Marine Protected Area Control Site Suitability Analysis Based On Geomorphic Interpretation Of Multibeam Bathymetry Data Using GIS

A Capstone Project

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By

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To the ESSP faculty of CSUMB:

Preventing the depletion of various fisheries is an important task that requires a large amount of input from a variety of factors. In the case of the Channel Islands Marine Protected Areas (MPAs) in southern California, the mission to design and execute a successful monitoring regime is one of great importance. Over the last two decades numerous MPAs have been established worldwide, but monitoring their success has been difficult to accurately measure. The Channel Islands National Marine Sanctuary (CINMS) was implemented in 2003 and marks the nation's third largest network of marine reserves. The Department of Fish and Game (DFG), CINMS, and the Channel Islands National Park System (CINPS) have begun efforts to design long-term monitoring programs that will evaluate the effectiveness of this reserve. In order to reliably assess the performance of MPAs it is important to monitor change, not only within the reserve, but also in adjacent waters outside reserve boundaries. Baseline information about the extent of habitats and their relationship to the marine communities will aide fisheries managers in their quest to design efficient monitoring programs. CSUMB's Seafloor Mapping Lab (SFML) in collaboration with the DFG, CINMS, and The Nature Conservancy (TNC) have begun efforts to characterize habitats both within MPA boundaries as well as neighboring areas just outside existing MPAs.

In June of 2003, a research cruise to Santa Rosa Island, California was undertaken. The general approach was to use the CSUMB Seafloor Mapping Lab's acoustic remote sensing system to map the MPA and its designated control site off Carrington Point. My role in this project was the acquisition, processing, and interpretation of multibeam bathymetry data collected by the SFML along with the production of GIS habitat maps. This project is of critical importance for several reasons: First, defining similarities of habitat within the MPA and its control will aide fisheries managers to determine whether the control site at Carrington Point is suitable enough to evaluate the performance of its MPA. Secondly, habitat maps can help provide information about species abundance, diversity, and possibly distribution. Thirdly, the CINMS with the use of habitat maps will be able to determine appropriate sites for sampling stations to be placed. Finally, with the combination of the information above, fisheries managers will be better able to justify placement of existing MPAs within the Channel Islands National Marine Sanctuary.

I believe my capstone should be assessed in the following areas of depth:

- Acquisition, Display and Analysis of Quantitative Data
- Application of Knowledge in the Physical and/or Life Sciences

In science if you truly wish to solve a problem, you must first recognize and fully understand the problem. In the case of Carrington Point's MPA and control sites, I have teamed up with not only state and local agencies, but also other experts in the field of marine biology, marine geology, and marine technology to gain a better insight of the issue at hand. These people include, but are not limited to, Dr. Kvitek, Dr. Smith, and Mr. Iampietro of the SFML. My interactions with these individuals are helping me to understand the direct and indirect, short and long-term obstacles that many marine reserves face as well as the hope they hold in being successful.

As an ESSP student with a Marine and Coastal Ecology concentration, I am interested in the interactions of humans upon marine resources as the search to find equilibrium becomes more and more essential in preserving the marine environment. Thus the implementation of marine reserves peaks my interest, for I feel if it weren't for the overexploitation of these natural resources, by humans, several marine ecosystems and fisheries would still be flourishing. My interest in this project was aided by the fact that I was given the opportunity to experience first hand the Channel Islands National Marine Sanctuary. To see such a pristine environment and to know that I will be able to complete this project in all aspects from the collection of raw data, to data processing, to interpreting and characterizing the data, and finally to the distribution of final products to the appropriate agencies all in an effort to help better understand marine fisheries was an opportunity I could not pass up.

I thank all of you for spending the time and energy to review my capstone. It is my hope that you will find the information useful and enchanting to the point that it inspires and piques your interest as well as your courage to conserve one of nature's most prized possessions.

Sincerely,

Saori Marie Zurita

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ABSTRACT

Currently the world's oceans and coastal waters are facing increasing threats from an array of human pressures, including overfishing, pollution, and habitat destruction. As a result both fisheries and biodiversity within many areas are in rapid decline. Although Marine Protected Areas (MPAs) have been promoted and implemented as important tools in the conservation and management of living marine resources, accurate assessment of their true value requires reliable monitoring of their performance as compared to appropriate and unregulated control areas. This project conducted a comparative study of the newly designated Carrington Point, Santa Rosa Island MPA and its control site. The comparison was based on a geomorphic analysis of high-resolution multibeam bathymetry data used to quantify the relative abundance and distribution of seafloor habitat within both areas to assess the suitability of the selected control site. The results showed enough similarities, based on a t-test statistical method, of habitat in both the MPA and control for species of concern (*Haliotis sorenseni*, *Sebastes serronoides*, *Ophiodon elongates*) to potentially be monitored. Overall the results of this study suggest the control site will be suitable to evaluate the performance of its respective MPA. Adequate similarities in the distribution and abundance of habitat will provide ample sites to place future monitoring stations.

INTRODUCTION

Threats to the integrity, functions, and values of the world's oceans and coastal marine environments are increasing as the need for marine resources continue to emerge. The Food and Agriculture Organization estimates at present 47-50% of marine fish are globally overexploited and between 9 -10% have been depleted or are recovering from low population levels (FAO 2000). As a result, environmental impacts such as the decline of species-specific fisheries, loss of habitat, and ultimately loss of biodiversity not only affect marine organisms, but other stakeholders including commercial and recreational fisheries, various commercial and tourism industries, and recreational marine users as loss of regional economies and cultures materialize. These environmental effects are keen in U.S. near-shore coastal waters where human activities have the greatest impact (http://environment.sa.gov).

Marine Protected Areas (MPAs) are "any area of the marine environment that has been reserved by Federal, State, local, territorial, or tribal laws or regulations to provide lasting protection for all or part of the natural and cultural resources therein" (www.csc.noaa.gov). MPAs are considered by the World Wildlife Federation (WWF), International Union for the Conservation of Nature (IUCN), and the United Nations Environmental Program (UNEP) to be an effective means of protecting marine biodiversity, marine resources, and marine ecosystems (Norse 1993). They range from small, highly protected areas in which no extractive uses are permitted to large, multiple-use areas that are often zoned to provide different levels of protection by permitting various activities and usages within the designated MPA (Baker 2000). It is believed that integrating large scale networks of MPAs into fishery management can help reverse the decline of global fisheries as well as provide urgently needed protection for species and their habitats (Gell and Roberts 2003).

Within the last 20 years over 1000 MPAs have been established worldwide (Sobel 1993). The performance of MPAs are difficult to measure as several factors such as routine studies on fishing intensity, effectiveness of enforcement, and habitat characterization must be taken into account (Cote et al. 2001). Baseline knowledge on the extent of MPA's habitat and their relationships to marine communities would provide needed information for fisheries managers who work not only to design effective monitoring programs, but who must also justify the placement of MPAs. Along the coasts of the United States, numerous people have been displaced as a result of MPAs. For example, on the west coast of California, the Monterey Bay National Marine Sanctuary (MBNMS) along with the Channel Islands Marine Protected Areas (CIMPAs) "no-take" zones have closed areas to fishing pressures and forced commercial fishermen to relocate to alternate fishing grounds. Efforts to acquire information on the performance of the MBNMS include regular water quality assessments throughout the reserve as well as regular surveys on the abundance and health of marine organisms (http://www.bonita.mbnms.nos.noaa.gov/).

Although these methods provide useful information on the performance of the MBNMS, simply monitoring change within a reserve may not be sufficient for determining the MPAs overall performance. Without the use of designated MPA control sites, natural variations within the marine community as a result of closure cannot be accurately assessed. Along with monitoring environmental changes within an MPA, it is also necessary to study changes that occur outside existing MPA boundaries. An in depth understanding of how MPAs affect areas not only within their limitations, but how they affect nearby adjacent waters is beneficial in increasing awareness of how truly successful MPAs are in achieving their goals of escalating species densities, species size, and species diversity.

MPAs are predicted to benefit adjacent fisheries through two mechanisms: 1. Net emigration of adults and juveniles across MPA boundaries termed “spillover” and 2. Export of pelagic eggs and larvae (Gell and Roberts 2003). Inside MPAs species populations increase in size, live longer, and develop increased reproductive potential (Gell and Roberts 2003). Densities of the commercially important sparred fish (*Chrysoblephus laticeps*) within the world’s oldest marine reserve, in Tsitsikamma National Park in South Africa, have been reported as 42 times higher since the reserve was established in 1964. In the Scandola Nature Reserve in Corsica densities for 11 fish species were recorded as being 5 times greater after 13 years of protection and in the Apo Island Reserve in the Philippines larger predatory fish densities reported a sevenfold increase after 11 years of protection (Gell and Roberts 2003). Catch per unit effort (CPUE) as a result of spillover has seen an overall increase in many fisheries. Gala (2002) stated the CPUE for the trammel net fishery adjacent to the reserve in Nabq, Egypt has increased by 66% while CPUE of fish traps around a network of reserves in St. Lucia have increased 46-90% (Roberts 2001). Experimental CPUE for lobsters inside the Columbretes Island Marine Reserve in Spain were 6-58 times greater than those from fished sites (Gell and Roberts 2003).

Large fish (> 32.5 cm) in the Maria Island Reserve in Tasmania are over 3 times more common after only 6 years of protection while the average size of the grey snapper (*Lutijanus griseus*) within the Florida Everglades National Park increased to 25-30 cm compared to 15-20 cm in nearby fisheries (Gell and Roberts 2003).

Increases in size and abundance of marine species may translate to an increase of reproductive potential. It is estimated that 70% of the biomass in Kenya’s Mombass Marine National Park was reproductively active compared to 20% in nearby fishing grounds (Rodwell et al., 2000). In one of New Zealand’s rocky reserves, egg production of lobster (*Jasus edwardsii*) within deeper waters has increased by roughly 9.1%. After more than 20 years of protection in the Edmunds Underwater Park in Washington State, the lingcod (*Ophidon elongates*) produced 20 times more eggs than in nearby fished areas. The copper rockfish (*Sebastes caurinus*) produced 100 times more eggs within this same reserve (Gell and Roberts 2003).

