The Southern California Bight Pilot Project: Sampling Design

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A general description of the Southern California Bight Pilot Project (SCBPP) is provided in the *Southern California Bight Pilot Project: An Overview* (in this annual report). It describes the justification for the Project, the basic elements of the sampling design, and the project management used to implement the program. This paper will provide a detailed description of the sampling design used for the SCBPP.

SAMPLING DESIGN

The Steering Committee used the conceptual framework of the United States Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) (Overton *et al.* 1990, Stevens 1994) to design the SCBPP survey. EMAP sampling is based on a randomly-placed, triangular grid of points covering the contiguous United States and associated coastal waters. The interpoint distance for the EMAP grid is approximately 27 km (White *et al.* 1992); however, the grid spacing can be adjusted as needed for a particular sampling design. Use of the triangular grid ensures that sample points are well-distributed over the study area. Moreover, the explicit spatial basis of the design ensures that each sampling point represents a known area, so that it is possible to estimate the amount of area with a particular characteristic, e.g., the area with total organic carbon (TOC) greater than 2%. Random placement of the grid and random selection of sampling points provides randomness needed for statistical inference.

To assure a sufficient sample size, the Southern California Bight (SCB) was divided into subpopulations of interest (Figure 1, Table 1), including three geographic zones; three depth zones; the areas around the four largest municipal wastewater outfalls, treated cumulatively; the areas within 3 km of the 11 largest rivers (excluding the Los Angeles River which discharges into Long Beach Harbor) and stormdrains, treated cumulatively; Santa Monica Bay; and the area around the Hyperion Treatment Plant (HTP) outfall. The goal was to have at least 40 samples per subpopulation.

The areas around the municipal wastewater outfalls and the rivers and storm drains were chosen as subpopulations to allow assessment of ecological changes near point and nonpoint discharges, respectively. The geographic and depth subpopulations were chosen because nonpoint sources are more likely to affect shallow areas and point sources are more likely to affect deeper areas in the central Bight. In addition, the Steering Committee expected benthic infaunal and demersal fish assemblages to vary with latitude and depth. Santa Monica Bay and the area around the HTP 5-mile outfall were chosen to enhance sampling density so that data from the SCBPP could be compared to data collected by the City of Los Angeles in their fixed-station monitoring.

The dividing lines for the geographic and depth zones were chosen using the Committee's collective knowledge of invertebrate and fish distributions in the SCB. The circles around the rivers and storm drains were drawn using a 3-km radius. Since there is no information about the impacts of nonpoint discharges on demersal fish or benthic infaunal asssemblages in Southern California, this distance was chosen arbitrarily.

Except for the HTP outfall, the areas around the outfalls were delineated by drawing a line around the sampling grid that is currently used to monitor each outfall. Since the monitoring program includes all of Santa Monica Bay, the HTP sampling grid was not used to delineate the HTP outfall area. This was because the Steering Committee wanted to distinguish between the outfall area and the rest of Santa Monica Bay. In addition they wanted to enhance the sampling effort around the outfall to allow for a comparison between the SCBPP data and HTP monitoring data. Therefore, monitoring data was used to delineate an area that included stations that were

