

CALIFORNIA STATE WATER SEAFLOOR MAPPING: PROGRESS REPORT ON A COLLABORATIVE APPROACH

*Rikk G. Kvitek, Ph.D., CSUMB Seafloor Mapping Lab
Guy R. Cochrane, U.S. Geological Survey, Pacific Science Center
Edward J. Saade, Fugro Pelagos Inc.
Gary H. Greene, Center for Habitat Studies, Moss Landing Marine Labs*

Problem: We cannot manage what we do not understand, and we cannot understand what we do not know. Such is the case for California's state waters. The entire surface of Mars has been mapped in greater detail than the narrow strip of seafloor within California's 3-mile state waters boundary. Yet over 85% of California's Gross State Product (the 7th largest economy in the world) and 75% of its population are based in the coastal market sectors that border and rely on these highly productive waters. The continued success of this robust coastal economy is dependent upon the health and sustainable management of California's coastal ocean ecosystem and resources. Despite having the ability to create the needed high-resolution base maps for these dynamic and critically important hidden landscapes, the only information available for managing the sustainable use and protection of more than 66% of California's seafloor habitats is in the form of nautical charts: tools never intended and inadequate for the tasks at hand. This lack of high-resolution seafloor maps has limited and profoundly compromised our ability to address a variety of critical marine and coastal management issues including:

- **Coastal Erosion**, sediment transport and beach loss
- Baseline data for environmental change detection and **Coastal Ocean Monitoring**
- Development and implementation of true **Ecosystem Based Management**
- Restoration of **Degraded Habitats**, **Depleted Fish Stocks** and **Endangered Species**
- Identification, classification and protection of **Essential Fish Habitats**
- Effective design and monitoring of **Marine Protected Areas**
- Discovery, assessment and monitoring of **Earthquake** and **Tsunami Hazards**
- Placement and maintenance of **Oil, Gas** and **Telecommunication Facilities**
- Location and removal of **Seafloor Debris** and **Derelict Fishing Gear**
- Identification and protection of **Submerged Archaeological Sites**
- Managing offshore **Sand** and **Aggregate Mining**
- Maintaining **Shipping Channels** and **Harbor Entrances**
- Surveillance for submerged threats to **Homeland Security**

Solution: The California State Coastal Conservancy (SCC), Ocean Protection Council (OPC), Department of Fish and Game (DFG), and the NOAA National Marine Sanctuary Program (NSP) have launched the first phase of a comprehensive state waters mapping program for California. The ultimate goal is the creation of a high-resolution 1:24,000 scale geologic and habitat base map series covering all of California's 14,500 km² state waters out to the 3 mile limit. This statewide project requires, involves and leverages expertise from industry, resource management agencies and academia. The first phase of the program is the North Central Coast Mapping Project. This phase has served as the proof-of-concept model demonstrating the viability, efficiency and value of this approach in support of the state's Marine Life Protection Act Initiative (MLPA) goal to create a statewide network of Marine Protected Areas (MPAs).

The tiered mapping campaign involves the use of state-of-the-art sonar, LIDAR (aerial laser) and video seafloor mapping technologies; computer aided classification and visualization; expert geologic and habitat interpretations codified into strip maps spanning California's land/sea boundary; and the creation of an online, publicly accessible data repository for the dissemination of all mapping products. Because the project involves and trains many university students, it is helping to meet the rapidly growing demand for professionals in the public and private sectors skilled in the applications of these geospatial technologies.

Here we describe the steps leading up to the launch of California's historic state waters mapping campaign, the approach and technologies being employed, progress and products to date, lessons learned, applications of the results, and plans for completing the statewide enterprise.

Laying the foundation – Strategic Planning Workshop

The SCC funded a Statewide Marine Mapping Planning Workshop held at CSU Monterey Bay, December 12-13, 2005 (<http://seafloor.csUMB.edu/StrategicMappingWorkshop.htm>). The purpose of the workshop was to create a strategic plan for completing the mapping of all seafloor habitats within California State Waters (shoreline out to 3 nm). The approach was to involve key stakeholders in a gap analysis of existing data coverage, identification and ranking of current mapping information needs, the prioritization of areas for new field data acquisition, and the definition of minimum survey and analysis specification required to support these needs.