Not only can emigration of marine species and export of pelagic egg and larvae be assessed from MPAs, but the rate at which fishermen fish MPA boundaries can also be examined. The practice of "fishing the line" has been observed here on the west coast of California and is believed that catches are greatest along the "line" (Davis and Dodrill 1980; Grantham et al In press; Kinlan and Gaines In press.). If control sites are to be suitable enough to evaluate their respective MPAs they would need to be closely related in size, quantity, contain similar habitat, and undergo the same geomorphic processes as that of the MPA. Ideally, selection of a suitable control for a given MPA should involve a geomorphic analysis and comparison of the habitats within the MPAs and prospective control sites. With the use of proper control sites the performance of MPAs can be more accurately assessed. This knowledge will allow fisheries managers to implement more efficient long-term monitoring programs for existing and future MPAs. The creation of spatially explicit habitat maps will also enable resource management agencies to accurately locate sampling stations within comparable habitat types inside and outside of existing reserves.

Determining a proper site for the placement of MPAs must take into account all factors, which may have an effect on the ecosystem itself. These include recreational/commercial fishermen, tourism/commercial industries (cruise ships, whale watching, shipping), and recreational use (boating, scuba diving). If MPAs are to be successful in protecting biological resources from human activities it is necessary to evaluate the extent and health of habitat as well as biodiversity within and adjacent to the reserves.

The Channel Island MPA Network

The Northern Channel Islands are located off the coast of southern California and signify a seaward extension of the Santa Monica mountain range (Norris and Webb 1990). They have earned a reputation as the "American Galapagos" as this area is a unique transition zone of cool waters from the northern and central coasts combining with warmer water from the south. This mixing of water creates exceptional habitats and breeding grounds for numerous marine species including pinnepeds, cetaceans, invertebrates, fish and giant kelp (www.csc.noaa.gov).

The Northern Channel Islands include the islands of Anacapa, Santa Cruz, Santa Rosa, and San Miguel. This area encompasses 249,354 acres, half of which is located under water (www.csc.noaa.gov). These islands lie within a geologic region known as the Continental Borderland and consist of the section offshore of California between Point Conception and Punta Banda in Baja California, Mexico (Norris and Webb 1990). The Continental Borderland entails basins and elevated ridges. Those ridges that rise above sea level are what we know as the Channel Islands today (Norris and Webb 1990).

The Continental Borderland is believed to have been the result of continued large-scale overriding of the North American Plate by the Pacific Plate in southern California. This event has forced movement along the San Andreas Fault System and this movement is the primary cause of the Continental Borderland's wide shelf and laterally shifted blocks (Dailey et al. 1993). Active folding, thrusting, and strike slip faulting in response to the North American and Pacific plate convergence (Pinter et al. 2003) have combined to create a very complex topography of ridges and shelves that extend from the land onto the shallow continental shelf. This complex and diverse geometry forms prime habitats for many marine organisms.

In October 2002, the Channel Islands National Marine Sanctuary (CINMS) along with the Department of Fish and Game (DFG) and the Fish and Game Commission (FGC) implemented the largest network of marine reserves off the west coast within the Northern Channel Islands. These reserves encompass 465km^2 and include the islands of Santa Barbara, Anacapa, Santa Cruz, Santa Rosa, and San Miguel (Kvitek, 2003). Within this network of marine reserves, 12 individual MPAs exist as either "no-take zones" or have limited access **(Figure 1)**. In addition, specific areas adjacent to each MPA have been designated as "controls". These control sites are areas similar in size to their respective MPAs, remain open to the public, and are intended to help evaluate the performance of individual MPAs.

The Channel Island MPA network marks the nation's third largest marine reserve, behind the Hawaiian Islands Humpback Whale National Marine Sanctuary and the Florida Keys National Marine Sanctuary (www.flmnh.ufl.edu). The Department of Fish and Game (DFG), Channel Islands National Marine Sanctuary (CINMS), and the Channel Islands National Park System (CINPS) have begun a cooperative effort to devise and implement the monitoring program needed to evaluate the performance of the CIMPA network. Effective monitoring requires specific knowledge of the location and extent of ecologically significant habitats and communities. This baseline information is being used for the selection of appropriate control sites outside the CIMPA network. Moreover, most of the distribution and abundance of habitats and communities in the northern Channel Islands have never been mapped previous to this study as cooperating agencies lacked the highly specialized resources needed to conduct the comprehensive exploration and mapping. Without this knowledge, it is impossible to objectively assess if the MPAs actually support species of concern or to design the cost effective, habitat-specific monitoring program required to rigorously evaluate the performance and success of the CIMPA network.

In addition to assessing environmental change within each MPA, the CIMPAs were also designed to provide certain levels of protection and enhancement for a variety of marine species whose populations have declined over the past several decades due to increased fishing pressure. In order for MPAs to be ecologically and economically successful, it is essential to define and understand the relationship of the physical habitat with the resident biological communities. The Channel Islands MPA boundaries were assigned without a prior knowledge of the underwater terrain, therefore putting into question the adequate protection of habitat-specific marine organisms. To address the issue within the scope of this study, a subset of economically important marine species were selected from Marine Protected Areas in National Oceanic and Atmospheric Administration's Channel Island National Marine Sanctuary (Ugoretz 2002) to allow for a comparison of available preferred habitat (within the defined MPAs) at depths appropriate for each **(Table 1)**.

The white abalone (*Haliotis sorenseni*) population has declined by 96% since 1970 and has therefore been recognized by the federal government as needing immediate protection. This species marks the first mollusk in history to be placed on the federal endangered species list. White abalones are sedentary, inhabiting deep-water rocky reefs (20 – 60m.) near sand channels. Surveys in the Channel Islands area estimate density to be around 0.0001per m^2 (Davis et al. 1998).

During the 1980's olive rockfish (*Sebastes serranoides*) were an important recreational species throughout southern California. They inhabit areas under kelp or among rocks in waters ranging from the surface to 190 meters. As a result of overfishing and poor juvenile survival due to changes in oceanographic conditions, catches between 1980-1996 have declined by approximately 83%. Although there are no current stock assessments of olives it is believed that their abundance has greatly dropped south of Point Conception (Leet et al. 2001).

Lingcod (*Ophidon elongates*) in the Channel Islands are mostly found in the colder water regions of San Miguel and Santa Rosa Islands. They inhabit rocky substrate at depths ranging from 1 – 106 meters. During the 1970's this fishery just about tripled as the markets for their liver oil and seafood increased. Recent lingcod stock assessments suggest that their population is seriously depleted. Currently California populations are believed to be less than 25% of their pre-1970's level (Leet et al. 2001).

Table 1. Selected species-of-interest from <u>Marine Protected Areas in National Oceanic and Atmospheric Administration's Channel Island National Marine Sanctuary</u> (Ugoretz 2002).

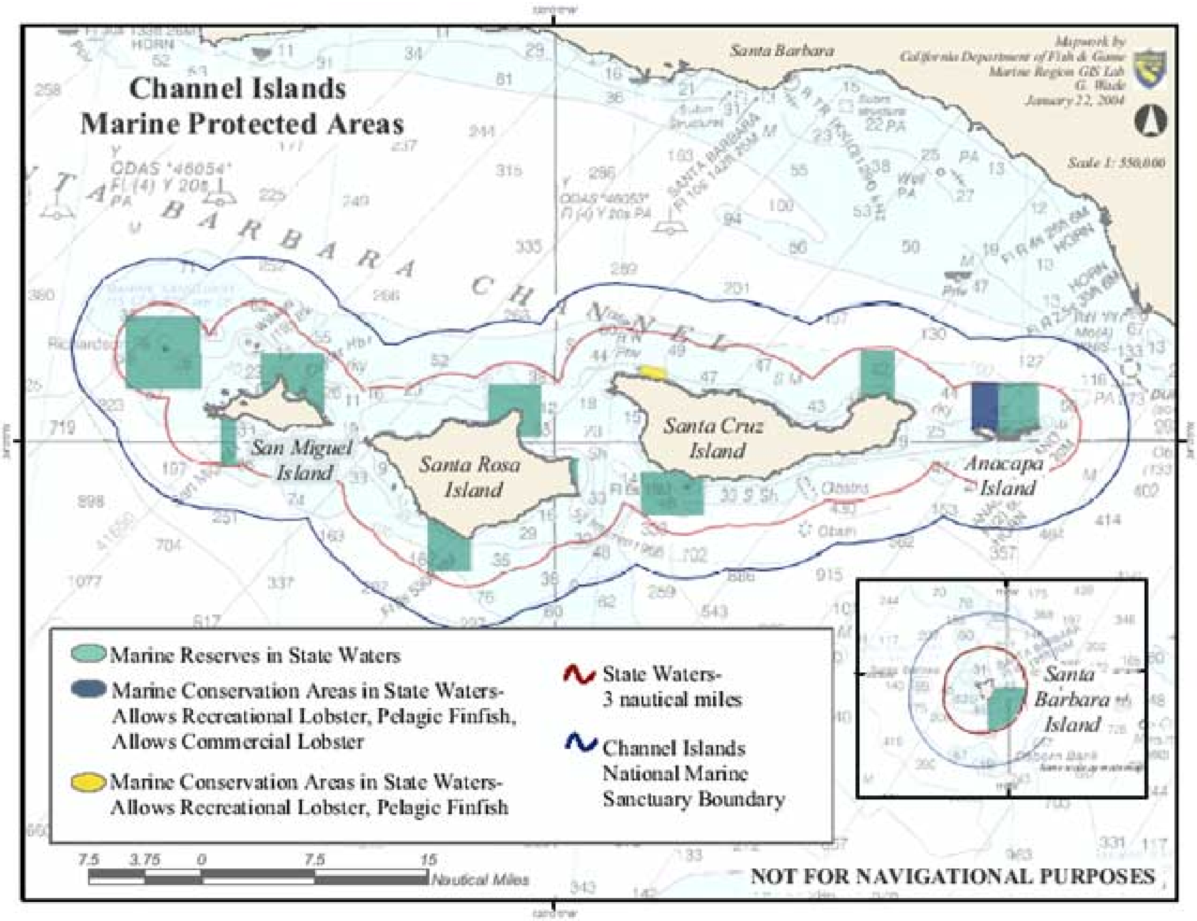
Species of Concern	Common Depth Range	Preferred Habitat	Federal Status
White Abalone ***(Haliotis sorenseni)***	20 - 60 meters	Rock	Candidate
Olive Rockfish ***(Sebastes serranoides)***	3 - 190 meters	Rock	Vulnerable (declining)
Lingcod ***(Ophiodon elongatus)***	0 - 106 meters	Rock	Vulnerable (declining)