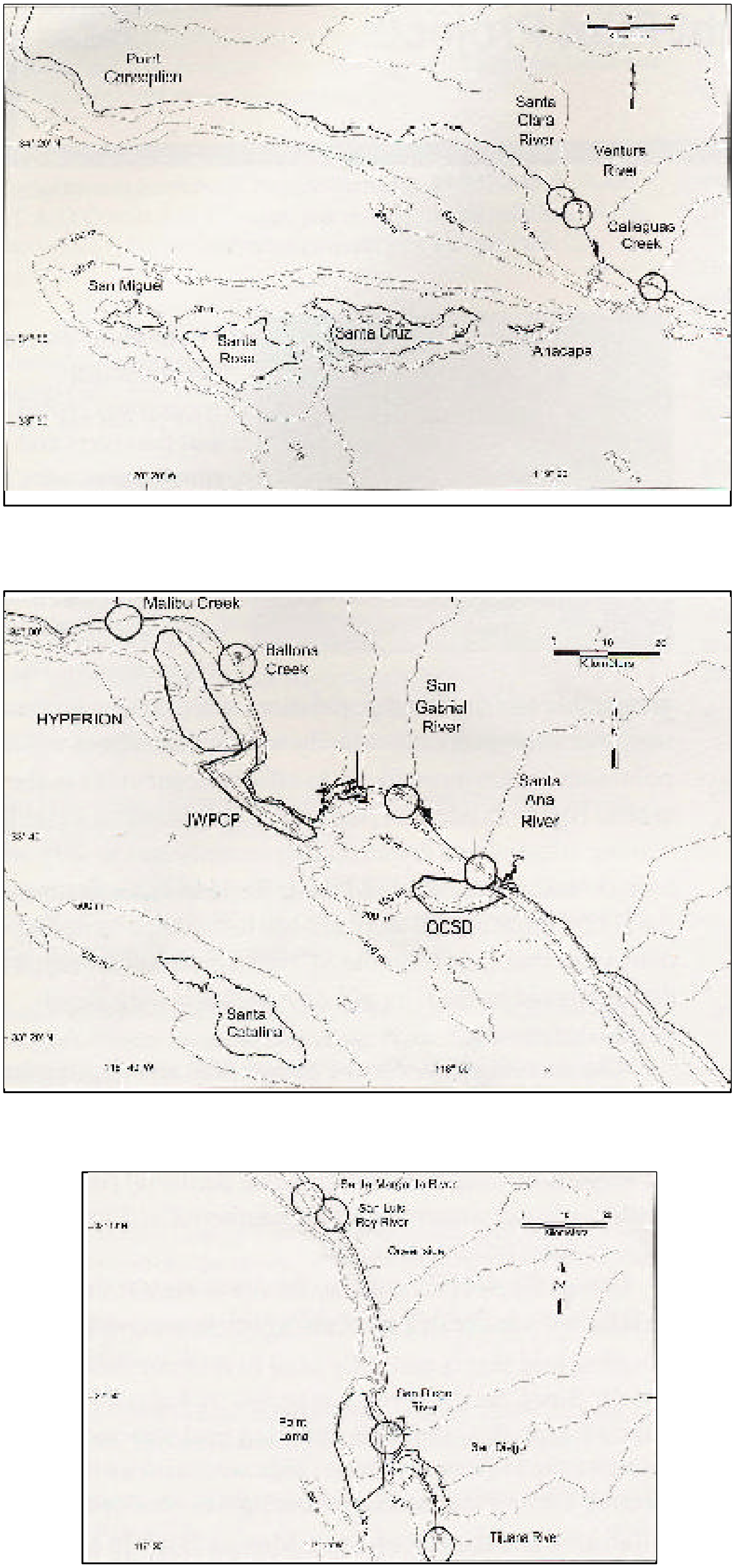

FIGURE 1. River and outfall subpopulation areas for the Southern California Bight Pilot Project survey, July - August 1994.

shown to be impacted by the HTP outfall in the winter of 1989 (CLAEMD 1990).

For the assessment, the Committee chose 12 indicators of ecological health, including four measures of water quality (dissolved oxygen, temperature, salinity, and transmissivity), benthic infauna, epibenthic macroinvertebrate and demersal fish assemblages, sediment characteristics, including contamination, sediment toxicity, external fish pathology and bioaccumulation, and marine debris.

The assessment period was targeted for summer (July-August) since populations of demersal fish and benthic infauna are expected to be more stable in summer than in winter or spring, and sampling is less likely to be interrupted by bad weather. In addition summer sampling corresponds to the “index period” used in the EMAP program.

Due to financial and logistical constraints, it was not possible to collect enough samples to characterize all indicators in all subpopulations. Given available resources, it was possible to take enough trawls to characterize fish assemblages, fish pathology, and marine debris in the three geographic zones, three depth zones, and cumulative outfall areas. Sediment toxicity and fish tissue contamination were characterized for the cumulative outfall areas and for the SCB as a whole. Water quality, sediment characteristics and benthic invertebrate assemblages were characterized for all subpopulations.

STATION SELECTION

The stations to be sampled were chosen using a modification of the sampling protocol used by EMAP for estuaries in the Louisianan province (Summers *et al.* 1993). First, to have enough grid points to produce approximately 40 stations per subpopulation, the EMAP grid was enhanced 7x7x7 fold. Then, stations were selected by a process that involved (1) randomization of the grid points, (2) random selection of grid points, and (3) random placement of a sampling point around each grid point.

The grid points were randomized using a process that produced an optimum spatial spread of samples, while retaining the randomness needed for statistical evaluation. To do this, each point in the grid was given a number and spatial address. The spatial address preserved information about the original location of the point. The numbering was in groups of seven and of powers of seven. Grid points were then completely randomized within the smallest

TABLE 1. Subpopulations of interest in the SCBPP. Subpopulations are defined in detail in the text.

