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A Marine Geographic Information System for the Channel Islands National Marine Sanctuary

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Abstract. In 1980, the U.S. Congress designated the waters surrounding San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara islands as the Channel Islands National Marine Sanctuary, 1 of 13 national marine sanctuaries in the United States. The sanctuary Management Plan identifies 4 goals: resource protection, research, interpretation, and visitor use. The sanctuary staff have identified 3 key uses of a geographic information system (GIS) that will help achieve these goals: site characterization, monitoring, and disaster preparation. A GIS—in this case, a marine GIS—is a tool that the sanctuary staff can utilize to map resources and analyze the effects of man or nature on the environment of the sanctuary.

Keywords: Channel Islands; California; sanctuary; geographic information system; resource protection; oil spills.

Introduction

The management of marine sanctuaries in the United States was delegated to the National Oceanic and Atmospheric Administration (NOAA), an agency of the Department of Commerce, by the Marine Protection, Research and Sanctuaries Act of 1972 (16 U.S.C. 1431-1434). In 1977, NOAA proposed protecting the waters surrounding 5 of the 8 Channel Islands in California, and in 1980 the Channel Islands National Marine Sanctuary (CINMS) was designated by Congress as the nation's third National Marine Sanctuary (15 CFR Part 935) (Fig. 1).

The CINMS Management Plan identifies 4 goals for optimum management of the sanctuary: resource protection, research, interpretation, and visitor use (Dobbin and Associates 1983). To assist in fulfilling these goals, CINMS staff are developing a marine geographic information system (GIS) that encompasses the 1,252 sq nautical mi of sanctuary waters. When completed, the GIS will be a means of portraying the location of features within the sanctuary and an analytical tool to predict changes to sanctuary resources.

Key Uses of the GIS

The 3 key uses of the marine GIS that will help in the sanctuary's management process are: site characterization, monitoring, and disaster preparation-damage assessment. These 3 elements require extensive databases that are best managed by sophisticated computers and software. The distinguishing factor of a GIS from computer mapping or drawing programs is the capability of a GIS to collect, store, and analyze objects and phenomena where geographic location is an important characteristic or critical to the analysis (Aronoff 1991). Varying the interactions of different data sets stored in a GIS utilizes the efficient storage, retrieval, and manipulation capabilities of computers (Fig. 2).

The sanctuary GIS databases and the analytical power of computers will help provide answers to the geographical questions of *what*, *how*, and *where*.

Site characterization

A site characterization is an inventory of the resources within the sanctuary, geo-referenced to a common coordinate system. Three questions are answered by the site characterization: *What* resources are in the sanctuary? *How* abundant are these resources? *Where* are these resources? Eleven databases have been identified for the characterization element:

1. Oceanographic data
   a. collected during the coming year by sanctuary staff from standard depths (surface, 1 m, 5 m, 10 m, and so forth) at selected sites throughout the sanctuary
   b. temperature
   c. salinity
   d. conductivity
   e. density
   f. fecal bacteria (selected anchorages)
   g. sea state