Purpose of Study

The purpose of this project was to use multibeam bathymetry data to interpret and compare the underwater geology of one of the twelve CIMPAs (Carrington Point, Santa Rosa Island) with that of its designated control site. High-resolution and accurate geospatial habitat maps were used to quantify similarities and differences in the topographic relief found within Carrington Point's MPA and control site. This approach presented a more explicit understanding of whether or not enough similar habitat exist in the control to make it a suitable comparison site for Carrington Point's MPA as well as to help identify where to place long-term monitoring stations.

Project Goal

The objective of this study is to provide the CINMS, DFG, National Oceanographic and Atmospheric Administration (NOAA), and CINPS with valuable high-resolution (3m) habitat maps displaying similar characteristics of rocky substrate between the two mapped areas. The MPA at Carrington Point was prioritized as the second area to be mapped by DFG; therefore this information is needed to help fisheries managers within the various agencies begin a successful monitoring program for Carrington Point. The CIMPAs are a test case for the MPA network model and verification of their success with an appropriate control site will have global implications for the development and application of MPA theory.



(Figure 1: CINMS consists of twelve MPAs, ten of which are designated as "no-take zones" and two, which allow limited recreational fishing)

METHODS

Study Site

At 84 mi^2 in size Santa Rosa Island is the second largest of the Northern Channel Islands. It is positioned 26.5 miles off the southern California coast of Santa Barbara **(Figure 2)** with its closest neighbor, San Miguel Island just three miles to the east.

Santa Rosa Island hosts a series of east-west trending faults and is primarily bisected by the Santa Rosa Island fault which contains about 8 km of left lateral slip (Weaver, 1969). North of the Santa Rosa Island fault, marine terraces cut into the middle and lower Miocene (23.5 million years) marine sedimentary rocks. In many places these terraces are covered by young dune sand (Norris, 2003). Within this region the Black Mountain Anticline and Beechers Bay Syncline include young sedimentary deposits of the pre-Quaternary (Pre 2 million years) era.

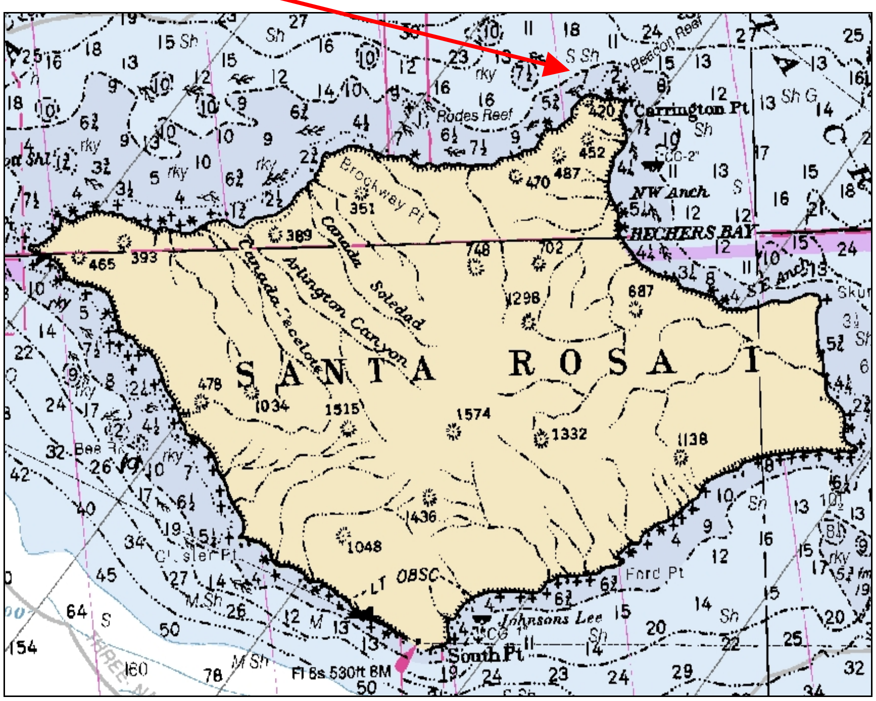
The survey area off Santa Rosa Island consists of a MPA and its control site located at Carrington Point. This area extends from shore to the three-mile state water limit and is positioned off the northern coast of the island **(Figure 3)**. Marine and non-marine terrace deposits from the Pleistocene period (1.8 million to 10,000 years) overlie the Miocene rocks offshore (Norris and Webb 1990). Sediment deposited offshore includes sand, silt, clay, and biogenic particulate or aggregates of plankton (Dailey et al. 1993).

Survey Design

The California State University Monterey Bay (CSUMB) Seafloor Mapping Lab (SFML) conducted surveys using its Reson 8101 multibeam system aboard the National Park Service's R/V Pacific Ranger from June 16-20, 2003. Selected by DFG as one of the areas in greatest need to be mapped, the survey site included Carrington Point's MPA and its designated control site. The SFML survey team consisted of four people operating during the day (0600-1800 hrs). The entire surveyed area required a total of 171 lines providing complete sonar coverage with a 50% overlap. The multibeam swath was 150 degrees, depth range fell between 6.3 to 88.3 meters, and survey speed was roughly 10 knots. Prior to data collection a series of survey lines were created using Hypack 8.9 from Coastal Oceanographics. This software was also used to guide the vessel during field operations. A Trimble 4700 differential global positioning system (DGPS) was used to position the vessel during data collection. A TSS POS/MV motion sensor accounted for motion changes of the vessel such as heave, pitch, and roll (heading accuracy $\pm$ 0.02^{o}, heave accuracy $\pm$ 5cm). Tides and Currents software using NOAA predicted tides were used to account for tide cycle fluctuations and sound velocity profiles were collected with an Applied Microsystems SVPlus sound velocimeter (http://seafloor.csumb.edu).

(Figure 2: Santa Rosa Island is located approximately 26.5 miles off the west coast of Santa Barbara, California)

(Figure 3: Carrington Point MPA and control site are located on the north facing side of Santa Rosa Island)



Data Processing

Initial multibeam processing was done aboard the R/V Pacific Ranger via PC computers utilizing Caris Hips Hydrographic software. Post-processing of data was completed in the Seafloor Mapping Lab at CSUMB using Caris Hips Hydrographic software. Soundings were corrected for vessel motion using the TSS POS/MV data, corrected for variations within the water column using AML SV+ data, and adjusted to MLLW using NOAA predicted tide tables. All data points were filtered, merged and cleaned of false data points or “noise” within Caris Hips. Geotiffs were exported from Caris Hips Spatial Editor with 3m resolution in sunshaded grayscale and 10 color rainbow imagery with sun azimuth set at 315 degrees, elevation set to 45 degrees and vertical exaggeration set at 5. Soundings were exported from Caris Hips as decimated x,y,z ASCII text (shoal biased) with 3m, 100m, 300m, and 500m spacing.

The 3m decimated x,y,z ASCII text was imported into Fledermaus Average Gridder to generate a 3m grid. The 3m Fledermaus grid (.asc) was imported into ArcView 8.0 Spatial Analyst to generate a 3m bathymetry grid with 5m and 10m contour lines. Querying bathymetry grids to select non-null cells and converting the query result into a shapefile created multibeam data coverage shapefiles. Coverage shapefiles were then simplified (polygons with Area_m2 < 100 were removed) by deleting all but 5 main polygons. Area fields (m^2) were added to the theme attribute table using the areacalcUTM_m2 tool provided by SFML.

Digital processing and mosaics of sidescan data was accomplished using the Isis Sonar and Delph Map software packages (Microimages, Inc., Lincoln, NE). Individual trackline files were replayed and bottom tracking of the sonar was supervised to aid in proper slant range correction. Sidescan sonar (SSS) files were snipped to remove portions with poor imagery from the beginning and/or end of the trackline. Tracklines were slant-range, layback (4.02), and lateral offset (-0.76) corrected and the position data for each line was smoothed using a speed filter. Each line was then gridded, georeferenced and exported from Isis Sonar/Delph Map in Geotiff format (1m pixel size, UTM Zone 10, WGS84). Individual SSS line tiff images were imported into TNT Mips GIS software and areas of poor image quality were extracted and removed. Individual tracklines were then overlaid to produce a mosaic image. Geotiffs were exported from TNT Mips at a1m resolution.

Data Analysis

Within ArcMap 8.3, the geomorphic analysis involved a georeferenced, geologic map of Santa Rosa Island's terrain overlayed onto a NOAA nautical chart of the island. The geologic map was paired with a 3m-grayscale multibeam bathymetry image off Carrington Point and used to make assumptions about the offshore underwater geology by way of a visual interpretation (Smith, Personal Communication). Rugosity and slope analyses were applied to the Digital Elevation Model (DEM) to classify habitat within Carrington Point's MPA and control site. Using the raster calculator extension within ArcMap 8.3, area of rocky substrate was calculated for the entire depth range of the MPA as well as the control. Area of rocky substrate was also calculated per site at a specified depth of 20 to 60m, for this is the preferred depth range for *H. sorenseni*. Through defining parameters of the type of habitat such as depth, rugosity, and slope values, the raster calculator would highlight cells within the 3m DEM that matched the query. Multiplying the number of cells that matched the query by 9, then dividing by 1,000,000. produced area values in km^2.