The sponsors also requested a separate ranking of mapping priorities within the proposed pilot project area that was subsequently funded as the North Central Coast Mapping Project (NCCMP) (Fig. 1). The two-day workshop attracted 56 invited participants representing 38 institutions including regional, state and federal resource management agencies, universities, research institutions, NGO's and private industry. A surprising degree of overlap was discovered among the participants regarding their need for mapping data products including:

- MPA mapping in support of the MLPA process
- Environmental monitoring and change detection
- Sediment transport dynamics (erosion, deposition and beach nourishment)
- Geologic hazards (faults and landslides capable of producing tsunamis)
- Habitat maps for fisheries management, stock assessment and identification of biological hot spots
- Safe navigation in shallows, bays, harbors and estuaries
- Economical sources of sand
- Data to support wave, current, sediment transport and oil spill prediction models
- Location of shipwrecks with potential for oil leaks
- Location of derelict fishing gear
- Tsunami run-up modelling

Identification and ranking by the participants of areas for future mapping within state waters was conducted through a voting process making use of the existing 10' CDFG commercial fishing block designations (Fig. 1). Recommendations for data acquisition and final products were obtained during group and breakout sessions regarding critical elements key to the success of a

statewide mapping effort. These elements included: data acquisition, level of interpretation, metadata, and dissemination. There was consensus that the minimum universal seafloor mapping information should cover all “lands” from the shore strand line (MHHW) out to the 3 nm state water limit and include:

- Seabed geomorphology (relief via xyz digital elevation models - DEM)
- Texture (substrate type via backscatter mosaics).
- Ground truthing (via video or physical samples)
- Subsurface structure, sediment thickness and stratigraphy via subbottom profiles & coring
- Meet or exceed International Hydrographic Organization (IHO) Order 1 standards, and be carried out at the maximum resolution obtainable using state-of-the-industry tools.
- Best available geodetic positioning technology (vertical and horizontal)

All present acknowledged the ultimate need for and great value in full geologic and habitat interpretation of collected mapping data. The recommended approach was to consider map product generation as a 3 tiered process, with each tier being constructed from the previous. The first tier consists of the basic survey data (xyz grids [bathymetry] and backscatter [substrate] mosaics). These first tier data sets can be efficiently converted into second tier products in GIS at little additional cost using automated numerical derivatives including autoclassification of substrates and surface models based on parameters (slope, aspect, rugosity, contours, relief, etc.). Second tier products are GIS-ready and are often of high value to management agencies because many of the patterns they are interested in (e.g. rocky versus soft bottom habitats, bed forms, and depth zones) are easily discernable at this intermediate level of data analysis. The third product tier (fully interpreted, classified and attributed geologic and habitat maps), enables consideration of a variety of different types of data of varying scales and so represents considerable “value added” when there are several different data sets to be considered.

Finally, all acknowledged the critical importance of having all data meet FGDC metadata standards. For archiving and dissemination, the recommendation was for a tiered system of

