

SANTA MONICA BAY MAPPING PROJECT
(SMBMP)

**Final Report
and
GIS User's Guide**

Dr. Rikk G. Kvitek
Tania M. Leisten
Pat J. Iampietro
Carrie K. Bretz

Seafloor Mapping Lab
Institute for Earth Systems Science & Policy
California State University Monterey Bay, 100 Campus Center, Seaside, Ca 93955

Sponsored by:
Santa Monica Bay Restoration Project
320 W. Fourth Street, 2nd Floor
Los Angeles, CA 9001

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PROJECT DESCRIPTION

Project Summary

The goals of the *Santa Monica Bay Mapping Project (SMBMP)* were to create a high-resolution basemap of seafloor habitats within the Santa Monica Bay nearshore environment (~0-50m water depth), and where appropriate to determine the depths of sediment covering rocky substrate that historically supported kelp forests. Since this work mapped the locations of natural substrates suitable for kelp forest and rockfish replenishment within the nearshore region of Santa Monica Bay, the results will be critical to the design and success of restoration programs targeting these species.

The Geographic Information System (GIS) products presented here are the result of two hydrographic surveys conducted by the California State University Monterey Bay (CSUMB) Seafloor Mapping Lab (SFML) during summer 2001 and spring 2002. The surveys covered two study areas totaling 30 miles of Santa Monica Bay coastline, including the north shore from Pt. Dume to Topanga Canyon, and the Palos Verdes Peninsula from Malaga Cove¹ to Pt. Fermin (Fig. 1). The mapping methods included acoustic remote sensing (multibeam, sidescan sonar and sub-bottom profiling), sediment sampling, and underwater video surveys for ground truthing the acoustic results. These data sets were combined with public domain results from deeper water hydrographic surveys conducted by the U.S. Geological Survey (USGS) and historic kelp cover information from the California Department of Fish and Game to present the most complete characterization to date of Santa Monica Bay marine habitats.

Scientific Objective

Extensive development and erosion of coastal watersheds have long been suspected of negatively impacting coastal marine habitats. The scientific objective of this study was to provide evidence for the evaluation of the hypothesis that the dramatic declines in kelp forests of Santa Monica Bay (SMB), California, might be attributed, in part, to sediment deposition and the resultant loss of near shore rocky habitat. GIS tools were used to compare kelp coverage from 1893, 1912, 1989 and 1999 SMB surveys to identify areas of significant kelp loss over time. The current distribution of rocky habitat was determined using acoustic remote sensing (multibeam bathymetry, sidescan sonar, and sub-bottom profiling) and video substrate verification. These data were used to determine whether or not rocky habitat capable of supporting kelp was still present within the areas of kelp loss or if it had been lost due to sedimentation.

Results and Conclusions

Results confirmed extensive kelp loss within the study area (Fig. 2). Kelp loss was calculated in two ways: within the area of historic kelp coverage only (Fig 3) and throughout the current and historic coverage area (Fig. 4). Both methods gave comparable results, with the exception of a net gain (“negative loss”) of kelp cover in unsurveyed areas using the latter method (Fig. 4). Most of the kelp losses occurred over what is now buried or degraded (sediment "dusted") rocky habitat, suggesting that watershed erosion and sediment runoff may have been factors

¹ The project was not originally budgeted to include Malaga Cove. The Santa Monica Bay Restoration Project Technical Advisory Committee requested that CSUMB include Malaga Cove in the Palos Verdes Peninsula survey area. To accommodate this request for additional survey and processing time, some of the originally planned data collection and analyses on temporal habitat variation were not included.

contributing to both habitat and kelp loss. The conditions of other former kelp areas along the north coast suggest that there has been a decline in large boulder material that once entered the bay via the watershed drainages providing suitable substrate for kelp recruitment. Along the Palos Verdes Peninsula (PVP), however, much of the kelp loss has occurred in deeper water (15 - 30 m water depth) over what is still very clean and exposed rocky substrate, suggesting factors other than loss of available rocky habitat, e.g. water clarity and quality. Other areas of SMB kelp loss are associated with sites where there is no evidence of there ever having been rocky habitat, suggesting that the missing kelp once grew directly on the sediment surface or attached to biogenic substrates (e.g. worm tubes) that are no longer present. All quantitative and geospatial data collected and produced for this project are available and provided here in GIS format on a DVD ROM disk. A detailed description of the data and the GIS products are given below in the SMBMP GIS User's Guide. Following is a description of the methodologies and techniques employed.

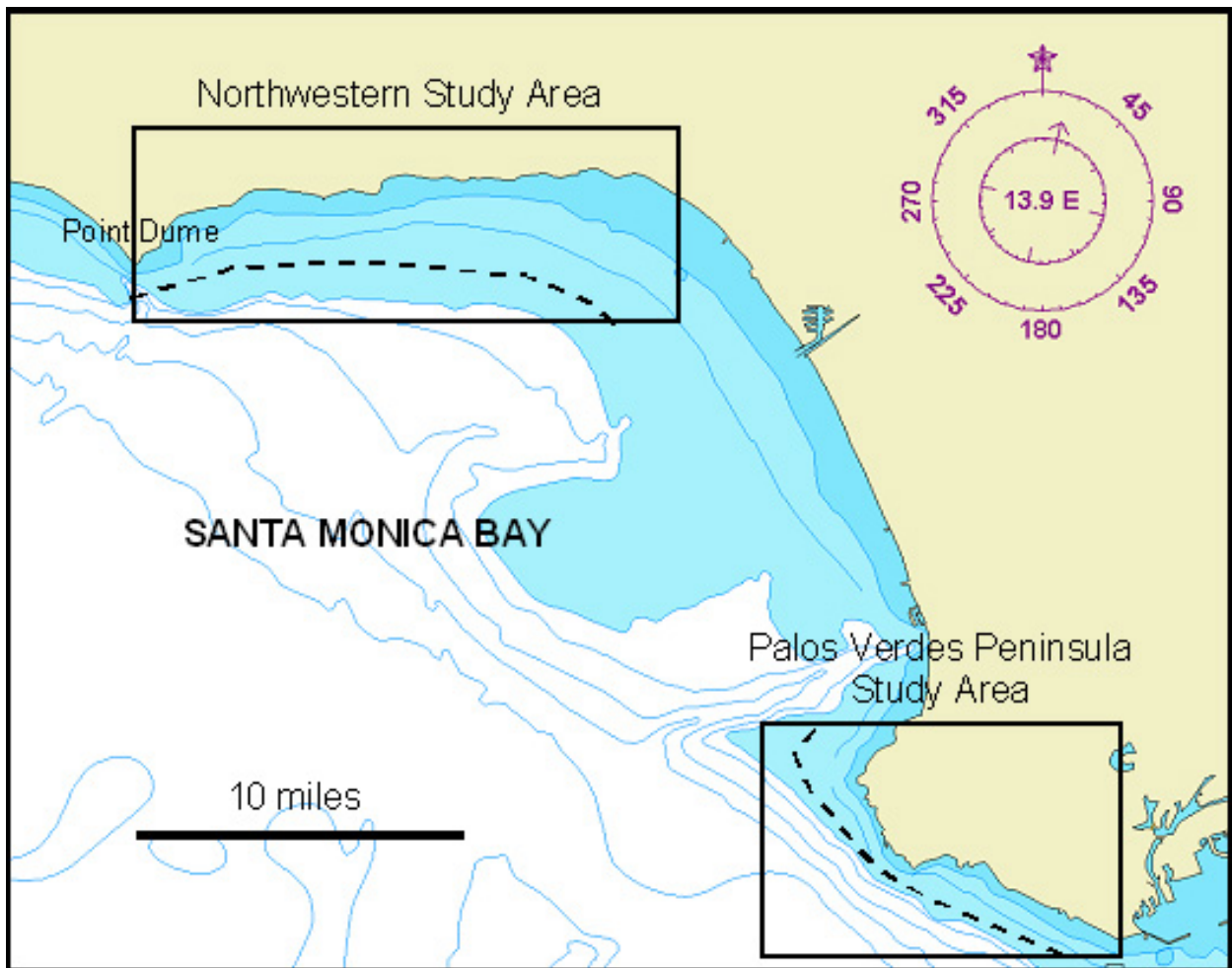


Figure 1. Regional map showing the two approximate SMBMP survey areas along the northwestern shore and Palos Verdes Peninsula of Santa Monica Bay. Actual survey areas extended from the shore out to the shallowest extent of USGS Santa Monica Bay hydrographic data (indicated by the dashed line).