Rugosity

Locating areas of rough (rock) substrate was conducted using a rugosity analysis on the DEM. This habitat classification tool compares the surface to planar ratios giving smooth areas a surface to planar ratio of 1, while extremely bumpy areas reflect a ratio of 3. Rocky substrate both within Carrington Point's MPA and control site were classified by values of 1.5 and greater while values less than 1.5 were distinguished as smooth. Rugosity grids were generated using the ArcView 3.x extension Surface Areas and Ratios from Elevation Grids (Jeness, Jeff 2003).

Slope

The slope function calculates the maximum rate of change in elevation between each cell and its neighbor. Values range from 0 to 90 degrees. The lower the value, the flatter the surface. Using the Spatial Analyst extension within ArcMap, the slope was calculated using the DEM. The raster calculator extension within ArcMap was used to help classify habitat with a slope greater than 5 degrees.

Random Sampling

In order to compare habitat in Carrington Point's MPA with that of its control site, randomly sampled points for each site were generated using the Generate Randomly-Distributed Points extension (Lead, Stephen 2003) in ArcView 3. Twenty points per site were randomly distributed throughout the entire depth range (6.3 - 88.3m), for these are the depths at which *S. serronoides* and *O. elongates* inhibit. Twenty points were again randomly distributed for each site within the 20 - 60m depth interval, as this is the preferred depth range for *H. sorenseni*. All points were then added from within ArcMap 8.3 and overlayed onto site-specific habitat shapefiles. Using the Buffer Wizard tool, a 250-meter buffer was applied to each point. The buffered polygons were then intersected with each site's habitat shapefile via Geoprocessing Wizard. Area of habitat that fell within the intersected polygons was then calculated using the areaUTMcalc tool provided by the SFML. Values from the calculated area (m^2) of both the MPA and control sites enabled a two-tailed t-test to be conducted using specific formulas created in Excel. This statistical approach allowed for a comparison of habitat within the MPA versus control (Brower et al.1997).

RESULTS

Geologic Interpretation of MPA and Control Rocky Habitats

A 3-meter multibeam bathymetry image **(Figures 4 and 5)** of the entire study site revealed a depth range of 6.34 to 88.3 meters. Using multibeam bathymetry data with a vertical precision of 1m along with sidescan sonar imagery **(Figures 6 and 7)**, the geology offshore at Carrington Point was identified and linked to the island's terrestrial geology. Visual interpretations of both onshore and offshore geologic structures may suggest that the east-west oriented family of faults on and offshore played no significant role in the development of the MPA and control site habitats. West of Carrington Point, offshore structures appear to dip towards the coastline exposing San Onofre breccia to the north and Rincon formation and Vaqueros sandstone further west. If the structure seen on land is chiefly a homocline that extends offshore, then the well-bedded strata forming the submarine ridges include these formations: Monterey shale, Santa Cruz Island volcanics, Rincon Formation and Vaqueros Formation. Following the Rincon formation and Vaqueros sandstone are older substrates consisting of the Sespe and Cozy Dell formations. Folding south of the San Onofre breccia may also suggest that this area consists of the Rincon Formation and older substrates of the Vaqueros, Sespe, and Cozy Dell formations. East of Carrington Point young sediment deposits were believed to be identified using the multibeam bathymetry image and is believed to be linked to the shoreline's Beechers Bay formation. A local outcrop of jointed rocks was also apparent in the upper portion of this area; that outcrop may be Upper Cretacious diorite or schist, which is present in the nearby terrestrial geology. Extending to the outer depths of Carrington Point's MPA and control sites, marine terraces that were once above sea level now lie below the surface.

At this time the geology of the seafloor of the Carrington Point MPA and control site is believed to comprise recent sedimentary deposits underlain by Tertiary sedimentary rocks and Mesozoic igneous rocks. The entire study site contains two families of faults: 1. east-west oriented left-lateral slip faults and 2. northwest-southeast trending faults whose dominant slip direction is unknown. The northwest-southeast faults contain a downward, north dip-slip component range of approximately 20 to 80 meters. Both families of faults are believed to have had no significant role in the development of Carrington Point's offshore MPA and control site geology **(Figure 8)**.

MPA and Control Site Rocky Habitat Comparison

Slope for the entire surveyed region showed most of the habitat as having values between 5 and 11 degrees. This also holds true for the habitat within the 20 to 60m-depth range **(Figure 9)**. Rugosity for the entire surveyed site fell in the range of 1 and 1.87 with the majority of habitat within both Carrington Point's MPA and control retaining values between 1.1 and 1.5. This classifies most of the habitat as neither highly rugose nor smooth, meaning the habitat contains a medium rugosity and is not considered to be smooth or rough and bumpy **(Figure 10)**. This holds true for the rugosity between 20-60m. The majority of habitat within this depth range was classified as also having a medium rugosity.

Results from the randomly generated points showed the total area of habitat within the buffered regions of Carrington Point's MPA to be 0.32 km^2 with percent cover of habitat amounting to 0.08%. Total area of habitat within the buffered regions of the control site was 0.38 km^2 with percent cover of habitat equaling 0.10% **(Table 2)**. Within the 20 to 60m-depth zone of the MPA, the total area calculated within the buffered regions was 0.47km^2 with a

0.12% cover of habitat. Within the 20 to 60m-depth zone of the control site, the total area calculated was 0.38km^2 with a 0.10% cover of habitat **(Table 2)**.

Using area calculations from the twenty buffers generated for the entire depth range within each the MPA and control site **(Figure 12)**, the two-sample testing method revealed a t-value of 0.58 which is much lower than the t_{crit} value of 2.09 (Brower et al, 1997). Due to the t-calculated value being lower than the $t_{crit,}$ there is a high probability that the two sample means (MPA and control) are similar. In this case the null hypothesis is accepted with $p > 0.05$, meaning there is a low probability the two sample means are different.

Within the 20 to 60m-depth range of the MPA and control site, the two-sample testing method revealed a t-calculated value of 0.97, which is lower than the t_{crit} value of 2.09 (Brower et al, 1997). As a result, there is a high probability that the two sample means between 20 to 60m (MPA and control) are similar. The null hypothesis is accepted with $p > 0.05$; therefore the probability that the two sample means are different at depths of 20 to 60m is very low.

Table 2. Carrington Point, Santa Rosa Island habitat distribution by species of concern.

Species of Concern	Common Depth Range	Preferred Habitat	MPA Available Habitat at Depth		Control Available Habitat at Depth	
			Area (km^2)	% Rock Habitat	Area (km^2)	% Rock Habitat
White Abalone (*Haliotis sorenseni*)	20 - 60 m	Rock	6.87	30.6	2.90	21.5
Olive Rockfish (*Sebastes serranoides*)	3 - 190 m	Rock	8.73	21.6	4.18	19.2
Lingcod (*Ophiodon elongatus*)	0 - 106 m	Rock	8.73	21.6	4.18	19.2

Carrington Point, Santa Rosa Island, California

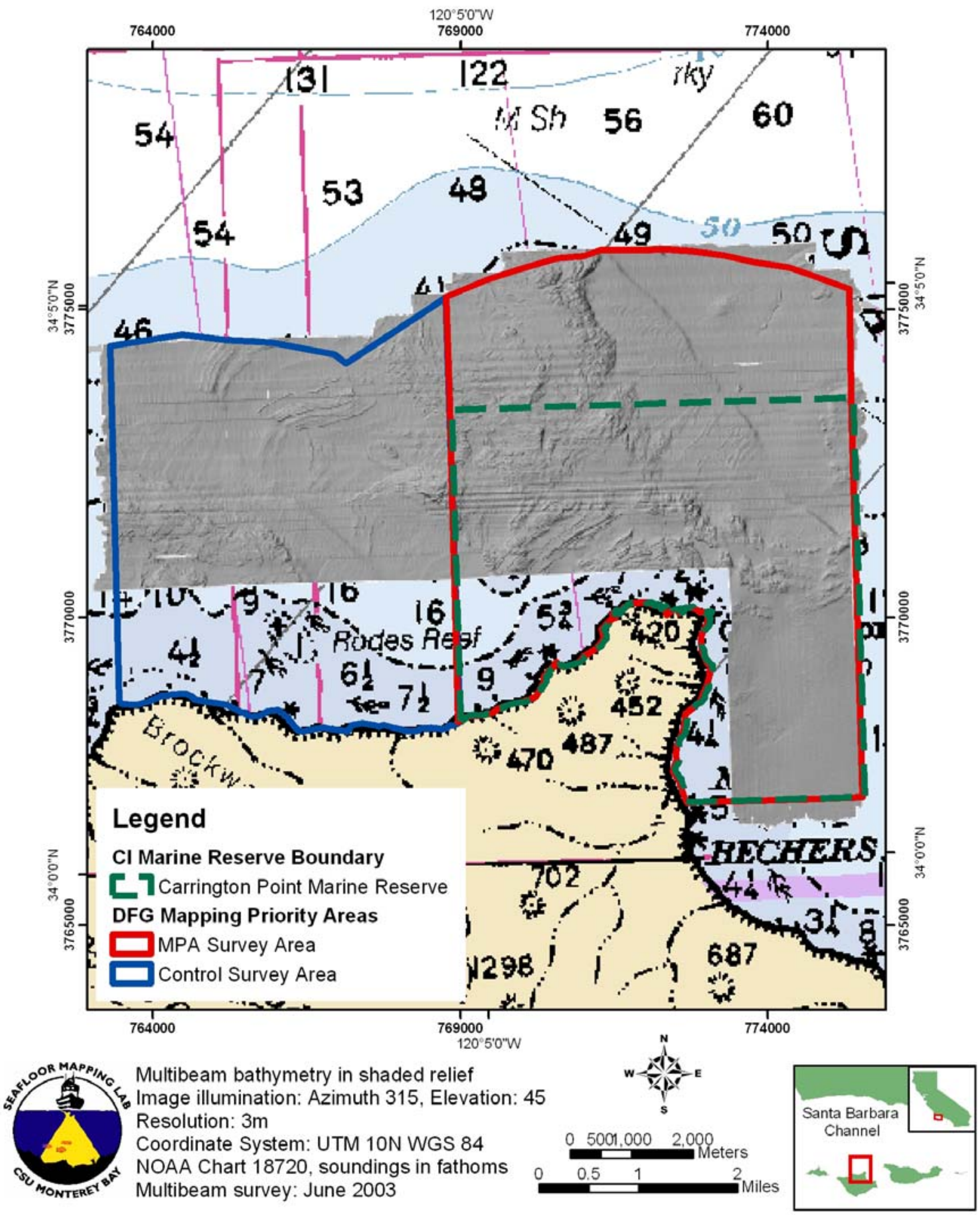


Figure 4. Multibeam bathymetry data in shaded relief for Carrington Pt., Santa Rosa Island.