1. Geographic zones:
    - Northern - Point Conception to Point Dume
    - Central - Point Dume to Dana Point
    - Southern - Dana Point to the U.S.-Mexico border
2. Depth zones:
    - Shallow (Inner shelf) - 10-25m
    - Mid-depth (Middle shelf) - 26-100m
    - Deep (Outer shelf) - 101-200m
3. The areas around the outfalls of the four largest municipal wastewater outfalls treated cumulatively.
4. The areas within 3 km of the following 11 largest rivers[a] and storm drains treated cumulatively:
    - Ventura River
    - Santa Clara River
    - Calleguas Creek
    - Malibu Creek
    - Ballona Creek
    - San Gabriel River
    - Santa Ana River
    - Santa Margarita River
    - San Luis Rey River
    - San Diego River
    - Tijuana River
5. Santa Monica Bay
6. The area around City of Los Angeles Hyperion Treatment plant 5-mile outfall.

[a]Los Angeles River (the largest river) was excluded because it discharged into Long Beach Harbor.

group, and the groups were randomized within the next larger group. In this way the order of points was randomized but geographically adjacent points remained close to each other during randomization.

To select grid points for benthic and water quality sampling from the total population of grid points, each grid point (in random order) was assigned an inclusion probability based on the number of samples needed in the area in which the point was located. For instance, grid points in the river discharge areas were given larger inclusion probabilities than points in nondischarge areas because more samples per unit area were needed. To choose the first grid point, the inclusion probabilities were sequentially summed, starting with the first point, until the cumulative probability was greater than or equal to one. Then a point was randomly chosen from the group of points with a cumulative probability of one or less. Subsequent grid points were chosen by adding 1 to the first randomly chosen probability (= r) and the number of points selected (i.e., grid points were selected at r + 1, r + 2, etc.).

To select grid points for the trawl sampling, which would only be analyzed for depth, geographic, and outfall subpopulations, the same procedure was used; however, the selection process included only the grid points selected for benthic and water quality sampling. Finally, the stations to be sampled for sediment toxicity and tissue analysis were selected from the grid points chosen for trawling.

SAMPLING LOGISTICS

Five organizations were responsible for collecting samples: City of Los Angeles, Environmental Monitoring Division; City of San Diego, Metropolitan Wastewater Department, County Sanitation Districts of Los Angeles County; County Sanitation Districts of Orange County; and the Southern California Coastal Water Research Project (SCCWRP). The number of samples was based on the number of samples each agency collects in the summer quarter. Due to institutional restraints, such as insurance and travel restrictions, it was necessary to divide the sampling effort geographically. South of Point Dume, lines were drawn to divide the area into sample areas. Each agency sampled the geographic area that included their monitoring grid. SCCWRP, through contracts to MEC Analytical Systems, Inc., and MBC Applied Environmental Sciences, sampled the area north of Point Dume.

Between July 11 and August 22, 1994, water quality profiles were taken at 261 stations, benthic grab samples were taken at 252 stations, and trawls were taken at 114 stations. Since the participating organizations have separate field crews for each type of sampling, each station was sampled three times: once with a conductivity-temperature-depth profiler (CTD), once with a Van Veen grab sampler, and once with a otter trawl.

QUALITY ASSURANCE AND QUALITY CONTROL

Since five agencies were involved with sample collection and analysis, procedures for intercalibration and quality assurance/quality control (QA/QC) were of paramount importance. A field coordination team agreed on standard methods for collecting field samples and prepared a field operations manual for the survey (SCBPP, FCT 1994). The manual provided detailed descriptions of all procedures for sample collection and field analyses, including detailed QA/QC procedures and criteria.

Because methodologies (including instrumentation) differ widely among laboratories, the Committee opted to undertake a performance-based approach for sediment chemistry. The Committee envisioned a two-step process for implementing performance-based standards for laboratory analyses. In the first step, the laboratory would demonstrate the ability to perform the analyses by providing documentation about the procedure to be used, including documentation of the method detection limits and calibration curves, and by blind analysis of a known sample. Following successful performance in the first phase, the laboratory would continue to demonstrate performance by participation in interlaboratory intercalibration exercises, repeated analyses of Certified

Reference Materials, calibration checks, and analyses of laboratory reagent blanks and fortified samples.

Intercalibration procedures for sorting and identification of specimens for benthic samples were developed by the specialty group for benthic sampling. Measurement Quality Objectives (MQOs), procedures for redressing problems, and standard reporting requirements were established for each stage of processing. Considerable effort was taken to ensure taxonomic consistency between the laboratories. Workshops under the auspices of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) were held every two to four weeks to examine infaunal specimens and discuss taxonomic problems.