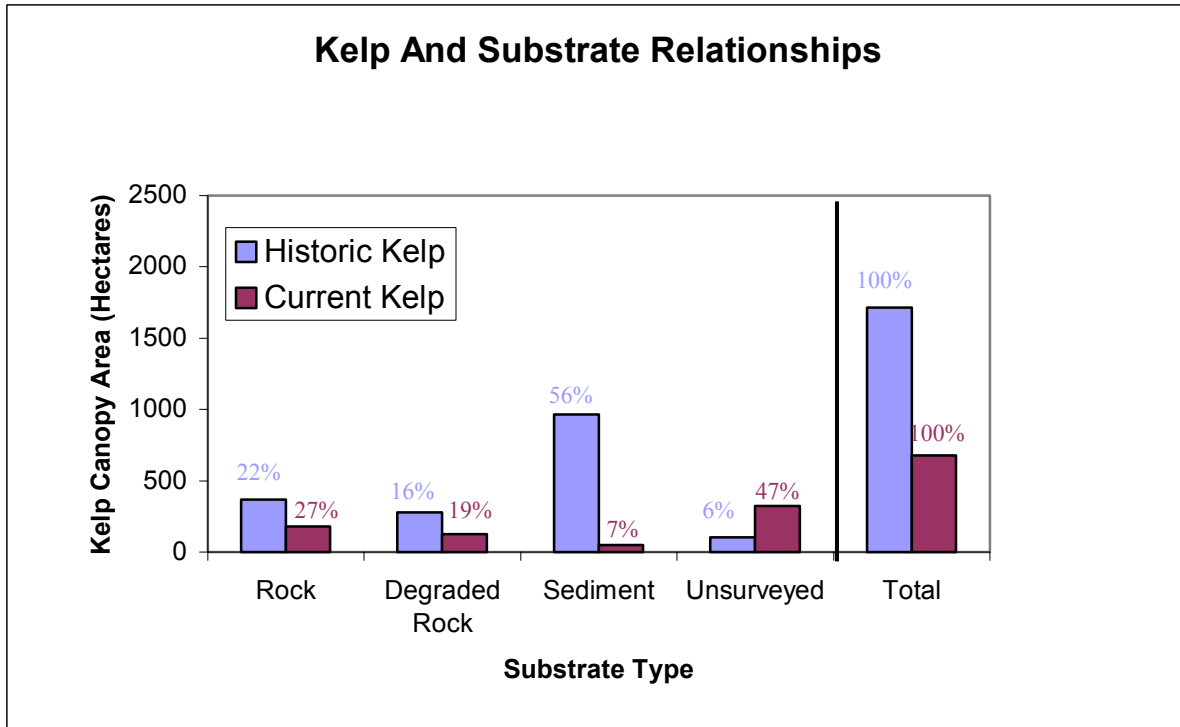


Figure 2 Historic and current kelp canopy area over four different present-day substrate types (rock, degraded rock, sediment, and unsurveyed) in the SMBMP study site. Substrate types interpreted from acoustic and other survey data collected for this study. Unsurveyed areas were either too shallow or had kelp canopy so dense it precluded multibeam data collection. Values associated with each bar denote percentages of kelp found on each substrate during the given time period (historic or current)

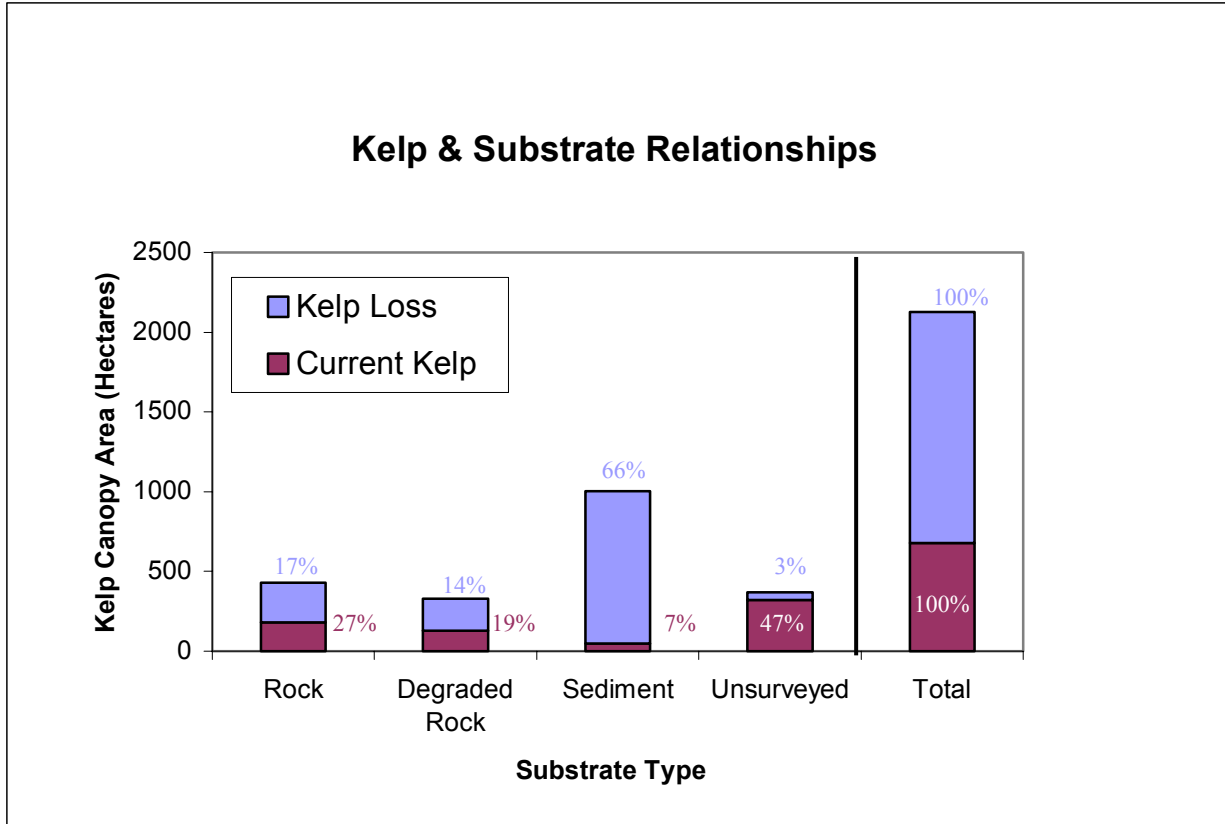


Figure 3 Kelp loss and current kelp canopy area over four different present-day substrate types (rock, degraded rock, sediment, and unsurveyed) in the SMBMP study site. Substrate types interpreted from acoustic and other survey data collected for this study. Unsurveyed areas were either too shallow or had kelp canopy so dense it precluded multibeam data collection. Kelp loss calculated within historic kelp areas only for this analysis. Total height of each bar indicates historic plus current kelp coverage. Values associated with each bar denote percentages of kelp found on each substrate during the given time period (historic or current)

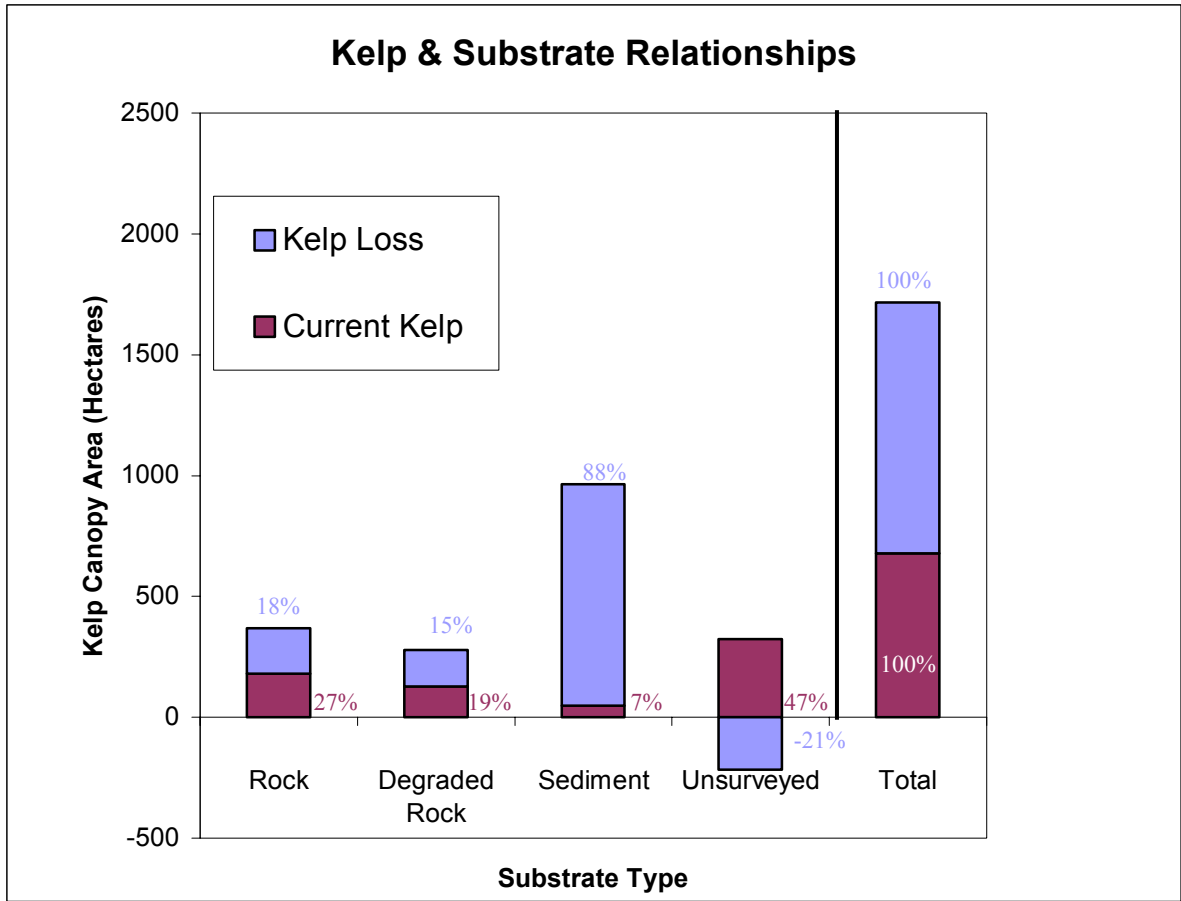


Figure 4 Kelp loss and current kelp canopy area over four different present-day substrate types (rock, degraded rock, sediment, and unsurveyed) in the SMBMP study site. Substrate types interpreted from acoustic and other survey data collected for this study. Unsurveyed areas were either too shallow or had kelp canopy so dense it precluded multibeam data collection. Kelp loss calculated using net change in total kelp coverage (historic minus current) for this analysis. Total height of each bar indicates historic plus current kelp coverage. Values associated with each bar denote percentages of kelp found on each substrate during the given time period (historic or current)

Project Methodology

Kelp Loss

The ESRI software program ArcGIS® 8 was used to compare kelp cover results from 1893, 1912, 1989 and 1999 surveys to identify areas of significant kelp loss in the Santa Monica Bay over time. These data were obtained from historic National Oceanographic and Atmospheric Administration (NOAA) charts and the California Department of Fish and Game (CDFG). The kelp layers were combined into two categories: historical kelp data (1893 and 1912) and current kelp data (1989 and 1999), illustrating the maximal extents of kelp within those time periods. The current kelp data (1989/1999) obtained from DFG was in the form of shape files. The historical kelp data (1893/1912) obtained in the form of a gray scale raster image was georeferenced in ArcGIS® 8. Kelp polygons were then traced from the raster image and saved

as shape files. Polygons from the historical and current kelp data were subtracted to form polygons that represented areas of kelp loss.