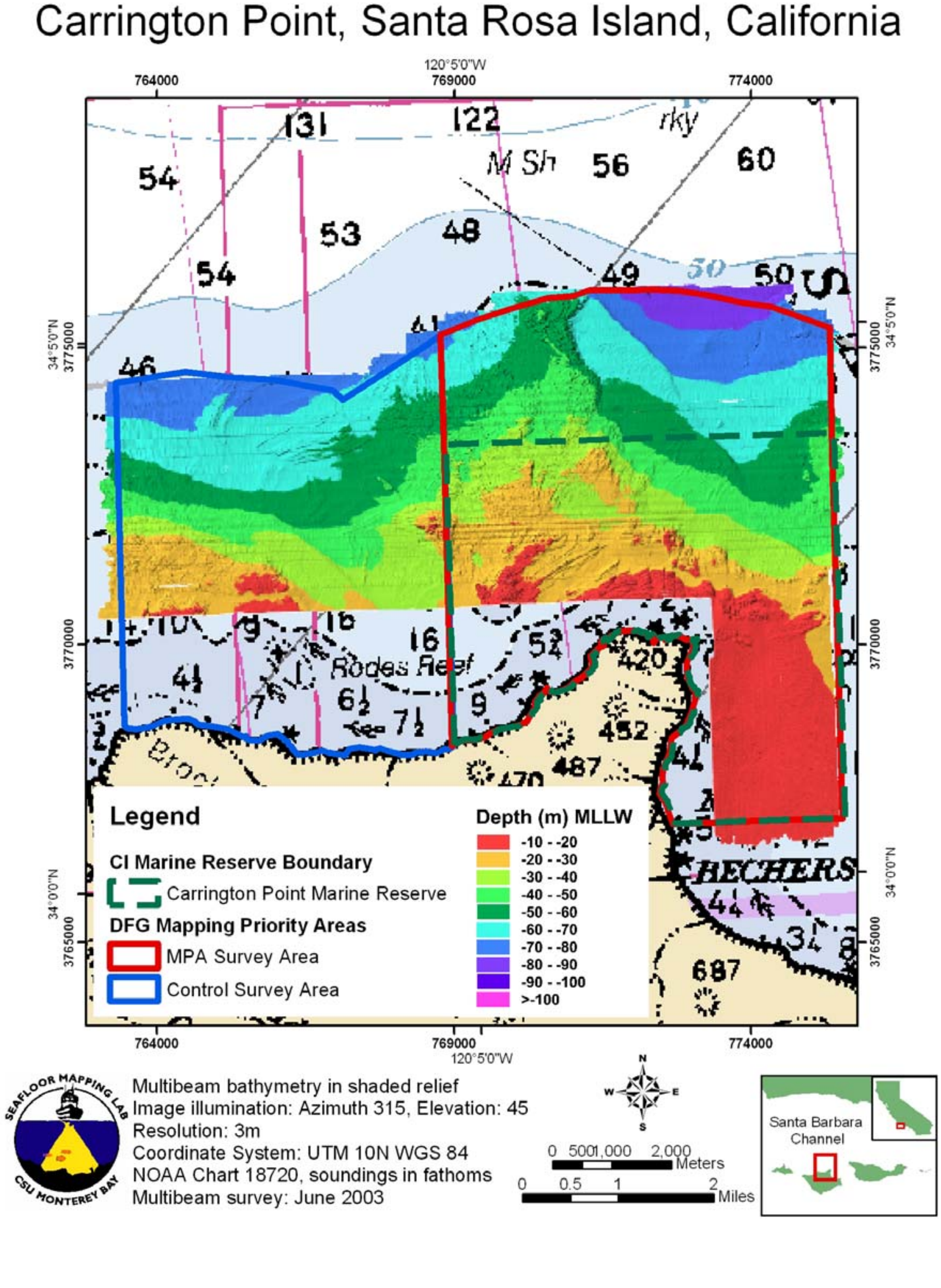


Figure 5. Multibeam bathymetry in shaded relief, colored by depth for Carrington Point, Santa Rosa Island.

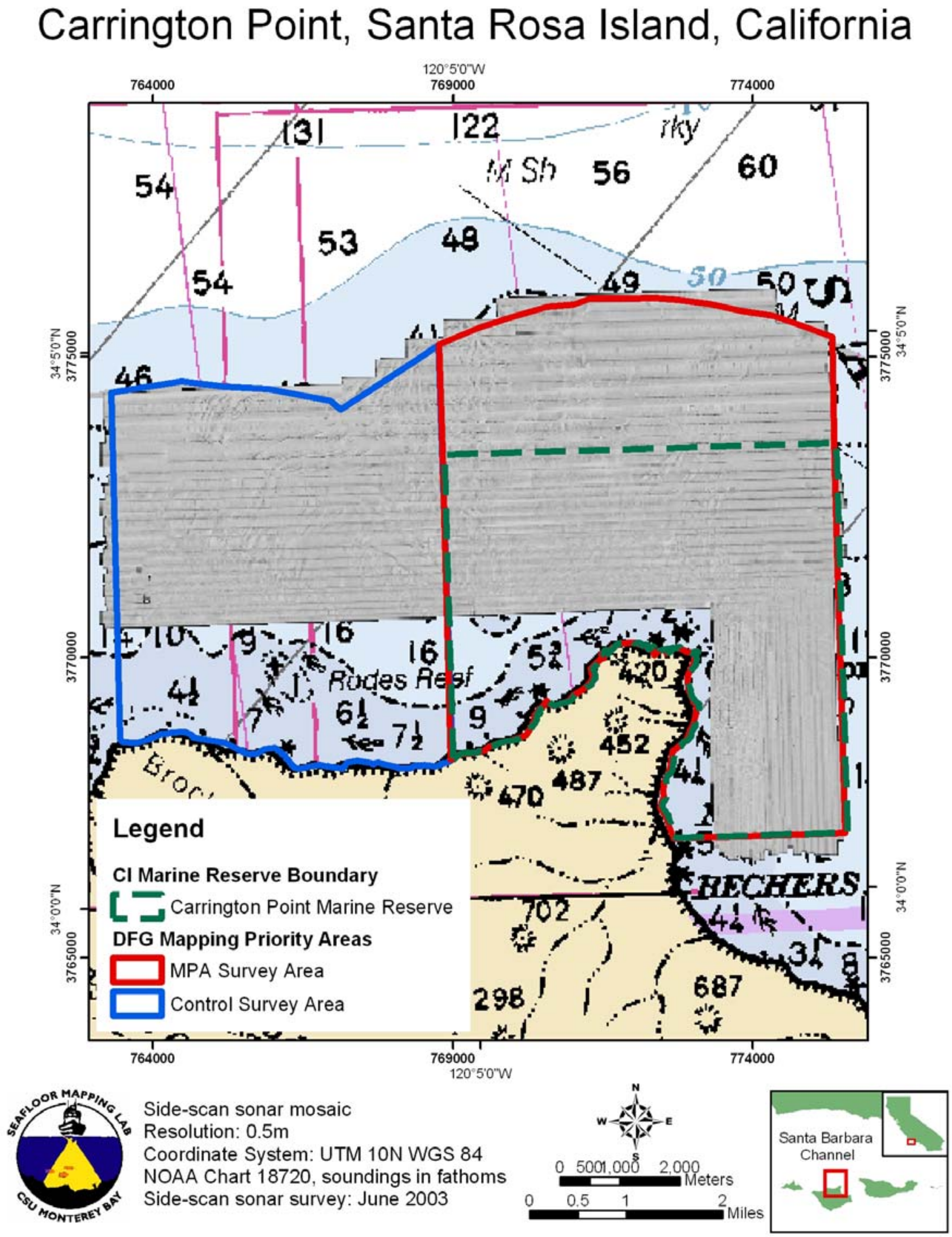


Figure 6. Sidescan sonar mosaic for Carrington Pt., Santa Rosa Island.