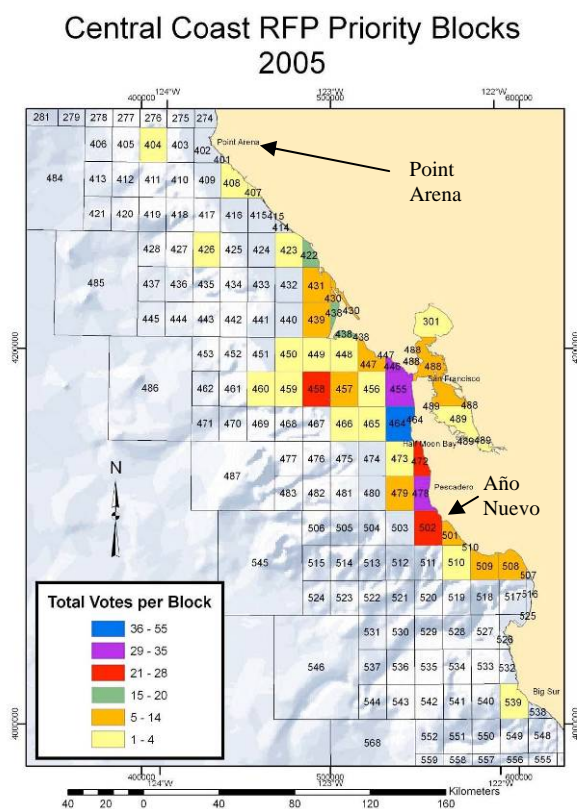


Figure 1. Spatial distribution of number of votes cast per block for the NCCMP priority mapping needs during the 2005 Statewide Marine Mapping Planning Workshop

accessible databases (ftp with links, http download sites, website images of data that link to data sources, internet GIS map servers).

Initiating Phase I Pilot Project - North Central Coast Mapping Project

The first phase of the anticipated statewide mapping program commenced in November 2006 with support from the OPC, SCC, DFG and NMS. The NCCMP mission is to map the state waters between Ano Nuevo and Point Arena (Fig. 1). The team conducting this work is a uniquely qualified partnership between academia, industry and resource management. Members include the Seafloor Mapping Lab at California State University Monterey Bay, US Geological Survey National Seafloor Mapping and Benthic Habitat Studies Group, Fugro Pelagos Inc. and the Center for Habitat Studies at Moss Landing Marine Labs.

Acquisition of mapping data involves bathymetric LIDAR and multibeam echo sounders (MBES) to obtain bathymetry data, acoustic backscatter and reflectance imagery, as well as acoustic sub-bottom profiling data. The surveys and the information created will comply with the recommended requirements for statewide seafloor mapping as specified in the Workshop Report, including:

- Seabed geomorphology (relief via xyz digital elevation models - DEM)
- Texture (substrate type via acoustic backscatter and reflectance mosaics)
- Ground-truthing (via video or physical samples)
- Surveys designed to meet or exceed IHO Order 1 standards, and to be carried out at the maximum resolution obtainable using state-of-the-industry tools
- Best available geodetic positioning technology (vertical and horizontal)

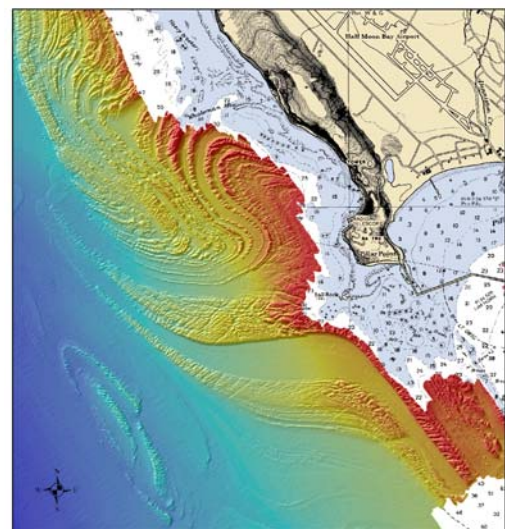


Figure 2. Mavericks, Half Moon Bay, California. Preliminary Tier 2 results from NCCMP. High-resolution multibeam sonar map showing spectacularly faulted and deformed seafloor geology, in shaded relief and colored by depth, overlain on the NOAA 18682 nautical chart (depth soundings in feet). This level of detail is needed, but not available for 66% of California state waters. (Source: California OPC North Central Coast Mapping Project).