The current and kelp loss polygons were separated by study site (Malibu and Palos Verdes Peninsula). Area and percent loss was calculated within ArcGIS® 8 for each study site (Figs. 2 and 3).

Multibeam Sonar Data Collection

All multibeam bathymetry and sidescan sonar data was collected using the Seafloor Mapping Lab's Reson 8101 sonar system from aboard the 27ft R/V MacGinitie. All data was collected in full compliance with NOS and FGDC data standards and protocols. A Reson 8101 with sidescan sonar option was used in conjunction with a Triton-Elics Isis System for data logging and sonar control, along with Delphmap and BathyPro software for real-time sidescan mosaicking and DEM generation. Vessel motion correction was performed using a TSS POS/MV (pitch, roll and heading accuracy $\pm 0.02^\circ$, heave accuracy $\pm 5\%$ or 5cm). Survey planning and navigation was done with Hypack Max from Coastal Oceanographics and a Trimble Navigation 4700 GPS with Probeacon and internal radio for DGPS horizontal positioning. Tidal correction of multibeam data was done using NOAA predicted tidal height values from Tides and Currents software (Nobeltech, Inc). Sound velocity profile data was collected with an Applied Microsystems SVPlus sound velocimeter.

Ground Truthing Acoustic Results

Ground truthing of the real-time sidescan sonar mosaic was done following the completion of the acoustic survey in each study area using a Petite PONAR sediment grab fitted with a SplashCam video drop camera. Sediment grain size analysis (40 μm – 2 cm) was done with a Micromeritics Optisizer 5400 PSDA, and nested screens (see below). Video data was recorded on a JVC mini-DV digital video tape deck equipped with a Horita GPS-3 interface for stamping each frame with time and GPS position.

The video footage was collected at sites selected along preplanned transects that crossed areas of multiple types of substrate. Transect locations were selected using the seafloor DEMs and kelp coverage maps.

Video analysis was accomplished by haphazardly selecting still frames of the video footage from each camera drop/sediment grab. An attempt was made to select still frames showing the best possible view of the substrate; generally frames were selected from video footage recorded while the camera & sediment grab were held just above the substrate prior to contact with the seafloor and performing the sediment grab. Each still frame was hyperlinked to the drop points within ArcGIS® 8, which were used to analyze the substrate within the study areas. The sediment grab sample grain size data was processed using wet & dry sieve methods. Wet sieve analysis was used to separate the fine (< 63 μm) fraction and dry sieve analysis for the coarse fraction, yielding an overall frequency histogram for particle size fractions from silt/clay through gravel. Folk & Ward parameters, such as sorting and skewness, were calculated as well. The techniques used were a modification of those described in Folk, R. L., Petrology of Sedimentary Rocks. Hemphill Pub. Co., Austin, Texas, 1974. 182p. Results were exported as a table that was incorporated into the drop point shapefile within the ArcMap 3.x and ArcGIS® 8.2 projects.

Acoustic Data Processing

Initial post-processing of the raw XTF files for multibeam was done with CARIS HIPS® 5.1, and Isis Sonar was used for post-processing the original sidescan sonar. Final xyz grids for ArcGIS® were created using Fledermaus 3-D visualization software (IVS, Ltd).

Habitat Interpretations and Classifications

Using ArcGIS® 8, final products for each study site (Malibu and Palos Verdes Peninsula) were created which included a high-resolution (2m) DEM, habitat raster image of SMB near shore marine environment, historical and current kelp abundance, kelp loss coverage and habitat type maps. These maps were used to assess the three different habitat conditions (rock, degraded rock, and sediment) within SMB.

In ArcGIS®, multibeam bathymetry DEMs and the video imagery were used to trace polygons outlining different types of substrate (rocky substrate, degraded rocky substrate, and sediment). Rough surfaces visible in the DEMs were designated as rock, and flat surfaces as sediment. Video imagery was used to distinguish between degraded (sediment dusted) and clean rocky habitat. Sub-bottom profile data was used to identify buried rocky habitat. Results were then extrapolated based on the appearance of the DEM for the surrounding area. From those generalizations polygons were designed to display each substrate type (rocky substrate, degraded rocky substrate, and sediment).

Dr. Gary Greene and his staff at the Moss Landing Marine Lab's Center for Habitat Studies created more detailed habitat interpretations from the DEM's and sidescan sonar images provided by the SFML and USGS. This additional work was provided through funding from a National SeaGrant award to Dr. Kvitek and Dr. Greene. Details of Dr. Greene's methods and classification scheme are given in the appendix B below.

Rugosity

Automated rugosity analysis was also applied to the DEM grids as a way of delineating rocky versus sedimentary habitats.

This algorithm calculates a planar area to surface area ratio for each cell in a DEM grid using the elevation of the cell and its eight neighbors. Flat areas will result in ratios near 1, while bumpy, high relief areas will exhibit higher rugosity values. Rugosity grids were created using the ArcView® 3.x extension *Surface Areas and Ratios from Elevation Grids* (surfgrids.avx, Jeff Jeness, Jenness Enterprises <http://www.jennessent.com>).

Sub-bottom Profiling

The SFML used an EdgeTech SB-424® Full-Spectrum sub-bottom chirp profiler for determination of seafloor sediment layer thickness and to look for buried rocky habitat. The SB-424® has a frequency range of 4-24 KHz, with ±4 cm vertical resolution and a typical penetration ranging from 3 m in calcareous sand, to 40 m in clay. Profile data from the SB-424 were recorded using Triton-Elics International Delph Seismic® data acquisition system and processed using Seismic-GIS® software.

Sub-bottom profiling data was used to determine where buried rocky habitat was located within the two study sites in Santa Monica Bay. The analysis was done with Delphseismic® and Delphmap® software from Triton Elics. This allowed for tracing sediment and rock layering within each line file. The difference between layers was exported to produce an x,y,z text file

that contained sediment thickness values for sediment covering rocky habitat. The text file was converted into a DBF file and then into a point shapefile that was used in ArcView® 3 and ArcGIS® 8 to display the data.

GIS Project Creation

All new and existing data sets acquired by the SFML were incorporated into the GIS products provided to the sponsor, in SMBMP on DVD-ROM and described in detail within the SMBMP GIS Users Guide below.

SMBMP GIS USER'S GUIDE

GIS Product Description

The Santa Monica Bay Mapping Project (SMBMP) GIS final product is presented in ArcView® GIS 3.x® and ArcGIS® 8.2® [Environmental Systems Research Institute, Inc.™ (ESRI)] formats. Optimal display and utilization of the data, however, will only be achieved using the newer ArcMap 8.2. Neither of these GIS applications are provided with the project. The ArcGIS® formatted files and data frames can, however, be viewed as read-only with the ESRI freeware, ArcReader®, which is included on the DVD. The final *SMBMP* GIS product combines new thematic layers from data collected for this project with existing marine thematic content drawn from past SFML studies, and a variety of external sources. Due to the file sizes involved and complexity of the data structure, the themes and layers of the predefined ArcView® and ArcGIS® projects have been organized into a variety of data frames. Each of the GIS projects, data frames and data layers are described in detail below.

Using this Guide

This guide is written specifically for users of the *SMBMP GIS* and assumes familiarity with basic computer operations and file management. In addition, some familiarity with GIS applications, in particular ArcView® and ArcGIS® is helpful, but not essential. The basics of using the *SMBMP GIS*, including data and layer descriptions, viewing graphical (map) and tabular (database) outputs, along with viewing imagery, are covered in the *Tutorial* section of this manual.

System Requirements

Data and image files derived from high-resolution multibeam and sidescan sonar mapping tend to be large, frequently hundreds of megabytes. The *SMBMP GIS* is no exception, with the final GIS project files nearing 4 gigabytes. For this reason, only a high-performance PC should be used to view and work with these GIS files. Minimum requirements include a fast Pentium III or better CPU, with a DVD ROM drive and 256 MB of RAM. If you will be running the project from the DVD and do not intend to save any work to the hard drive, available disk space will not be a serious issue. If you plan to copy the projects and files to the local hard drive, at least 4 GB of available disk space will be required after all needed GIS applications and extensions have been installed.

Installation and Configuration Instructions

The data layers on the Santa Monica Bay Mapping Project GIS DVD have been configured for three ESRI GIS applications: ArcReader®, ArcView® GIS 3.x and ArcGIS® 8.2. Of these, only the installation software for the ArcReader® freeware is provided on the DVD. **(Caution: do not install this stand-alone version of ArcReader® on a PC with ArcGIS® Desktop or ArcInfo® Workstation already installed as it cannot co-exist with these applications. If you wish to use the ArcReader® project on a machine with ArcGIS® Desktop or ArcInfo® Workstation installed, use the version of ArcReader® that is included on the ArcGIS® Desktop CD).** If ArcView® or ArcGIS® 8.2 are to be used, they must be installed on the computer before the GIS projects can be displayed. The ArcView® and ArcGIS® project files also require that the ESRI Spatial Analyst® Extension be installed and turned on. Due to the

hierarchical nature of the data file organization, following the instructions below will be essential for optimal setup and use of the data.