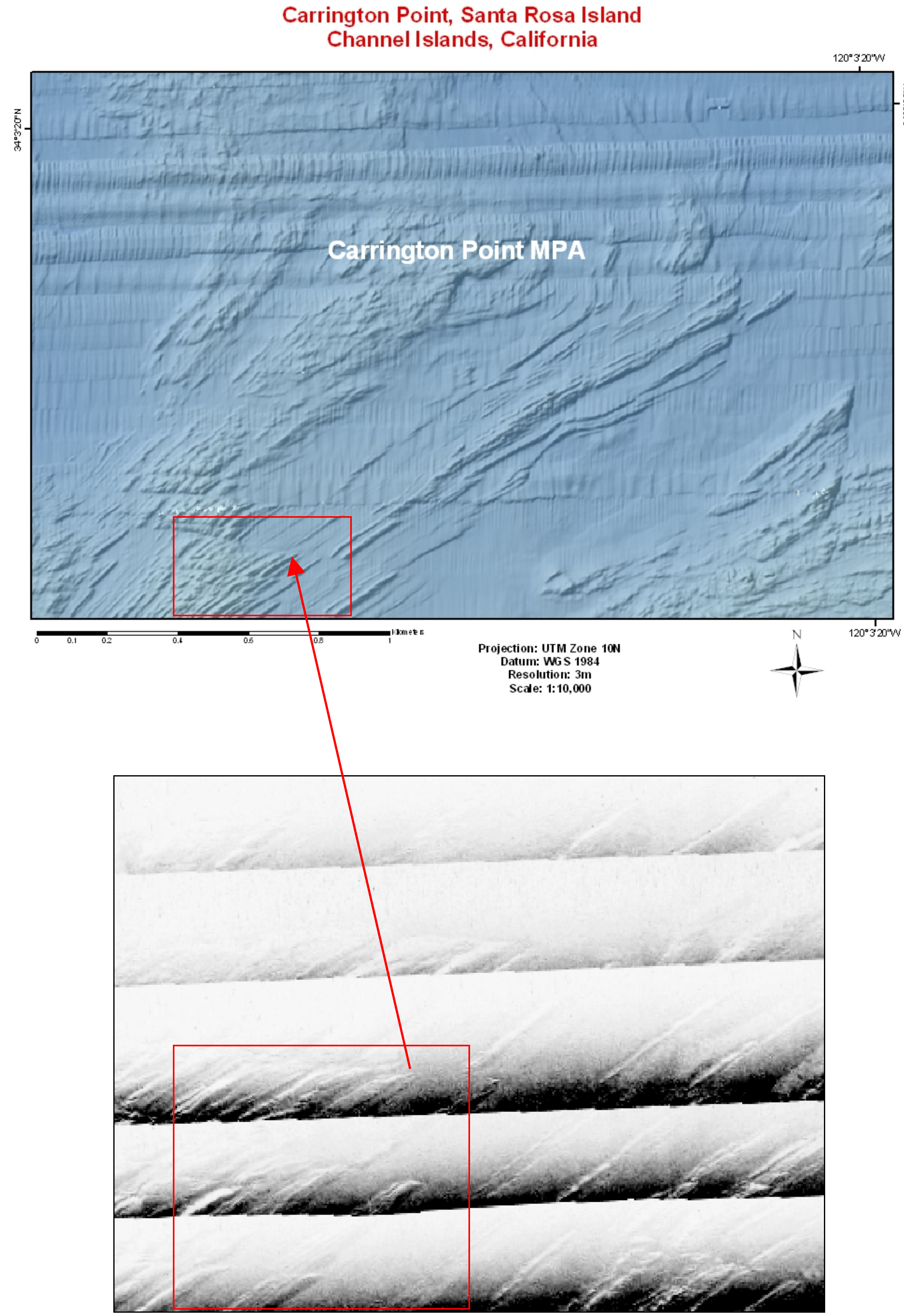
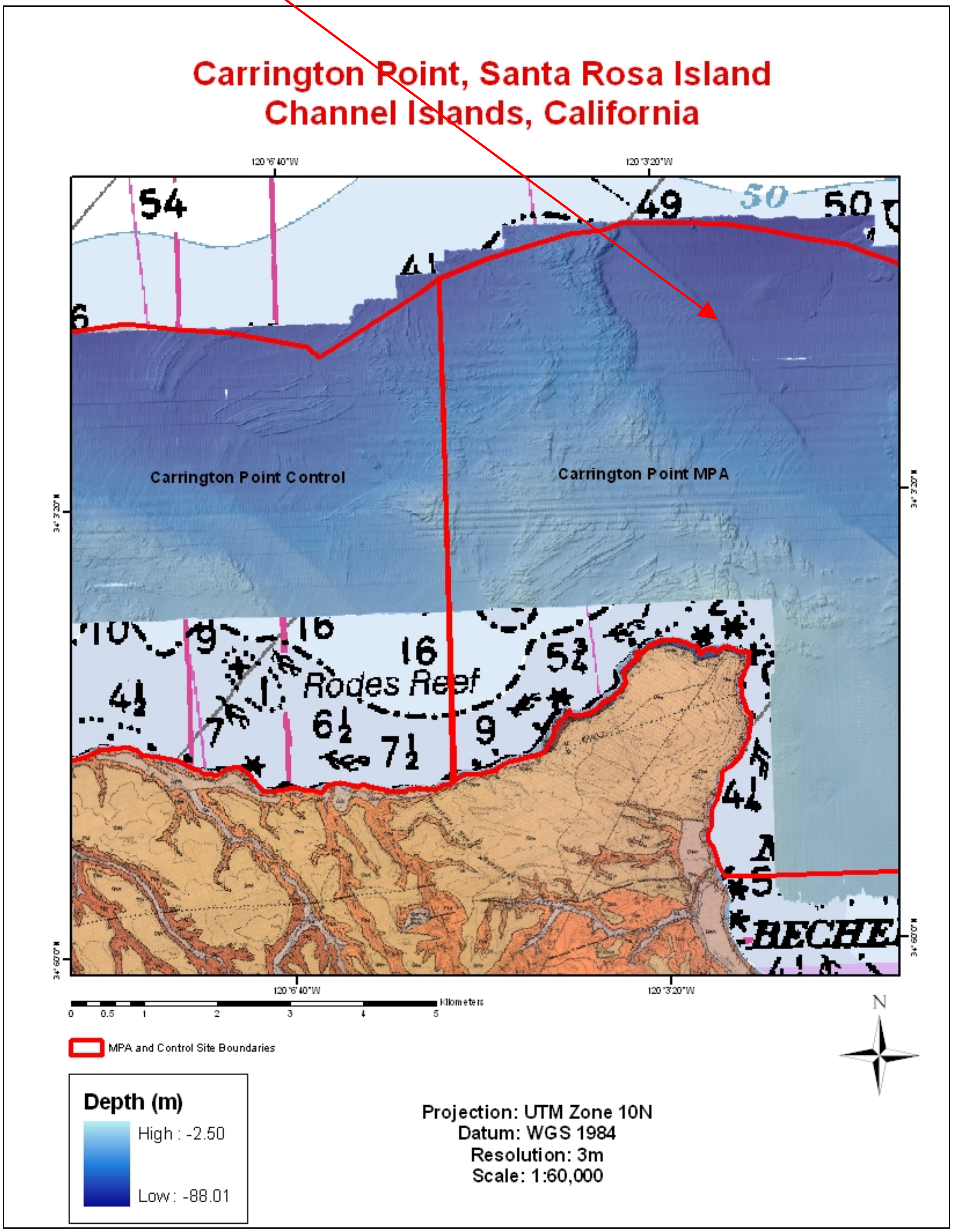


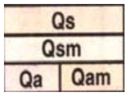
Figure 7: Rocky habitat identified using sidescan sonar image.

Figure 8: Northwest-southeast fault believed to have played no significant role on the development of the underwater geology at Carrington Point. Geologic map of Santa Rosa Island courtesy of Dibblee, 1998

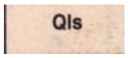


Geologic legend based on Dibblee geologic maps, 1998.

Surficial Sediments

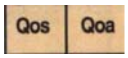


Qs – beach sand
Qsm – wind-deposited sand on coastal terrain
Qa – alluvial gravel, sand, and silt
Qam – alluvium on coastal marine terrace



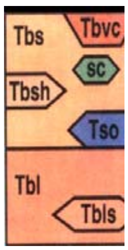
Qls – landslides

Older Surficial Sediments



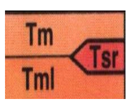
Qos – dune and drift sand
Qoa – elevated, dissected terrace of older alluvium

Bechers Bay Formation



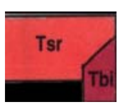
Tbs – bedded sandstone
Tbvc – volcanic conglomerate-breccia
sc – lenticular mass of gray schist
Tbsh – siltstone-shale
Tso – bedded conglomerate breccia (San Onofre Breccia) composed of basaltic, andesitic, and Dacitic volcanic rocks
Tbi – fine-grained sandstone with interbeds of Shaly siltstone
Tbls – fine-grained sandstone

Monterey Shale



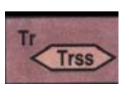
Tm – siliceous shale
Tml – siliceous shale which underlies **Tsr** where present

Santa Rosa Island Volcanics



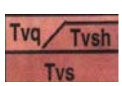
Tsr – basaltic volcaniclastic rocks
Tbi – intrusive basalt-diabase

Rincon Formation



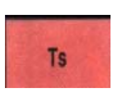
Tr – clayshale, siltstone and claystone
Trss – gray, fine-grained sandstone

Vaqueros Sandstone



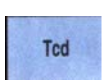
Tvq – medium gray, fine-grained sandstone that includes **Tvsh**
Tvsh- gray claystone and siltstone
Tvs – light-gray sandstone

Sespe Formation



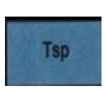
Ts – light brown, reddish, pinkish to greenish sandstone which includes a thin layer of claystone