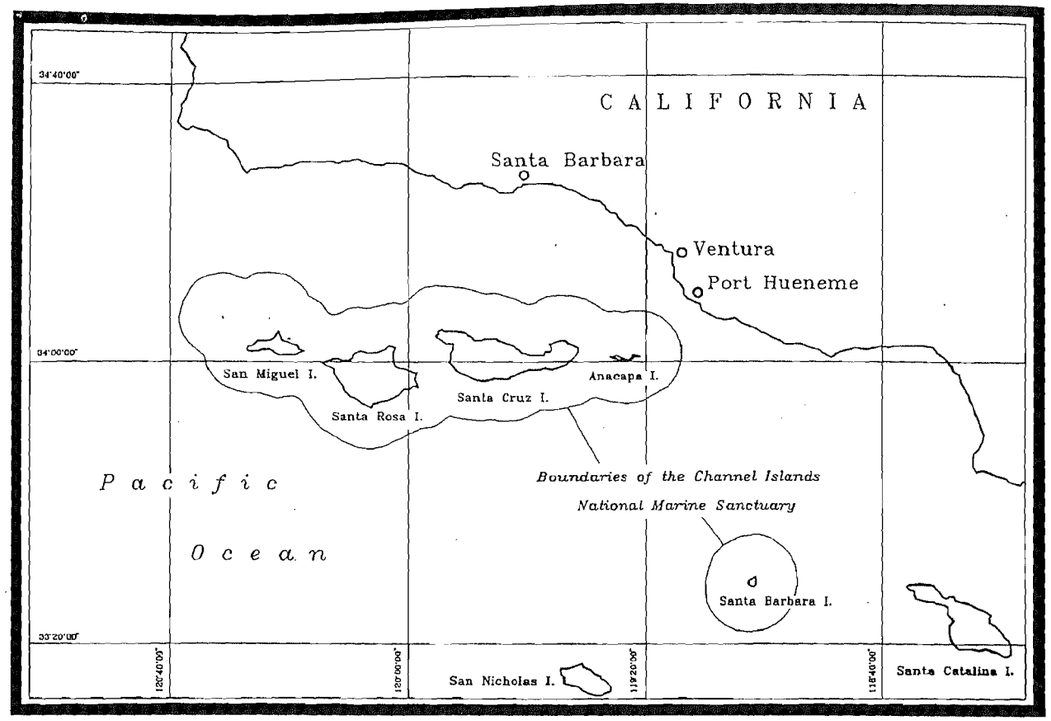

Figure 1. Five of the 8 Channel Islands encompassed by the Channel Islands National Marine Sanctuary.

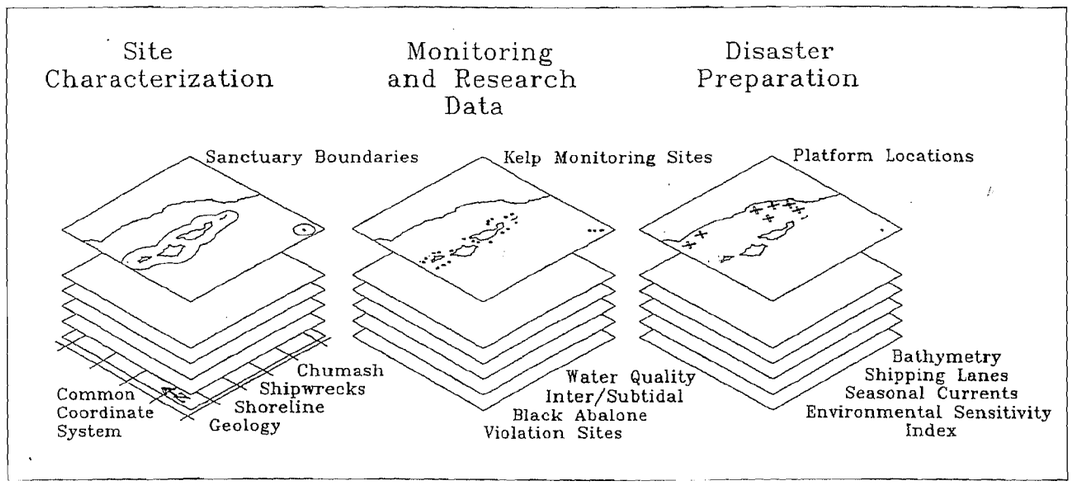

Figure 2. Three elements of a marine GIS that will help achieve management goals.

h. other data collected by non-sanctuary staff (dissolved oxygen, nutrients, plankton counts, and so forth) during research cruises

2. Weather data
   a. collected during the coming year by sanctuary staff at the selected oceanographic stations and Santa Cruz and San Miguel islands
   b. air temperature
   c. pressure
   d. wind speed
   e. wind direction
   f. precipitation
   g. relative humidity