After verifying the installation of an appropriate GIS application, proceed with the following options depending on how you intend to explore the *SMBMP* data.

Option A: Running project from DVD

The easiest way to display the project and view the data is to insert the DVD into your DVD-ROM drive and open the appropriate project file by double clicking on it. The project file selected will depend on the application you are using and the data frames and layers you wish to view (see tables below for choices and content description).

Table 1. GIS applications and their respective GIS project files for multibeam and sidescan sonar derived products.

| GIS Applications and SMBMP GIS Project Names | | |
|---|--------------------------|-------------------------------|
| GIS Application | Multibeam Project | Sidescan Sonar Project |
| ArcGIS® 8.2 | SMBMP.mxd | SMBMP_SSS.mxd |
| ArcView® 3.x | SMBMP.apr | SMBMP_SSS.apr |
| ArcReader® | SMBMP.pmf | SMBMP_SSS.pmf |

If you are using ArcGIS® you will not need to direct the program to the DVD-ROM drive when using hyperlinks. If you are using ArcView®, when you click on a hyperlink the program will prompt you to select the DVD-ROM drive where the data can be found. You may need to change the drive letter presented in the prompt box to that of your DVD-ROM, but only change the letter. DO NOT change the project name or extension.

Option B: Copying project to hard drive

While this option requires a large amount (4 GB) of space on your hard drive, it will provide better performance and is necessary if changes are to be made and saved to the project or data files. Make sure that there is sufficient space available on your hard drive to accommodate all the files on the DVD. Copy all files to the hard drive. It is essential that you copy the entire *SMBMP_GIS_Project* Folder on to your hard drive intact with all its contents in the proper order and placement; otherwise the project will not perform correctly.

Dataset Overview

Geographic Extent

Two study areas totaling 30 miles of coastline include the north shore from Pt. Dume to Topanga Canyon, and the Palos Verdes Peninsula from Malaga Cove to Pt. Fermin (Figure 1).

Projection & Coordinate System

Thematic coverage's are provided in Universal Transverse Mercator (UTM) projection, zone 11 North, WGS 1984 spheroid, units in meters. Data appended to the *SMBMP GIS* by an ArcView® user must be in this same coordinate system for the added layers to display correctly. Layers added to ArcGIS® must have their coordinate system correctly defined to allow proper projection on-the-fly.

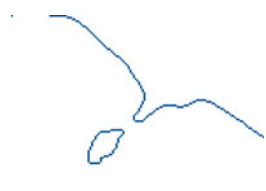




GIS Project Construction

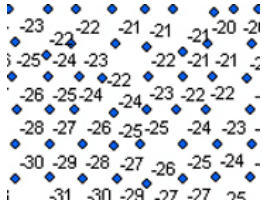


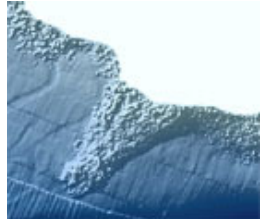
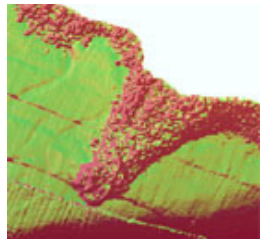
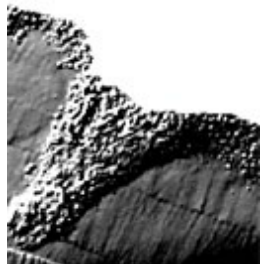
Two GIS project files were created for each of the three GIS project applications: ArcGIS® 8.2, ArcView® 3.x, and ArcReader®. For each application there is a project based on the multibeam bathymetry derived layers and one for the sidescan sonar derived layers (Table 1). The data layers are further organized into data frames or views.

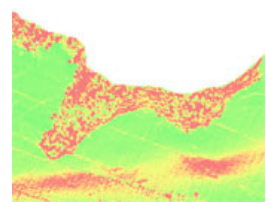
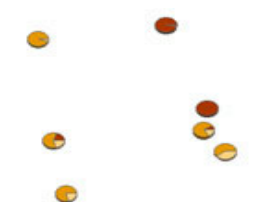

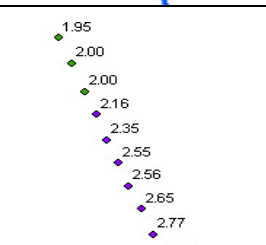
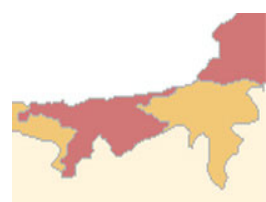
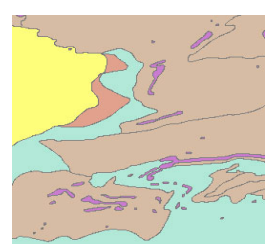
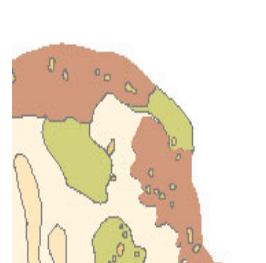
General Description of Data Layers

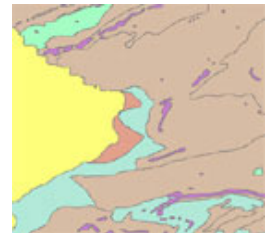
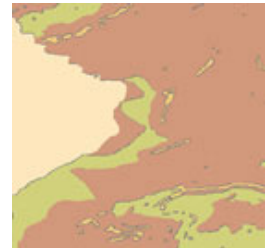


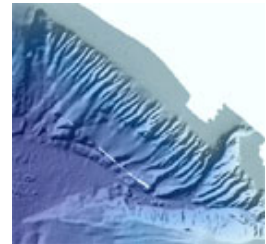
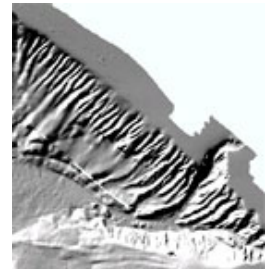
Data layers included in the ***Santa Monica Bay Mapping Project GIS*** consist of raster, vector and tabular data sets from a variety of sources. Each of these layers is described in the table below followed by their placement within the data frames and views.

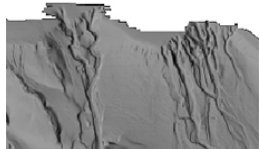
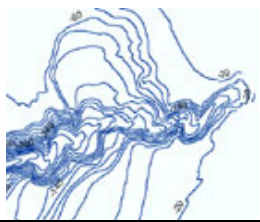

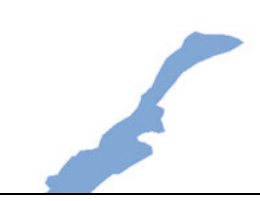

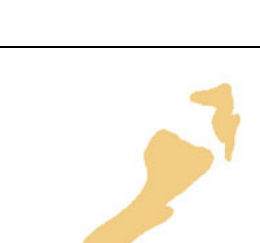

Table 2. Data layers in the SMBMP GIS, including: example graphic, layer label as displayed, source file and description of content and source.

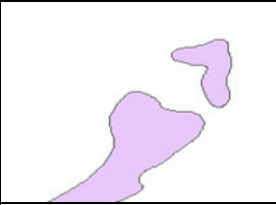
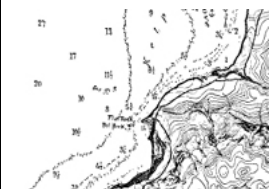
| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|---------------------------------|--|--|
|  | Santa Monica Bay Coastline | smbaycoast_line_utm11.shp | Polyline shapefile of coastline derived from Teale Data Center California Coastline (ccoastn27.shp), warped to WGS1984 UTM Zone 11. |
|  | Santa Monica Bay Coast Polygon | smbaycoast_poly_utm11.shp | Polygon shapefile of coastline derived from Teale Data Center California Coastline (ccoastn27.shp), warped to WGS1984 UTM Zone 11. |
|  | Bathymetric Contour Lines | smb13_50mbathy_5mcontour.shp smb14_50mbathy_5mcontour.shp smb15_50mbathy_5mcontour.shp smb16_50mbathy_5mcontour.shp | 5-meter bathymetric contours derived from a 50-meter bathymetric grid for CDFG blocks 13 – 16. (These and other data types were divided into sections according to CDFG statistical fishing blocks). |
|  | Navigation Charts | 18744_1.tif 18746_1.tif | NOAA electronic raster charts. |
|  | Survey Coverage Polygons | smb13_2mbathycoverage.shp smb14_2mbathycoverage.shp smb15_2mbathycoverage.shp smb16_2mbathycoverage.shp | Survey coverage (footprint) polygons from SFML 2001 & 2002 multibeam surveys. |

| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|--------------------------------------|--|--|
|  | XYZ Soundings | SMBlk13_01-02_100mxyz.shp SMBlk13_01-02_300mxyz.shp SMBlk13_01-02_500mxyz.shp SMBlk14_01-02_100mxyz.shp SMBlk14_01-02_300mxyz.shp SMBlk14_01-02_500mxyz.shp SMBlk15_01-02_100mxyz.shp SMBlk15_01-02_300mxyz.shp SMBlk15_01-02_500mxyz.shp SMBlk16_01-02_100mxyz.shp SMBlk16_01-02_300mxyz.shp SMBlk16_01-02_500mxyz.shp | Shoal-biased soundings exported from Caris HIPS® for combined SFML 2001 and 2002 survey multibeam bathymetry data sets. Soundings were exported in 100, 300, and 500-meter intervals for each block section (Blocks 13-16). |
|  | Multibeam Geotiffs | Smbblk13_01-02_2mgs.tif Smbblk14_01-02_2mgs.tif Smbblk15_01-02_2mgs.tif Smbblk16_01-02_2mgs.tif | Shaded-relief geotiff images for each block section (Blocks 13-16) exported from Caris HIPS® for combined 2001 and 2002 multibeam data sets. Each geotiff was exported with a 2-meter resolution in grayscale color format. |
|  | Sidescan Sonar Mosaic Geotiffs | smbblk13_sssmosaic50cm.tif smbblk14_sssmosaic50cm.tif smbblk15e_sssmosaic50cm.tif smbblk15w_sssmosaic50cm.tif smbblk16e_sssmosaic50cm.tif smbblk16w_sssmosaic50cm.tif | 50cm resolution sidescan sonar mosaic geotiffs for each block section (Blocks 13-16) created using MicroImages TNT Mips® and Triton Elics International Isis and Delphmap software. Blocks 15 and 16 divided into east and west mosaics to limit file sizes. |
|  | Bathymetric Grids | smb13_2mbathy smb14_2mbathy smb15_2mbathy smb16_2mbathy | 2 meter resolution Arc Grid seafloor DEMs from multibeam bathymetry. |
|  | Slope Grids | smb13_2mslope smb14_2mslope smb15_2mslope smb16_2mslope | 2 meter resolution Arc Grids of slope of seafloor DEMs from multibeam bathymetry. |
|  | Hillshade Grids | smb13_2mhill smb14_2mhill smb15_2mhill smb16_2mhill | 2 meter resolution Arc Grids of hillshade of seafloor DEMs from multibeam bathymetry. Illumination azimuth 315°, Angle 45°. |

| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|--|--|--|
|  | Rugosity Grids | smb13_2mrugos smb14_2mrugos smb15_2mrugos smb16_2mrugos | 2 meter resolution Arc Grids of rugosity (surface area ratio) of seafloor DEMs from multibeam bathymetry. Generated using surfgrids.avx ArcView® 3.x® extension. |
|  | Sediment Grab Data | SM_SedGrabData.shp | Sediment grainsize data derived from wet/dry sieve analysis. |
|  | Sub-bottom Track Lines | SM_SBP_all_line.shp | Sub-bottom profiler track lines. |
|  | Sub-bottom Point Data | SM_SBP_all_pt.shp | Sub-bottom profiler points displaying sediment thickness data derived from Triton Elics International SGIS+ software. |
|  | SFML Habitat Classifications | SM_SFML_Hab.shp | Seafloor Mapping Lab habitat classifications derived from a combination of multibeam bathymetry and video footage. |
|  | Center for Habitat Studies – Habitat Classifications | SM_1_hab.shp SM_2_hab.shp | Detailed habitat classifications performed by the Moss Landing Marine Laboratories Center for Habitat Studies. |
|  | Center for Habitat Studies – Generalized Habitat Classifications | SM_1_Genhab.shp SM_2_Genhab.shp | Generalized habitat classifications derived from interpretations performed by the Moss Landing Marine Laboratories Center for Habitat Studies. |

| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|--|--|--|
|  | SFML/Center for Habitat Studies joined habitat classifications | SM_1_01-02hab.shp SM_2_01-02hab.shp | Combination of detailed habitat interpretations from the Seafloor Mapping Lab (SM_SFML_Hab.shp) and Center for Habitat Studies (SM_1_hab.shp and SM_2_hab.shp). |
|  | SFML/Center for Habitat Studies joined – Generalized habitat classifications | SM_1_01-02Genhab.shp SM_2_01-02Genhab.shp | Combination of generalized habitat interpretations from the Seafloor Mapping Lab (SM_SFML_Hab.shp) and Center for Habitat Studies (SM_1_Genhab.shp and SM_2_Genhab.shp). |
|  | USGS Habitat Interpretations | SM_USGS_hab.shp | Detailed habitat interpretations of USGS multibeam and sidescan data performed by Moss Landing Marine Laboratories Center for Habitat Studies. |
|  | USGS Generalized Habitat Interpretations | SM_USGS_Genhab.shp | Generalized habitat interpretations of USGS multibeam and sidescan data performed by Moss Landing Marine Laboratories Center for Habitat Studies |
|  | USGS Bathymetric Grid | Usgs_smbathy | 16 meter resolution Arc Grid DEM from USGS multibeam bathymetry. |
|  | USGS Hill shade Grid | Usgs_sm_hs | 16 meter resolution Arc Grid of hillshade of seafloor DEM from USGS multibeam bathymetry. Illumination azimuth 315°, Angle 45°. |

| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|--------------------------------|--|---|
|  | USGS Shaded Relief GeoTiff | USGS_shaded.tif | USGS shaded relief image of multibeam data. |
|  | USGS Bathymetric Contour Lines | usgs_smbathy_10mcontour.shp usgs_smbathy_20mcontour.shp usgs_smbathy_60mcontour.shp | 10-, 20-, and 60-meter bathymetric contours derived from 16 meter resolution USGS multibeam bathymetry Arc Grid DEM . |
|  | USGS Survey Coverage Polygon | usgscoverage.shp | Survey coverage (footprint) polygon from USGS multibeam data. |
|  | Current Kelp | Current_kelp_1989-1999.shp | Kelp coverage polygons from 1989 to 1999 combined to make a current kelp polygon layer – Kelp polygons obtained from the Department of Fish and Game. |
|  | Individual kelp data | K89b13Summer.shp K89b14Summer.shp K89b15Summer.shp K89b16Summer.shp K89b17Summer.shp K89b18Summer.shp K99ak013.shp K99ak016Winter.shp K99ak017Winter.shp K99ak018Winter.shp k99ak14winter2.shp | Kelp coverage polygons obtained from California Department of Fish and Game, which were combined to produce the current kelp polygons. |
|  | Historical Kelp Data | Historical_Kelp_Data(1893-1912).shp | Combined historical kelp data from 1893-1912 derived from scanned maps from the Department of Fish and Game. |
|  | Kelp Loss | SM_KelpLoss.shp | Kelp loss polygons derived from subtracting the historical kelp data from the current kelp data. |

| <i>Graphic example</i> | <i>Layer/Theme label</i> | <i>Source file</i> | <i>Description of content</i> |
|---|--------------------------|-----------------------|--|
|  | 1912 Kelp Data | Kelp-bed_1912_utm.shp | Kelp bed data from 1912 obtained from the Department of Fish and Game. |
|  | 1893 Kelp Data | Sm1893kelp.tif | Kelp bed data from 1893 obtained from the Department of Fish and Game. |

GIS Project Organization

Within each project there are Data Frames (ArcGIS® 8.2) or Views (ArcView® 3.x), which contain the layers that pertain to a particular data type or analysis. This grouping allows for more efficient computer performance and a more logical organization of the layers. These Data Frames and Views are: Habitat Interpretations, Kelp Cover, Multibeam Bathymetry, Sediment & Sub-Bottom, and Soundings & Contours (Table 3).

Table 3. Project Data Frames (Views in ArcView®) and contents.

| Data Frame Contents | |
|--------------------------------|--|
| Data Frame | Layers within Data Frame |
| Habitat Interpretations | Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp Sm_1_01_02Genhab.shp Sm_2_01_02Genhab.shp Sm_1_01_02hab.shp Sm_2_01_02hab.shp Sm_1_hab.shp Sm_2_hab.shp Sm_1_Genhab.shp Sm_2_Genhab.shp Sm_sfml_hab.shp Sm_usgs_hab.shp Sm_usgs_Genhab.shp Smb13_01-02_2mgs.tif Smb14_01-02_2mgs.tif Smb15_01-02_2mgs.tif Smb16_01-02_2mgs.tif Usgs_shaded.tif Usgs_smbathy usgs_smbathy_20mcontour.shp 18746_1.tif 18744_1.tif |

| Data Frame Contents (continued) | |
|--|--|
| Data Frame | Layers within Data Frame |
| Kelp_Cover | Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp Sm_kelploss.shp Currentkelp_1989-1999.shp Historicalkelpdata(1893-1912).shp Kelp-bed_1912_utm.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp usgs_smbathy_20mcontour.shp Smb13_01-02_2mgs.tif Smb14_01-02_2mgs.tif Smb15_01-02_2mgs.tif Smb16_01-02_2mgs.tif 18746_1.tif 18744_1.tif Sm1893kelp.tif |
| Multibeam_Bathymetry | Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp Smb13_01-02_100mxyz.shp Smb13_01-02_300mxyz.shp Smb13_01-02_500mxyz.shp Smb14_01-02_100mxyz.shp Smb14_01-02_300mxyz.shp Smb14_01-02_500mxyz.shp Smb15_01-02_100mxyz.shp Smb15_01-02_300mxyz.shp Smb15_01-02_500mxyz.shp Smb16_01-02_100mxyz.shp Smb16_01-02_300mxyz.shp Smb16_01-02_500mxyz.shp Smb13_2mrugos Smb14_2mrugos Smb15_2mrugos Smb16_2mrugos Smb13_2mbathy Smb13_2mslope Smb13_2mhill Smb14_2mbathy Smb14_2mslope Smb14_2mhill Smb15_2mbathy Smb15_2mslope Smb15_2mhill Smb16_2mbathy Smb16_2mslope Smb16_2mhill |