Cozy Dell Formation



Tcd – micacious gray clay shale

South Point Sandstone



Tsp – tan, hard, medium-grained arkosic sandstone

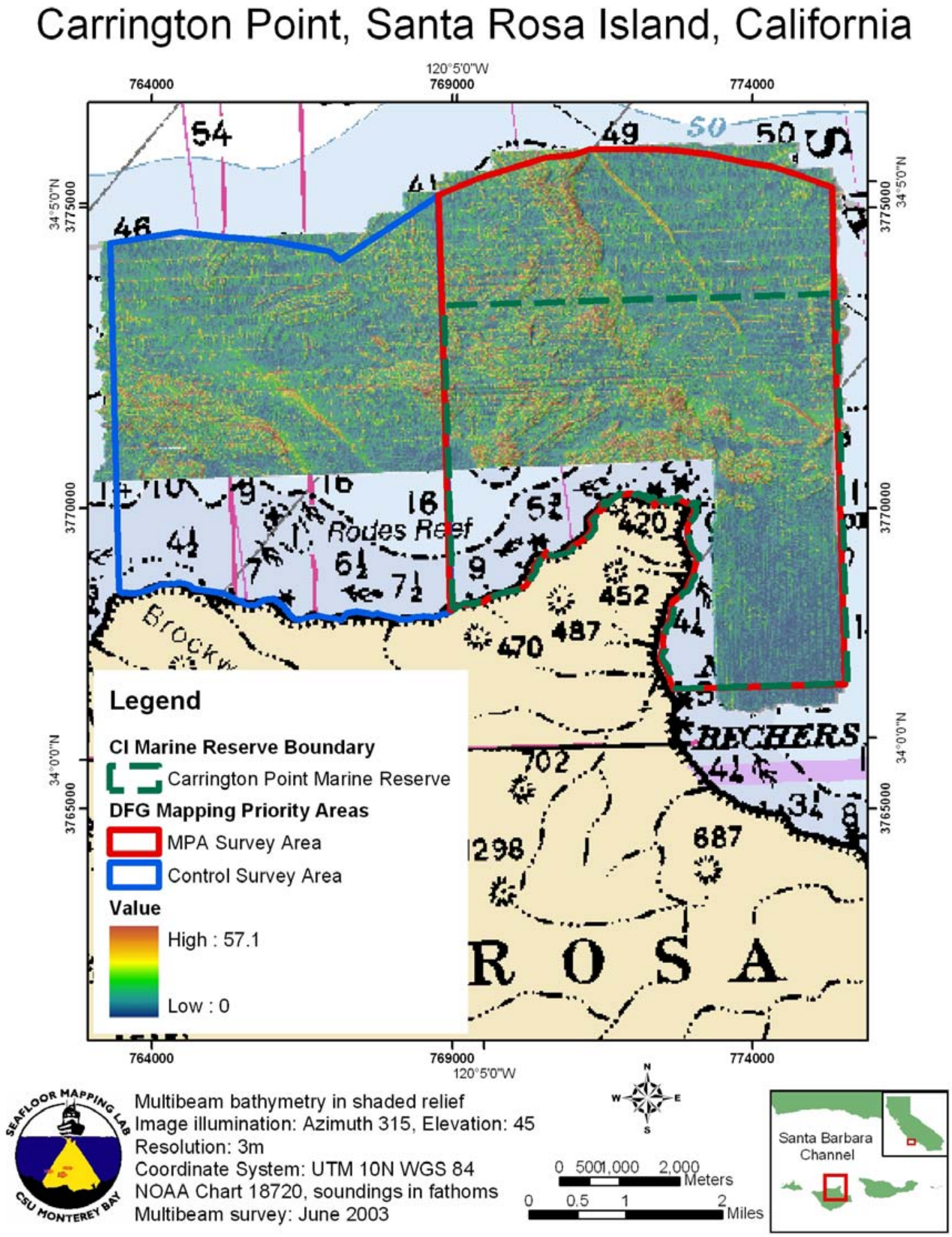


Figure 9. Slope analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.

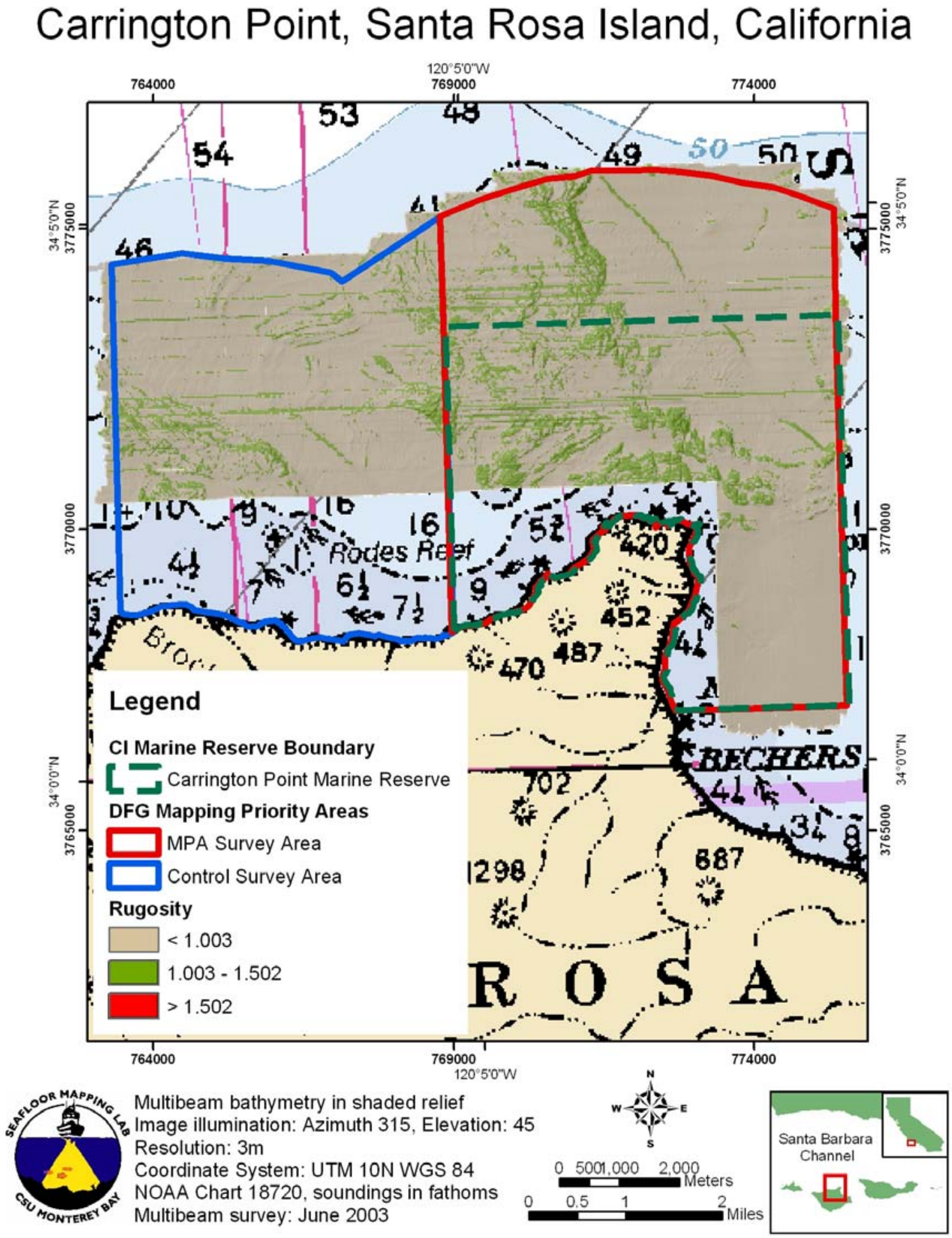


Figure 10. Rugosity analysis of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.

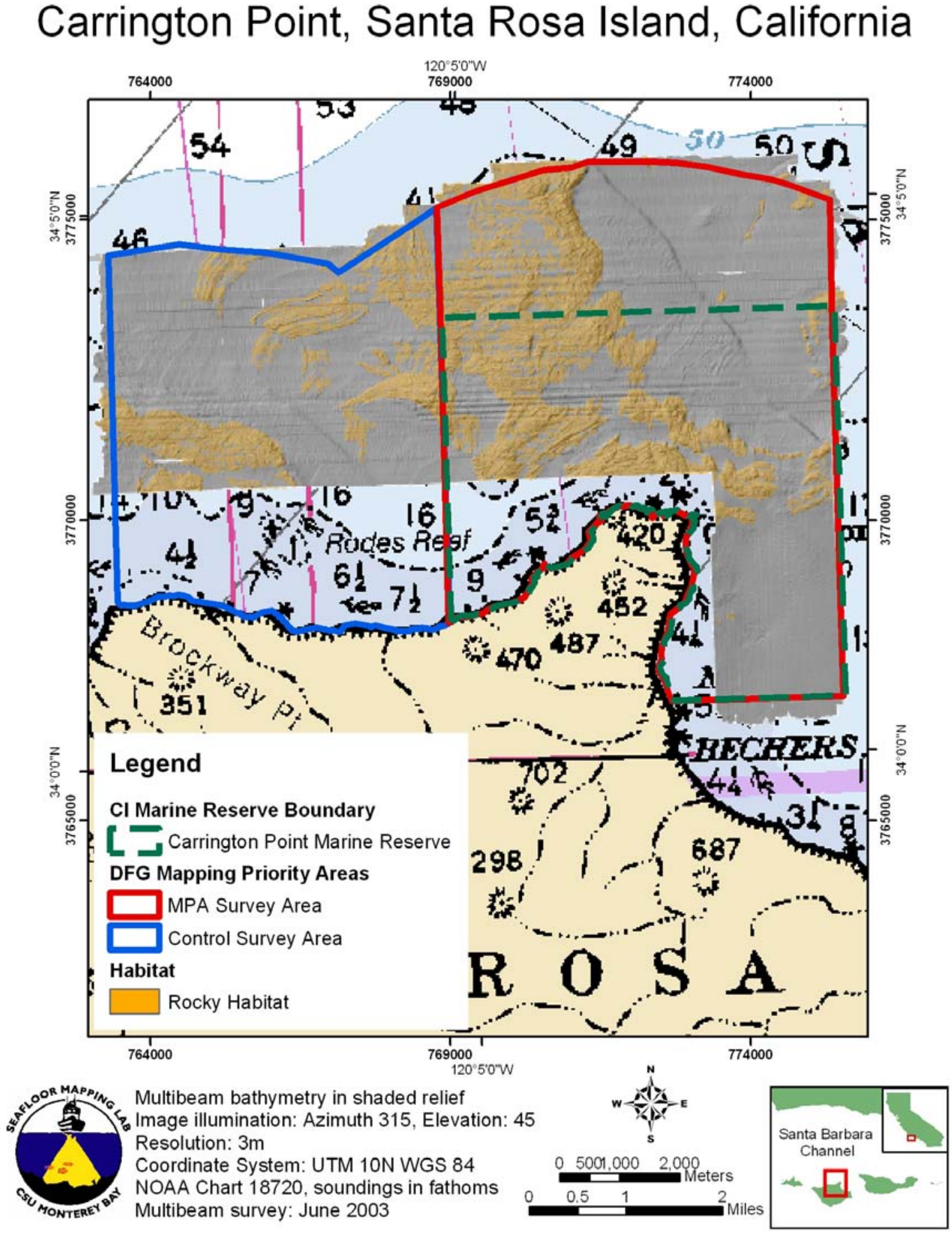


Figure 11. Rocky habitat map derived from slope and rugosity analyses of the multibeam bathymetry DEM for Carrington Pt., Santa Rosa Island.