3. Geology
   a. island and sea floor, collected from existing maps

4. Geodetic control
   a. fixed horizontal and elevation control points from NOAA

5. Topography
   a. island topography and cultural features from US Geological Survey (USGS) maps

6. Bathymetry
   a. depth data from NOAA

7. Shoreline type
   a. rock, pebble, sand, and so forth
   b. sensitivity to oil (from existing sensitivity maps)

8. Vertebrates/invertebrates
   a. data collected by Channel Islands National Park at selected monitoring sites throughout the sanctuary
   b. species
   c. population counts
   d. sizes
   e. shoreline species inventory from NOAA/UCSB/ Santa Barbara County

9. Kelp
   a. data collected by sanctuary staff
   b. location and extent of canopy
   c. species

10. Chumash Indian sites and artifacts
    a. data from various sources
    b. location
    c. type

11. Shipwrecks
    a. data from National Park Service and California State Lands Commission sources
    b. location
    c. name (if known)
    d. year wrecked (if known)
    e. type of vessel

Channel Islands National Marine Sanctuary has acquired digital databases of geodetic control, topography, bathymetry, and vector shoreline maps. The staff now has the capability to produce base maps of the sanctuary and the islands. The other databases will either be collected during planned field projects or manually input from existing data.

Monitoring

Monitoring the health of the sanctuary is fundamental to the protection of resources. Monitoring requires data collection and analysis over time. By using selected stations and incorporating separate layers for certain data indicators (example: salinity data collected from selected sites during the month of July will be incorporated into a July data layer that can be compared on a monthly or seasonal basis to other salinity data collected at the same points; this links the spatial component of the data with time, allowing the identification of trends).

The GIS will help answer these questions: *What* is the state of the health of the sanctuary? *How* is the health changing (or is it)? *Where* are the changes taking place?

Four components of the monitoring element are identified:

1. Water Quality
   a. fluctuations in nutrients, oxygen, temperature, salinity
   b. fecal bacteria

2. Targeted plant species
   a. fluctuations in specie diversity, populations

3. Targeted Animal Species
   a. fluctuations in specie diversity, populations

4. Public Use
   a. location and numbers of recreational, fishing, and commercial boat use
   b. diving locations and uses
   c. location and nature of infractions

The collation of existing monitoring data will be a primary activity in the initial phases of the GIS. By assessing the existing monitoring data, the GIS will aid in

assessing the effectiveness of mitigation and in planning future monitoring and research activities. Data sets from Channel Islands National Park, Santa Barbara County, and NOAA's Hazardous Materials Response and Assessment Division will be integrated to provide comprehensive coverage and format for monitoring issues. Long-term trends in biodiversity, population fluctuation and biomass productivity will be estimated by reviewing kelp extents and density, water quality samples, fishery populations and spawning sites, abalone die-off locations, seabird nesting, cetacean migration, pinniped haul-out sites, and commercial and recreational use of the sanctuary.

GIS-aided monitoring can manipulate buffer zones of pre-determined size around pollution point sources (or other problem areas). These areas can be monitored for changes in productivity and biodiversity. The monitoring data collected can then be input into the GIS to produce maps showing the extent of the effects of pollution over time.

Disaster preparation

The numerous oil platforms near the sanctuary boundaries and the commercial shipping lanes that provide a conduit for tankers and freighters through a portion of the sanctuary may one day set the stage for an oil spill or other hazardous materials disaster. Changes to weather patterns and water characteristics due to natural phenomena, such as El Niño, also affects sanctuary resources. A marine GIS will help answer these questions: *What* potential disasters could happen? *How* will these events affect resources? *Where* will these events occur?

Four components of disaster preparation are identified:

1. Hazardous Material Spills
   a. oil
   b. other hazardous materials

2. Groundings

3. Point/non-point Pollution
   a. agricultural runoff from island or mainland ranches and farms
   b. non-oil industrial discharges

4. Natural
   a. weather
   b. diseases in species
   c. changes to water characteristics

The marine GIS will allow sanctuary staff to quickly identify environmentally sensitive areas during actual emergencies, which will help the staff in the emergency-response, decision-making process. The GIS will provide a means to log and track damaged areas and restoration processes.