| Data Frame Contents (continued) | |
|---|---|
| Data Frame | Layers within Data Frame |
| Multibeam_Bathymetry (continued) | Smb1k13_01-02_2mgs.tif Smb1k14_01-02_2mgs.tif Smb1k15_01-02_2mgs.tif Smb1k16_01-02_2mgs.tif Usgs_shaded.tif Usgs_smbathy usgs_smbathy_20mcontour.shp 18746_1.tif 18744_1.tif |
| Sediment_Sub-bottom | Sm_sbp_all_pt.shp Sm_sedgrabdata.shp Sm_sbp_all_line.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp usgs_smbathy_20mcontour.shp Smb1k13_01-02_2mgs.tif Smb1k14_01-02_2mgs.tif Smb1k15_01-02_2mgs.tif Smb1k16_01-02_2mgs.tif Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp 18746_1.tif 18744_1.tif |
| Soundings_Contours | Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp Smb1k13_01-02_100mxyz.shp Smb1k13_01-02_300mxyz.shp Smb1k13_01-02_500mxyz.shp Smb1k14_01-02_100mxyz.shp Smb1k14_01-02_300mxyz.shp Smb1k14_01-02_500mxyz.shp Smb1k15_01-02_100mxyz.shp Smb1k15_01-02_300mxyz.shp Smb1k15_01-02_500mxyz.shp Smb1k16_01-02_100mxyz.shp Smb1k16_01-02_300mxyz.shp Smb1k16_01-02_500mxyz.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp usgs_smbathy_20mcontour.shp Smb1k13_01-02_2mgs.tif Smb1k14_01-02_2mgs.tif Smb1k15_01-02_2mgs.tif Smb1k16_01-02_2mgs.tif 18746_1.tif 18744_1.tif |

| Data Frame Contents (continued) | |
|---|---|
| Data Frame | Layers within Data Frame |
| Sidescan_Sonar *Data Frame is only available in SMBMP_SSS projects. | Sm_1_01_02Genhab.shp Sm_2_01_02Genhab.shp Sm_1_Genhab.shp Sm_2_Genhab.shp Sm_1_01_02hab.shp Sm_2_01_02hab.shp Sm_1_hab.shp Sm_2_hab.shp Sm_sfml_hab.shp Smbaycoast_poly_utm11.shp Smbaycoast_line_utm11.shp Smb13_50mbathy_5mcontour.shp Smb14_50mbathy_5mcontour.shp Smb15_50mbathy_5mcontour.shp Smb16_50mbathy_5mcontour.shp smb13_50mbathy_5mcontour.tif smb14_50mbathy_5mcontour.tif smb15_50mbathy_5mcontour.tif smb16_50mbathy_5mcontour.tif 18746_1.tif 18744_1.tif |

Metadata

All *SMBMP GIS* data layers have complete, FGDC compliant metadata associated with the actual data files in ArcGIS® ArcCatalog® . The Seafloor Mapping Lab used the ArcGIS® ArcCatalog® metadata system as an efficient way to document, review and manage the geodata holdings. ArcCatalog®'s metadata editor utilizes FGDC metadata content standards. Metadata in ArcCatalog® is stored in XML format, and consists of properties (geospatial footprint) and documentation (descriptive information). ArcCatalog® enables the user to associate a metadata record with the actual GIS data layer it describes allowing the user to extract and record metadata elements including bounding coordinates, point and vector object counts, native data environment and entity/attributes directly from the GIS data. Properties are automatically updated with current values via an internal synchronization process, ensuring that the metadata is kept up to date with changes to the data source. Once created, FGDC-compliant metadata becomes part of the data file itself. It is automatically moved, copied, and deleted along with the associated data file. The ArcCatalog® metadata system can be customized -template creation, stylesheets, user defined fields, and data cataloging all serve to enhance the completeness and reliability of metadata creation and reporting

Data Accuracy


The spatial accuracy of the *SMBMP* data themes is variable and values are shown in the metadata files within the ArcGIS® project. With the exception of other sources (noted), the authors of the *SMBMP* assume responsibility for the accuracy of the enclosed data.

SMBRP GIS TUTORIAL

Opening the Project

Start ArcView® 3.x, the ArcGIS 8.2® ArcMap® application, or ArcReader®, depending on which program you have or would prefer to use. From the File menu, select Open Project. Find and select the appropriate project on the DVD. Once the project is opened the default windows and themes will be selected. From hence forward, ArcGIS® Data Frames and ArcView® Views will collectively be referred to as Data Frames. ArcGIS® layers and ArcView® themes will collectively be referred to as layers.

Viewing Images – Video Clips and Images

There are cataloged video stills from the video verification data and images showing sub-bottom profile data. These images are hyperlinked to data layers in the Sediment_Sub-bottom Data Frame. The video verification photos are hyperlinked to the sediment grab points (SM_SedGrabData.shp) and the sub-bottom profile images are linked to the Sub-bottom line data (SM_SBP_all_line.shp). Both sets of imagery can be viewed by using the hotlink tool. 

The hot link tool will allow you to access the image data directly from a Data Frame.

To use a hot link

1. Make the Layer for which hot links have been defined active, by selecting that layer.
2. Select the hot link tool. If this tool is dimmed out, hot links have not been defined for the active layers.
3. Click a feature in the highlighted or “linked” theme in the viewing window with the hotlink tool. An image should appear for those features that have associated imagery.
4. In Arc View 3.x® the program will prompt you to tell it what drive the data is on, if you are running from the DVD enter the letter for your DVD drive (making sure you ONLY replace the drive letter; DO NOT change the rest of the path); if you are running the project from your hard drive, select the letter for the hard drive onto which you copied the data.

Using ArcReader®

If you do not have access to ArcView® 3.x or ArcGIS 8.2®, and wish to view the *SMBMP* GIS project files as read-only, you can access the data using ESRI’s ArcReader® program, which has been provided on the DVD. ArcReader® is a product that allows anyone to view, explore, and print portable map files (PMF’s). ArcReader® installation software has been provided on the *SMBMP* DVD so that it can be installed on the User’s computer.

(Caution: do not install this stand-alone version of ArcReader® on a PC with ArcGIS® Desktop or ArcInfo® Workstation already installed as it cannot co-exist with these applications. If you wish to use the ArcReader® project on a machine with ArcGIS® Desktop or ArcInfo® Workstation installed, use the version of ArcReader® that is included on the ArcGIS® Desktop CD).

ArcReader® can also be downloaded from the World Wide Web at www.esri.com.

Appendix A: Acknowledgments

We thank Gary Greene and the staff of Moss Landing Marine Lab's Center for Habitat Studies for creating habitat interpretation based on the SFML and USGS multibeam and sidescan sonar data layers, through additional support for California SeaGrant R/F-181B. We gratefully acknowledge California Department of Fish Game – Marine Region GIS Lab for providing kelp data for Santa Monica Bay. We also thank Jack Topel and the Santa Monica Bay Restoration Project for providing this project with the USGS Santa Monica data sets developed by Peter Dartnell and James V. Gardner. Brendan Reed of the Santa Monica Baykeepers also assisted with kelp data. We extend our sincere thanks to current and past members of the Seafloor Mapping Lab at California State University Monterey Bay, including: Kate Thomas, Matt Levey, Paul Chua, Billy Jakl, Jennifer Schellinger, Carla Engalla, Jason Mansour, and Tiffany Vann for assisting in the collection and processing of Santa Monica Bay Mapping Project data.

Appendix B: Methodology for creating habitat interpretations

Dr. Gary Greene, Center for Habitat Studies, Moss Landing Marine Lab's, Moss Landing, CA

Using processed sidescan or multibeam and (when available) backscatter data, layouts were created in ArcView® and exported as .tif files using the extension ArcPress. This process was repeated at different scales until a final scale, most appropriate to the data quality, was chosen as a final basemap for habitat interpretations. A list of region-specific final mapping scales is included (Table VI). If multibeam imagery was used, backscatter data were printed at the same scale. Mylar sheets were affixed over the final printed layouts and coordinate tic marks were copied onto the Mylar sheets for later georeferencing. For this project, all files are projected in Universal Transverse Mercator (UTM) with a WGS World Geodetic System 84 datum and spheroid.

A coding system was established to distinguish habitat types for species of interest and to facilitate ease of use and queries in GIS and other database programs. This code was modified from the deep-water habitat characterization scheme developed by Greene et al. (1999) and is based on interpretations of seafloor geology, morphology, and biology. A copy of this habitat attribute code and a corresponding explanation are included in this volume (see Classification Scheme and Classification Scheme Explanation) and can be found on the MLML Center For Habitat Studies web site: www.mlml.calstate.edu/groups/geooce/habcent.htm

Seafloor imagery was interpreted and habitat types were outlined (mapped), based on knowledge of the geology and seafloor processes in a particular study area, as the first steps in map production. Mapping was done on a light table by drawing polygons on a Mylar overlay of the image around distinct habitat features based on geological processes, structure and morphology. Multibeam and sidescan sonar data provided a general picture of the location of bedrock and unconsolidated sediment. Resolution of the interpretations varied with the quality and scale of the images. However, on most images, we could easily identify such seafloor features as bedrock types (e.g., sedimentary rocks, crystalline rocks, and carbonate mounds), structures (e.g., faults, folds, and landslides), and bedforms of unconsolidated sediment such as sand waves. When backscatter data was unavailable to complement multibeam imagery, interpretations are less certain.

In some limited cases, due to time constraints, not all final multibeam files were available at the time of interpretation. For Point Lobos, backscatter data was not completed for interpretations. For Santa Monica and La Jolla, multibeam imagery used for interpretation was further enhanced and (Santa Monica only) extended. In these and all cases, only the files used for habitat interpretations are included in the "habitat" views on the project CDs. The "bathymetry" views always contain final multibeam files and in most cases, additional files not used during interpretations

The Mylar overlays were scanned using the WideImage® program, with the scan preset on Mylar, georeferenced to 0.5m (when possible), and processed in GIS programs (TNT Mips® and ArcView®). Scanned Mylars were then printed and used to attribute habitats. Individual polygons were color coded on printed copies of the Mylars. This served to check the habitat interpretations and to assist in final editing. Processed files (rasters) were edited in the Spatial Data Editor within TNT Mips®. Unwanted features such as speckles, attribute numbers and text from within the polygons, and tick marks are erased during this process. Dashed lines were connected and missing lines were re-drawn using a drawing tool. The final raster file was then

converted to a vector file using the Auto Trace method in TNT Mips®. Several tests were run before the final conversion in order to check the results of the line editing and tracing.