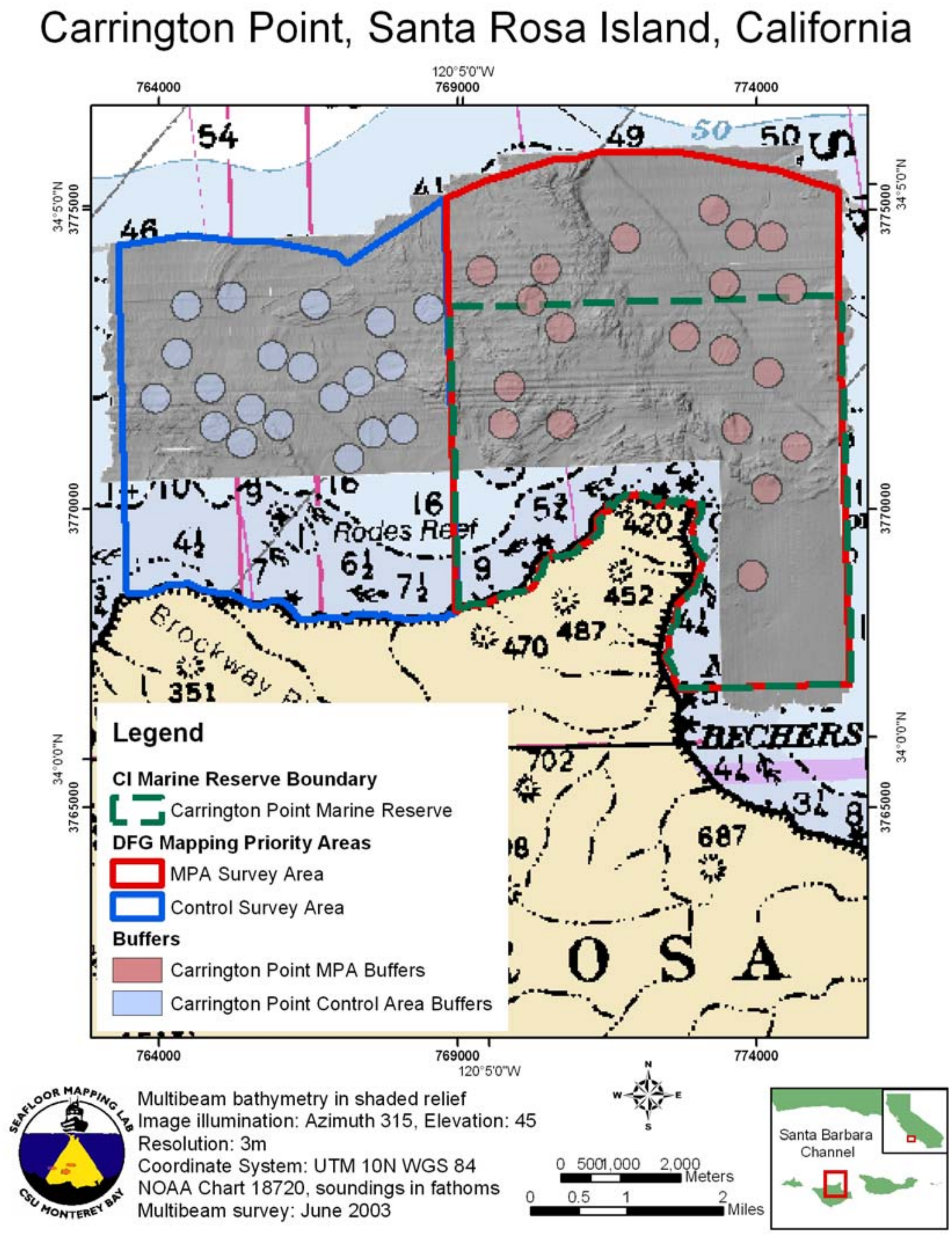


Figure 12. Buffers (250 m radius) placed around randomly generated points used to sample and compare the habitats at the Carrington Point MPA and control site.

DISCUSSION

Characterizing the habitat for Carrington Point's MPA and designated control site distinguished enough similarities between the two sites, suggesting the control site is suitable for evaluating the performance of its MPA. Although Carrington Point's MPA is almost twice the size of its control (40.34 km^2 and 21.76km^2 respectively), the percent cover of habitat relevant to each site are comparable according to the statistical analysis. Optimal habitat for species such as the white abalone (*Haliotis sorenseni*), olive rockfish (S*ebastes. serranoides*), and lingcod (O*phiodon elongates*) showed to be equivalent between the MPA and control **(Table 3)** suggesting that ample habitat is available for each species of interest. Based on a geomorphic visual analysis of the entire study site, it is assumed that the same geologic process formed equally the MPA and control site during the Cenozoic era. As a result similar rock formations can be found in both the MPA and control.

Table 3: Available habitat for species of interest within Carrington Point's MPA and control site.

Species of Concern	Common Depth Range	Preferred Habitat	MPA Available Habitat at Depth		Control Available Habitat at Depth	
			Area (km2)	% Cover	Area (km2)	% Cover
White Abalone (*H.sorenseni*)	20 - 60 meters	Rock	0.47	12	0.38	10
Olive Rockfish (*S. serranoides*)	3 - 190 meters	Rock	0.32	8	0.38	10
Lingcod (*O. elongatus*)	0 - 106 meters	Rock	0.32	8	0.38	10

Utilizing multibeam bathymetry in conjunction with GIS to classify habitat and interpret geomorphologic processes of underwater regions may give fisheries managers a clearer view of areas they designate as MPAs. This can also help to justify placement of MPAs based on habitat availability. The application of remote sensing technology to not only Carrington Point's MPA, but to other designated MPAs within the Channel Islands will be essential in determining proper sites for the placement of monitoring stations by fisheries managers. Such monitoring stations will be responsible for assessing environmental changes within and beyond MPA boundaries as well as the performance of individual MPAs. While many people and agencies including the WWF, IUCN, and UNEP believe MPAs are crucial in protecting marine ecosystems, resources, specific fisheries and biodiversity, there are also critics who feel the role of "uncertainty" may hinder the potential of MPAs.

Among many factors that contribute to fisheries management failures, the role played by uncertainty is an important aspect that needs to be addressed in greater detail (Doyen and Bene 2003). According to Charles (1998) uncertainty can be classified primarily in three forms: random fluctuations like those affecting fish survival rates or fish prices in the market; uncertainty in parameter estimates and nature of stock size and fish mortality; and structural uncertainty that reflects multi-species interactions like predator-prey effects. MPAs may fail to protect populations and marine ecosystems from major threats to the marine environment. These threats or "uncertainties" can arise through the spreading of exotic species, disease epidemics, and/or coastal modifications leading to the subsequent changes in local hydrodynamic and sedimentary regimes (Allison et al. 1998). Uncertainties were not the focus of this study and therefore are not included in this report.

Marine reserve planning for specific species is difficult because of limited demographic data (Gerber et al. In Press); therefore reserves alone cannot deliver sustainable fisheries. They must be complemented with reduced fishing efforts and clearer provisions of fishing rights and responsibilities. By protecting and restoring the productive capability of marine ecosystems, reserves can establish a base for which other tools in management can build upon (Gell and Roberts 2003). Determining the efficacy and proper site placement for MPAs and their control sites is one tool that will lead to the establishment of better fisheries management. The creation of spatially explicit habitat maps from multibeam bathymetry and GIS will continue to play a key role in habitat classification based on geomorphologic interpretations. Information provided by these methods will be crucial to fisheries managers as they begin efforts to implement long-term monitoring programs that will evaluate the performance of MPAs.

Utilizing explicit geospatial habitat maps generated from multibeam bathymetry data, allows underwater regions to be examined in great detail. Images displayed at high resolutions, such as 3m in this study, provide opportunities for more precise analysis and classification of specific habitats located beneath the surface of the ocean. In determining percent cover and distribution of rocky habitat within Carrington Point's MPA and control site, the estimation of rocky habitat maybe highly conservative. Only those areas that met the stringent criteria established for both slope and rugosity analyses were included to insure the most rigorous statistical comparison of habitat distributions within the MPA and control. There are many geomorphic features visible in the shaded relief images that may well be rocky habitat, but the definitive classification of these features as rock will require additional inspection and interpretation of the data in conjunction with video ground truthing of the site using ROV survey techniques. The algorithmic approach used for classifying rocky versus soft-sediment habitat was configured to minimize the misclassification of artifacts caused by boat motion, thus insuring the most reliable comparison of the MPA with their controls. This source of error should be strongly considered if attempts to regenerate these results are made. As technology continues to improve, artifacts (due to heavy seas and kelp in this case) during data collection may be minimized. Acoustic remote sensing along with GIS has allowed and will continue to allow scientists to examine the underwater world with more efficiency and clarity then ever before.

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