A significant amount of planning must go into emergency contingency plans. Adequate planning requires that protection priorities and shoreline-specific cleanup strategies are determined in advance. Managers need access to environmental sensitivity indexes (ESI) for pre-spill planning and emergency contingency plans (Hayes et al. 1992). The ESI provides data regarding seasonal changes in the biological life cycles of natural resources that determine sensitivity to pollution. The GIS will automate the manipulation of ESI data and make use of the extensive biological monitoring data associated with existing Channel Islands databases. Environmental Sensitivity Index data will provide critical information regarding shoreline exposure to wave and tidal activity, the presence of rookeries and nurseries, migration and foraging patterns, and species' life cycle sensitivities to pollution. Estimations of biological sensitivity and damage assessment will help prioritize cleanup and in choosing the appropriate cleanup strategy for each site. Familiarity with pollution disaster scenarios will help managers make the right decisions in protecting the resources of the sanctuary during times of real emergencies.

Long-term monitoring of damaged areas and assessment of biological recovery within these areas will be assisted by the GIS. Post disaster uses include efficient documentation of pollution on the shorelines, water quality degradation, and manipulation of statistical data regarding the percentage of species populations exposed and damaged by the event. Accurate monitoring of these issues is needed to help learn from these events and to plan appropriate responses to future events. Areas that are damaged can be identified, and products such as maps and charts showing the extent of damage and restoration can be generated for reports.

System Components

The marine GIS consists of 3 components: hardware, software, and data. Many agencies in the sanctuary area and in other offices of NOAA have been contacted to coordinate software compatibility. Most of the contacted organizations are working or plan to work in the ARC/INFO environment. The software package ArcCAD was chosen for the sanctuary's marine GIS because of import/export compatibility with ARC/INFO. ArcCAD runs within AutoCAD, a drawing program that the sanctuary staff is familiar with, and utilizes data-management software such as Dbase to build attribute tables. ArcCAD runs on IBM-compatible personal computers, which keeps the hardware costs at a reasonable level and eliminates the need to learn a work-station operating system such as UNIX.

Base Maps

All base maps and spatial databases of a GIS must be referenced to a common coordinate system. Federal government mapping organizations have begun the process of changing map datums of the United States from NAD 27 to NAD 83 on maps and charts. Geodetic control stations on the Channel Islands and along the California coast published by NOAA's Geodetic Survey are listed in NAD 83 (NOAA 1993). Software exists to convert control stations published in state plane coordinates to NAD 83 coordinates.

Nautical charts from NOAA covering the sanctuary area have been converted to NAD 83. These charts are the most detailed depictions of the water areas of the sanctuary and will be used as base maps for presenting much of the sanctuary's data. Vector shoreline data compiled at 1:80,000-scale and 1:24,000-scale has been obtained from NOAA and the California Coastal Commission which provides streamlined shore depictions without associated charting data found on NOAA charts.

Nautical charts from NOAA will be raster scanned and geo-referenced. The rasterized charts will be used as back-drop displays for data portrayal. Digital maps of the land portions of the islands are available from USGS. After some on-site manipulation (edge-matching of adjoining sheets) these maps have been incorporated into the GIS.

It is expected that continual data input, data maintenance, and scanning/digitizing of new information will be required to keep the system current and useful.

Summary

The first and foremost management goal of the Channel Islands National Marine Sanctuary is to protect the living and cultural resources within the sanctuary. To accomplish this requires an understanding of the many environmental, biological, and human-induced variables in a region encompassing an area of 1,252 sq nautical mi. The sanctuary staff must know what resources are in the sanctuary, how abundant these resources are, and where the resources are located before undertaking the installation of monitoring programs that will assess the continual health of the sanctuary. A GIS is the right tool to store varied spatial data bases and perform analysis on the complex interactions of environmental data sets. Modeling disaster scenarios will help the managers make the right decisions in protecting the resources of the sanctuary during times of real emergencies.

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