The Tier 1 and Tier 2 products specified as requirements in the RFP include the following ESRI compatible Data layers with FGDC compliant metadata files:

- Sediment sample point features with grain size attributes
- Video observation point features with geologic and biologic attributes
- Geologic structure with motion attributes
- bathymetric ESRI grid and ASCII xyz file
- bathymetry in shaded relief as georeferenced tiff image (colored by depth and in grey scale)
- backscatter intensity as georeferenced tiff image
- bathymetric contour feature layer at 5 meter intervals

- A seafloor texture grid derived from unsupervised clustering of derivatives of the bathymetry and backscatter intensity
- A surficial geologic ESRI grid produced using video-supervised classification of derivatives of the bathymetric and backscatter data

Two Tier 3 interpretation example products are also being created: 1) an updated 1:100,000 Essential Fish Habitat (EFH) interpretation map, and 2) a 1:24,000 quad map set composed of:

- Color coded bathymetry draped over shaded relief bathymetry overlain with bathymetric contours
- Backscatter intensity draped over shaded relief bathymetry
- Color coded seafloor texture draped over shaded relief bathymetry
- Color coded Geologic units draped over shaded relief bathymetry overlain with structure
- Color coded benthic habitat draped over shaded relief bathymetry

Habitat Abundance: Pt Lobos SMR vs Potential Reference Site

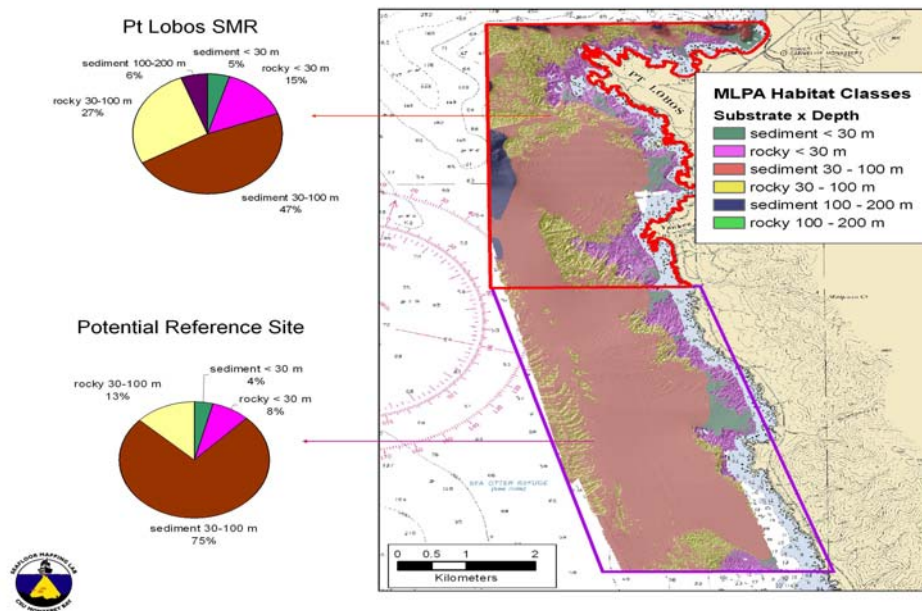


Figure 3. Auto-classified habitat map of the Point Lobos State Marine Reserve created from high-resolution, hyper-clean multibeam sonar data to aid in MPA monitoring program design for the MLPA initiative.

Hydrographic charting versus habitat mapping

Data collection and processing for habitat mapping must be held to the highest standards of precision and accuracy across a wide depth range. At times, this may exceed the standards set for hydrographic charting. The difference is because the current status for auto-classification or even the visual interpretation of seafloor habitat types (e.g. Fig. 3) is such that hyper-clean data is required for the processes to be accurate. Even small artifacts or erroneous data points projecting no more than 10-20 cm above or below what is actually a smooth seafloor will appear

and be classified as rough and therefore rocky habitat. Future improvements in data collection standards and techniques coupled with future improvements in the auto-classification tools will both be required to yield the highest accuracy possible.

Authors: Rikk G. Kvitek, Ph.D. – CSUMB Seafloor Mapping Lab
100 Campus Center, Seaside, CA 93955

Guy R. Cochrane
U.S. Geological Survey
Pacific Science Center, 400 Natural Bridges Dr., Santa Cruz, CA 95060

Edward J. Saade
Fugro Pelagos Inc.
3738 Ruffin Road, San Diego, 92123

Gary H. Greene
Center for Habitat Studies
Moss Landing Marine Labs
8272 Moss Landing Road, Moss Landing, CA 95039