After raster to vector conversion, the vector file was edited to either delete or add nodes and lines and to correct the shape of polygons. During vector editing the original sidescan sonar and multibeam geotiffs were used for reference. Original geotiffs were imported into TNT Mips® using the correct georeferencing, and then projected as layers beneath the vector file in the Spatial Data Editor. The edited vector was then warped to create an implied georeference with the output projection set, as appropriate. If necessary, smoothing of the warped vector file was performed with the Vector Filtering tool. If the lines were too angular, the smoothing process was used to better round the curves. Several tests were run before the final smoothing to ensure that no features were omitted during processing.

If more than one interpreted Mylar sheet existed for an area, the warped (and filtered) vector files were merged. Final cleaning was done with the Spatial Data Editor. The original sidescan and bathymetry geotiffs were once again projected as layers beneath the vector file and used as references. Special attention was paid to the overlaid areas to make sure that all of the lines met and all polygons closed. Once final cleaning changes were made, the file was exported as a shapefile (.shp). Shapefiles were opened in ArcView® where a legend (explanation) file was added and any additional attribute fields were included in the attribute table. The file was checked for proper georeferencing and for overlapping polygons, and area analysis (polygon specific areas are in square meters) was performed on each habitat type using the feature geometry calculator extension in ArcView®. The habitat shape file was incorporated into an ArcView® project (.apr) along with the imagery from which it was interpreted, creating a final digital product. Metadata was written and all data burned to CD-ROM.

Scientists who performed the original interpretations were available during all stages and consulted when questions arose. In this way, we were able to provide consistency within and among the various areas and regions.

The habitats we mapped include such features as hard rock exposures, deposits of unconsolidated sediment, canyons and gullies, sediment covered ridges, landslides, mounds, depressions, pinnacles, rills, and human (anthropogenic)-influenced morphologies. Where possible, we distinguished grain size (e.g., sand, mud, and mixed or bimodal distributions) of sediments and mapped dynamic bedforms such as sand waves, channel levees, and fans. All mapped characteristics are included in the deep-water marine benthic habitat scheme and GIS attribute code we developed and modified after Greene et al. (1999) for this work and are displayed in the Classification Scheme and Classification Scheme Explanation included in this volume and also on our web site: www.mlml.calstate.edu/groups/geooce/habcent.htm).

Marine Benthic Habitat Classification Scheme

Megahabitat – Use capital letters (based on depth and general physiographic boundaries; depth ranges approximate and specific to study area).

- A = Aprons, continental rise, deep fans and bajadas (3000-5000 m)
- B = Basin floors, Borderland types (floors at 1000-2500 m)
- F = Flanks, continental slope, basin/island-atoll flanks (200-3000 m)
- I = Inland seas, fiords (0-200 m)
- P = Plains, abyssal (>5000 m)
- R = Ridges, banks and seamounts (crests at 200-2500 m)

S = Shelf, continental and island shelves (0-200 m)

Seafloor Induration - Use lower-case letters (based on substrate hardness).

h = hard substrate, rock outcrop, relic beach rock or sediment pavement

m = mixed (hard & soft substrate)

s = soft substrate, sediment covered

Sediment types (for above indurations) - Use parentheses.

(b) = boulder

(c) = cobble

(g) = gravel

(h) = halimeda sediment, carbonate

(m) = mud, silt, clay

(p) = pebble

(s) = sand

Meso/Macrohabitat - Use lower-case letters (based on scale).

a = atoll

b = beach, relic

c = canyon

d = deformed, tilted and folded bedrock

e = exposure, bedrock

f = flats, floors

g = gully, channel

i = ice-formed feature or deposit, moraine, drop-stone depression

k = karst, solution pit, sink

l = landslide

m = mound, depression

n = enclosed waters, lagoon

o = overbank deposit (levee)

p = pinnacle (Note: Pinnacles are often difficult to distinguish from boulders. Therefore, these features may be used in conjunction [as (b)/p] to designate a meso/macrohabitat.)

r = rill

s = scarp, cliff, fault or slump

t = terrace

w = sediment waves

y = delta, fan

z_# = zooxanthellae hosting structure, carbonate reef

1 = barrier reef

2 = fringing reef

3 = head, bommie

4 = patch reef

Modifier - Use lower-case subscript letters or underscore for GIS programs (textural and lithologic relationship).

a = anthropogenic (artificial reef/breakwall/shipwreck)

b = bimodal (conglomeratic, mixed [includes gravel, cobbles and pebbles])

c = consolidated sediment (includes claystone, mudstone, siltstone, sandstone, breccia, or conglomerate)

d = differentially eroded

f = fracture, joints-faulted

g = granite

h = hummocky, irregular relief

i = interface, lithologic contact

k = kelp

l = limestone or carbonate

m = massive sedimentary bedrock

o = outwash

- p = pavement
- r = ripples
- s = scour (current or ice, direction noted)
- u = unconsolidated sediment
- v = volcanic rock

Seafloor Slope - Use category numbers. Typically calculated for survey area from x-y-z multibeam data.

- 1 Flat (0-1°)
- 2 Sloping (1-30°)
- 3 Steeply Sloping (30-60°)
- 4 Vertical (60-90°)
- Overhang (> 90°)

Seafloor Complexity - Use category letters (in caps). Typically calculated for survey area from x-y-z multibeam slope data using neighborhood statistics and reported in standard deviation units.

- A Very Low Complexity (-1 to 0)
- B Low Complexity (0 to 1)
- C Moderate Complexity (1 to 2)
- D High Complexity (2 to 3)
- E Very High Complexity (3+)

Geologic Unit – When possible, the associated geologic unit is identified for each habitat type and follows the habitat designation in parentheses.

Examples: Shp_d1D(Q/R) - Continental shelf megahabitat; flat, highly complex hard seafloor with pinnacles differentially eroded. Geologic unit = Quaternary/Recent.

Fhd_d2C (Tmm) - Continental slope megahabitat; sloping hard seafloor of deformed (tilted, faulted, folded), differentially eroded bedrock exposure forming overhangs and caves. Geologic unit = Tertiary Miocene Monterey Formation.

Combined Habitat Key for all Regions

Soft Substrate

- | | |
|-----------------------------|---|
| 1) Ss _u | Unconsolidated sediment |
| 2) Ss _u (?) | Unconsolidated sediment, questionable |
| 3) Ss(m) _u | Mud |
| 4) Ss(s?) _u | Sand, questionable |
| 5) Ss _b | Bimodal sediment |
| 6) Ss _b /u | Unconsolidated bimodal sediment |
| 7) Ss _b /u? | Unconsolidated (questionable) bimodal sediment |
| 8) Ss(g/p?) _b /u | Gravel and pebbles, questionable |
| 9) Ss _u 2 | Unconsolidated sediment on sloping bottom (1-30°) |
| 10) Ssw _u | Sediment waves |
| 11) Ssm _s | Scoured sediment mounds and depressions |
| 12) Ssm _s /u | Unconsolidated scour mounds and depression |
| 13) Ssg _u | Sedimentary gully |
| 14) Ssg _h /u | Hummocky sedimentary gully |
| 15) Ssg/f _u | Flat sedimentary gully floor |
| 16) Ss _c | Consolidated sediment |
| 17) Ssc _u | Sedimentary canyon |
| 18) Ssc _s /u | Scoured sedimentary canyon |
| 19) Ssc/f _u | Flat sedimentary canyon floor |
| 20) Ssc/f/w _u | Sediment waves on canyon floor |

| | |
|---------------|---|
| 21) Ssc/l_u | Canyon landslide |
| 22) Ssc/g_u | Gullies in sedimentary canyon walls |
| 23) Ss(s?)t_u | Sand (questionable) on terrace |
| 24) Ssc/t_u | Unconsolidated terrace deposits |
| 25) Sss_i/u | Scoured unconsolidated sediment interface |
| 26) Fs_u | Unconsolidated sediment |
| 27) Fsc/f_u | Flat sedimentary canyon floor |
| 28) Fsc/t_u | Unconsolidated terrace deposits |
| 29) Fsc/w_u | Sediment waves in canyon |
| 30) Fsc_u | Sedimentary canyon |
| 31) Fsg/f_u | Flat sedimentary gully floor |
| 32) Fsg/l_u | Landslide in gully |
| 33) Fsg_u | Sedimentary gully |
| 34) Fsg_u1 | Sedimentary gully on flat bottom (0 - 1°) |
| 35) Fsg_u2 | Sedimentary gully on sloping bottom (1 - 30°) |
| 36) Fsl_h/u | Hummocky landslide deposit |
| 37) Fsl_u | Landslide |
| 38) Fsm_s/u | Unconsolidated scour mounds and depressions |
| 39) Fsm_u | Unconsolidated mounds and depressions |
| 40) Fso_u | Overbank (levee) deposit |
| 41) Fss_i/u | Scoured unconsolidated sediment interface |
| 42) Fsw_u | Sediment waves |
| 43) Rs_u | Sedimentary ridge |
| 44) Bs_u | Unconsolidated sediment |
| 45) Bsc/f_u | Flat sedimentary canyon floor |
| 46) Bsc_u | Sedimentary canyon |
| 47) Bsg/f_u | Flat sedimentary gully floor |
| 48) Bsg_i | Sedimentary gully interface |
| 49) Bsg_s/u | Scoured sedimentary gully |
| 50) Bsg_u | Sedimentary gully |
| 51) Bsg_u2 | Sedimentary gully on sloping bottom (1 - 30°) |
| 52) Bsl_h/u | Hummocky landslide deposit |
| 53) Bsm_s/u | Unconsolidated scour mounds and depressions |
| 54) Bss_i/u | Scoured unconsolidated sediment interface |
| 55) Bsy_u | Submarine fan deposit |