DATA ANALYSIS AND INTERPRETATION

The sampling design is structured so that the extent and magnitude of change can be compared across subpopulations; that is, the areal extent of some parameter (e.g., toxicity) can be compared in the north, central, and southern zones or in outfall and nonoutfall areas. It is also possible to compare parameters, e.g., the spatial extent of toxicity and sediment with DDT higher than 3 ppb.

Determining the areal extent is a two-step process. First, the Horvitz -Thompson estimation (Cochran 1977) is used to develop a cumulative distribution function (CDF) from the area-weighted data (Appendix 1). The CDF shows the range of indicator values of an indicator as well as information about central tendency and extreme values. Then a threshold value is selected. The threshold value divides natural and changed values. Based on the threshold value, the percent area exceeding the threshold can be estimated.

The process of selecting a threshold value will be simple for some indicators and more difficult for others. For toxicity, the threshold can be set at the point where there is a statistically significant change in an experimental endpoint. For some sediment contaminants (e.g., silver), the thresholds can be chosen from estimates of the concentration of the compound expected to cause toxicity (Long and Morgan 1990). However, for a compound such as TOC, there is no definitive method to determine a threshold between natural and unnatural values. Regression analysis can be used to identify stations with higher than expected concentrations (Bergen *et al*. 1995, Daskalakis and O'Connor 1995). Then the sediment chemistry data along with data from other sources can be used to determine if increased concentrations are associated with anthropogenic activities. For demersal fish and benthic infaunal assemblages, the threshold will be based on an index (one for fish and one for infauna) that summarizes changes in community parameters, such as number of species and number of individuals. If the absolute value of the threshold is not clear, the Steering Committee will use all the available information to select a threshold.

SUMMARY

The SCBPP is a cooperative sampling effort intended to provide synoptic information about the ecological condition of the mainland shelf of Southern California.

The sampling design was based on a design developed by USEPA EMAP. Sampling points were chosen by random placement of a grid of points over the sampling area, followed by random selection of grid points and random placement of stations around the grid points. The grid ensured that the sampling effort was well distributed over the study area while the random placement of the grid and random selection of sampling stations provided randomness needed for statistical inference. Moreover, since the interpoint distance of the grid was known, each sampling point represents a known area so that the amount of area with a particular characteristic, e.g., the area with total organic carbon greater than 2%, can be estimated.

The sampling was designed for assessing ecological conditions in three geographic zones, three depth zones, the areas around the four largest municipal wastewater outfalls (treated cumulatively), the areas within 3 km of 11 rivers and stormdrains (treated cumulatively), Santa Monica Bay, and the area around the HTP outfall. The assessment of ecological condition will be based on measures of water quality, demersal fish and benthic infaunal assemblages, sediment characteristics, sediment toxicity, fish pathology and bioaccumulation, and marine debris.

The extent and magnitude of change between subpopulations will be measured by (1) developing a cumulative distribution function for a parameter and (2) selecting a threshold value to divide natural from changed. Then the percent area that has been changed will be estimated.

Analysis of data is in progress. Survey results will be presented in a series of reports, including an assessment of ecological conditions on the Southern California mainland shelf and an evaluation of the SCBPP survey design.

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APPENDIX 1.

The Cumulative Distribution Function

A cumulative distribution function (CDF) is the progressive summation of a distribution function. A distribution function presents the amount (e.g., frequency, percent of population, percent of area) for each category of a variable. The CDF presents the cumulative total (e.g., total percent area) for each category of a variable. This allows the determination of the amount of the distribution equal to or less than the category. Sokal and Rohlf (1995) describe the distribution function and cumulative distribution function for a normal distribution. For the SCBPP, the distribution function is the percent of the area of the SCB or of one of the subpopulations for the category of the variable; for instance, it is the percent of area with DDE of 10 ppb, 20 ppb, ... up to the maximum measured. The CDF shows the percent of area with DDE equal to or less than 10 ppb, 20 ppb, etc.

In the SCBPP survey, because some areas (e.g., around the HTP outfall) were more intensively sampled than others, the number of points per unit area and the amount of area that the points represent varies. Therefore, the area weight, (i.e., the amount of area represented by the point) must be used to calculate the CDF. The CDF for parameter value x (e.g., DDE = 30 ppb) is the sum of the area weights for observations with values equal to or less than x divided by the sum of all the area weights in the population or:

$$cdf_x = \frac{\sum_{i=1}^{x} areawt_i}{\sum_{i=1}^{n} areawt_i}$$

where:

where:	cdf_x	=	estimate of CDF for parameter value x (e.g., DDE = 40 ppb)
	$areawt_i$	=	area weight for parameter value x
	n	=	total number of observations
	x	=	parameter value