reference sites for comparison with potentially impacted sites. Some of the most comprehensive long-term data records in this country, such as those for Hudson River fisheries (Barnthouse *et al.* 1988) and California continental shelf benthos (Zmarzly *et al.* 1994, Stull 1995) have resulted from the integration of such compliance-based programs.

LITERATURE CITED

Barnthouse, L.W., R.J. Klauda, D.S. Vaughan and R.L. Kendall (eds.). 1988. Science, Law and Hudson River Power Plants: A Case Study in Environmental Impact Assessment. American Fisheries Society Monograph 4. Bethesda, MD.

Cantillo, A.Y. and G. G. Lauenstein. 1993. Performance based quality assurance of the NOAA National Status and Trends Project. pp. 34-43 *in:* M. Parkany (ed.), Quality Assurance for Analytical Laboratories. The Royal Society of Chemistry. Wiltshire, UK.

Coastal Research and Monitoring Strategy Workgroup. 2000. Coastal Water Action Plan: Coastal Research and Monitoring Strategy. U.S. Environmental Protection Agency. Washington, DC.

Conversi and McGowan. 1994. Natural versus human-caused variability of water clarity in the Southern California Bight. *Limnology and Oceanography* 39:632-648.

Culliton, T., M. Warren, T. Goodspeed, D. Remer, C. Blackwell and J. McDonough II. 1990. 50 years of population changes along the nation's coast. Coastal Trends Series, Report No. 2. National Oceanic and Atmospheric Administration, Strategic Assessments Branch. Rockville, MD.

Hashimoto, J. and S.B. Weisberg. 1998. Coordinating site-specific NPDES monitoring to achieve regional monitoring in southern California. pp. 41-48 *in:* Monitoring: Critical Foundations to Protect Our Waters, Proceedings of the National Water Quality Monitoring Council Conference, Reno, NV. U.S. Environmental Protection Agency. Washington, DC.

National Research Council (NRC). 1990a. Managing Troubled Waters, the Role of Marine Environmental Monitoring. National Academy Press. Washington, DC.

National Research Council (NRC). 1990b. Monitoring Southern California's Coastal Waters. National Academy Press. Washington, DC.

National Science and Technology Council (NSTC). 1995. Setting a New Course for US Coastal Ocean Science. NOAA Coastal Ocean Office. Silver Spring, MD.

National Science and Technology Council (NSTC). 1997. Integrating the Nation's Environmental Monitoring and Research Networks and Programs. NOAA Coastal Ocean Office. Silver Spring, MD.

Raco-Rands, V. 1999. Characteristics of large municipal wastewater treatment facilities in 1997. pp. 10-20 *in:* S. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1997-1998. Westminster, CA.

Schiff, K. 1997. Review of existing stormwater monitoring programs for estimating bight-wide mass emissions from urban runoff. pp. 44-55 *in*: S. Weisberg, C. Francisco, and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1995-1996. Westminster, CA.

Schiff, K.C., S.B. Weisberg and J.H. Dorsey. 2001. Microbiological monitoring of marine recreational waters in southern California. *Environmental Management* 27:149-157.

Stevens, D.L. 1997. Variable density grid-based sampling designs for continuous spatial populations. *Environmetrics* 8:167-195.

Stull, J. 1995. Two decades of biological monitoring, Palos Verdes, California, 1972 to 1992. *Bulletin of the Southern California Academy of Sciences* 94:21-45.

Turgeon, D.D., K.G. Sellner, D. Scavia and D. Anderson. 1998. Status of U.S. Harmful Algal Blooms: Progress Toward a National Program. National Oceanographic and Atmospheric Administration. Silver Springs, MD.

Zmarzly, D.L., T.D. Stebbins, D. Pasko, R.M. Duggan and K.L. Barwick. 1994. Spatial patterns and temporal succession in soft-bottom macroinvertebrate assemblages surrounding an ocean outfall on the southern San Diego shelf: Relation to anthropogenic and natural events. *Marine Biology* 118:293-307.

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