Mixed Substrate (soft sediment and hard bedrock)

| | |
|----------------|--|
| 1) Sm_u | Mixed bedrock and unconsolidated sediment |
| 2) Sme_b/u | Mixed bimodal sediment over bedrock |
| 3) Sme_s/u | Scoured mixed bedrock and sediment |
| 4) Sme_s/r | Scoured rippled sediment over bedrock |
| 5) Sme/f_u | Mixed sediment and flat bedrock |
| 6) Sme_u | Local sediment covered bedrock |
| 7) Sme_h/u | Local sediment covered hummocky bedrock |
| 8) Sme_d/u | Local sediment covered differentially eroded bedrock |
| 9) Smd_d/u | Local sediment covered deformed, diff. eroded bedrock |
| 10) Smd_d/u(?) | Sediment covered deformed diff. eroded bedrock, questionable |
| 11) Smd_h/u | Hummocky sediment covered deformed bedrock |
| 12) Smm_d/m/u | Local sediment covered differentially eroded sandstone |
| 13) Smt_u | Mixed terrace deposits |
| 14) Smt_b/u | Mixed bimodal terrace deposits |
| 15) Smp/t_h/u | Mixed sediment covered terrace with pinnacles |
| 16) Sme_v | Sediment and volcanic rock |
| 17) Sme_c | Sediment and consolidated sedimentary bedrock |
| 18) Sme_g | Sediment and granite |
| 19) Sme_g/u(?) | Sediment and granite, questionable |

| | |
|---------------|--|
| 20) Sme_g/u | Local sediment covered granite |
| 21) Sme/g_h | Mixed hummocky sediment and rock in gully |
| 22) Smg_b/u | Mixed bimodal and unconsolidated sediment in gully |
| 23) Smc/e_s | Scoured sediment and rock in canyon |
| 24) Smc/e_c/u | Sediment and consolidated sedimentary rock in canyon |
| 25) Smc/t_h/u | Mixed sediment and rock on hummocky canyon terrace |
| 26) Sm(b)/p | Mixed sediment, boulders and pinnacles |
| 27) Fms_i | Sediment and rock interface |
| 28) Fmd_d/u | Differentially eroded deformed bedrock and unconsolidated sediment |
| 29) Fmd_h/u | Hummocky sediment covered deformed bedrock |
| 30) Bml_h/u | Rock and sediment landslide deposit |

Hard Substrate

| | |
|-------------------|--|
| 1) She_d | Differentially eroded bedrock |
| 2) Shd_d | Differentially eroded deformed bedrock |
| 3) Shd_h | Deformed hummocky bedrock |
| 4) Shd_m | Deformed sandstone |
| 5) She_c | Hard consolidated bedrock |
| 6) She/m_d | Differentially eroded bedrock mounds |
| 7) She/m_d/m | Differentially eroded sandstone into mounds and depressions |
| 8) Sme/m_d/m/u | Differentially eroded sandstone with local sediment cover |
| 9) She_h | Hummocky bedrock |
| 10) She_f | Fractured bedrock |
| 11) She_v | Volcanic rock |
| 12) She_v(?) | Volcanic rock, questionable |
| 13) She_h/v(?) | Hummocky volcanic bedrock, questionable |
| 14) Sh_f/g | Fractured granite |
| 15) Sh_g(?) | Granite, questionable |
| 16) Shs_g(?) | Granite scarp, questionable |
| 17) Sht_s/u | Hard scoured terrace and unconsolidated sediment |
| 18) She_i | Bedrock interface |
| 19) She/s_d/i | Differentially eroded bedrock scarp (interface) |
| 20) Shc/e | Bedrock canyon |
| 21) Shcg | Granite canyon |
| 22) Shc/e_c | Consolidated sedimentary bedrock canyon |
| 23) Shc/l_h/c | Consolidated rock landslide in canyon |
| 24) Shp/t_f/h | Hard, fractured hummocky rock terrace and pinnacles |
| 25) Sh(b)/p | Boulders and pinnacles |
| 26) Sh(b)/p_d | Differentially eroded boulders and pinnacles |
| 27) Sh(b?)/p | Boulders (questionable) and pinnacles |
| 28) Sh(b)/p_s | Scoured boulders and pinnacles |
| 29) Sh(b?)/p_s | Scoured boulders (questionable) and pinnacles |
| 30) Sh(b?)/p_g(?) | Boulders (questionable) and granite (questionable) pinnacles |
| 31) Sh_a | Hard anthropogenic feature |
| 32) Shm_a | Hard anthropogenic mounds |
| 33) Shm_a(?) | Hard anthropogenic mounds, questionable |
| 34) Fhc/e | Bedrock canyon |
| 35) Fhc/l | Rockfall in canyon |
| 36) Fhe/g_i | Bedrock gully interface |
| 37) Fh(b)/p | Boulders and pinnacles |
| 38) Rhe | Rocky ridge |

Explanation of Habitat Classification Code

A habitat classification code, based on the deep-water habitat characterization scheme developed by Greene et al. (1999), was created to easily distinguish marine benthic habitats and to facilitate ease of use and queries within GIS (e.g., ArcView®, TNT Mips®, and ArcGIS®) and database (e.g., Microsoft Access® or Excel®) programs. The code is derived from several categories and can be subdivided based on the spatial scale of the data. The following categories apply directly to habitat interpretations determined from remote sensing imagery collected at the scale of 10s of kilometers to 1 meter: Megahabitat, Seafloor Induration, Meso/Macrohabitat, Modifier, Seafloor Slope, Seafloor Complexity, and Geologic Unit. Additional categories of Macro/Microhabitat, Seafloor Slope, and Seafloor Complexity apply to areas at the scale of 10 meters to centimeters and are determined from video, still photos, or direct observations. These two components can be used in conjunction to define a habitat across spatial scales or separately for comparisons between large and small-scale habitat types. Categories are explained in detail below. Not all categories may be required or possible given the study objectives, data availability, or data quality. In these cases the categories used may be selected to best accommodate the needs of the user.

Habitat Categories and Definitions

1) Megahabitat – This category is based on depth and general physiographic boundaries and is used to distinguish regions and features on a scale of 10s of kilometers to kilometers. Depth ranges listed for category attributes in the key are given as generalized examples. This category is listed first in the code and denoted with a capital letter.

2) Seafloor Induration – Seafloor induration refers to substrate hardness and is depicted by the second letter (a lower-case letter) in the code. Designations of hard, mixed, and soft substrate may be further subdivided into distinct sediment types, which are then listed immediately afterwards in parentheses either in alphabetical order or in order of relative abundance.

3) Meso/Macrohabitat – This distinction is related to the scale of the habitat and consists of seafloor features ranging from 1 kilometer to 1 meter in size. Meso/Macrohabitats are noted as the third letter (a lower-case letter) in the code. If necessary, several Meso/Macrohabitats can be included either alphabetically or in order of relative abundance and separated by a backslash.

4) Modifier – The fourth letter in the code, a modifier, is noted with a lower-case subscript letter or separated by an underline in some GIS programs (e.g., ArcView®). Modifiers describe the texture or lithology of the seafloor. If necessary, several modifiers can be included alphabetically or in order of relative abundance and separated by a backslash.

5) Seafloor Slope – The fifth category, represented by a number following the modifier subscript, denotes slope. Slope is typically calculated for a survey area from x-y-z multibeam data and category values can be modified based on characteristics of the study region.

6) Seafloor Complexity – Complexity is denoted by the sixth letter and listed in caps. Complexity is typically calculated from slope data using neighborhood statistics and reported in standard deviation units. As with slope, category values can be modified based on characteristics of the study region.

7) Geologic Unit – When possible, the geologic unit is determined and listed subsequent to the habitat classification code in parentheses.

Greene, H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, J.E. McRea Jr., and G.M. Cailliet. 1999. A classification scheme for deep seafloor habitats. *Oceanologica Acta*. Vol 22: 6. pp. 663-678.

Appendix C: Sediment Grain Size Analysis

Appendix D: Map Layout

Appendix E: Contacts & Resources

Questions regarding the methods and content of *Santa Monica Bay Mapping Project*, including technical support inquiries, should be addressed to the contacts listed below.

General questions regarding the study:

Dr. Rikk Kvitek, Principal Investigator
Director, Seafloor Mapping Lab (SFML)
Institute for Earth Systems Science and Policy
California State University, Monterey Bay
100 Campus Center
Seaside, Ca 93955 USA
(831) 582.3529
rikk_kvitek@csumb.edu
<http://seafloor.csumb.edu>

Questions regarding habitat interpretations:

Dr. Gary Greene
Director, Center for Habitat Studies
Moss Landing Marine Laboratories
8272 Moss Landing Rd.
Moss Landing, Ca 95039 USA
(831) 771.4140
[greene@mlml.calstate.edu](mailto:greeneg@mlml.calstate.edu)

Questions regarding USGS data:

Peter Darnell
United States Geological Survey
MailStop 999, 345 Middlefield Road
Menlo Park, Ca 94025-3561 USA
(650) 329-5460
pdartnell@usgs.gov

James V. Gardner
United States Geological Survey
MailStop 999, 345 Middlefield Road
Menlo Park, Ca 94025-3561 USA
(650) 329.5469
jvgardner@usgs.gov