Use of multi-beam bathymetric data to compare suitability of Marine Protected Areas with their control sites within the Channel Island MPA Network

A Capstone Project Presented to the Faculty of Earth Systems Science and Policy in the Center for Science, Technology, and Information Resources at California State University, Monterey Bay in partial fulfillment of the requirements for the Degree Bachelor of Science

By

Bryan Jones

April 14, 2004

To the ESSP Faculty:

Exploitation of our world's oceans becomes worse everyday. The degradation of fish stocks will continue to frustrate managers until an alternate management tool becomes available. The use of networked Marine Protected Areas (MPAs) as a management tool will allow for an ecological approach to fisheries management. Traditional single-species management strategies treat not only fish stocks, but also ignore the community in which they live. The Channel Island National Marine Sanctuary (CINMS) is home to the largest network of MPAs on the west coast, and third in the world. To measure the effectiveness of these MPAs, control sites were assigned to each of the MPAs within the network without prior knowledge of potential habitat within each area. The goal of this study was to compare habitat similarities between MPAs and control sites by way of bathymetric data and GIS analysis techniques in order to establish a relationship of comparable habitat.

The California State University, Monterey Bay (CSUMB) Sea Floor Mapping Lab (SFML) led by Rikk Kvitek, carried out survey operations from the National Park Service's R/V Pacific Ranger in June 2003. My role in this project has been to complete the post-processing and analysis of multibeam bathymetric data and creation of interpretive maps. This project is of critical importance to several stakeholders: California Department of Fish & Game (CDFG), California Fish & Game Commission (CFGC), and National Oceanic and Atmospheric Administration (NOAA), Channel Island National Parks (CINP), Channel Island National Marine Sanctuary (CINMS), and The Nature Conservancy (TNC) for the monitoring and management that may influence policy designed to protect future fish stock populations.

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

Through the duration of this project, I had calculated and analyzed a variety of digitally created maps and created statistical support for each of the claims yet mentioned. The accuracy and analysis of these products demanded that I had a greater understanding for the geological, and geospatial environments surrounding my sites.

The work that I was able to put forth has offered ideas of future career avenues and some potential employer contacts. I was honored (maybe, a little intimidated at first) to work under Dr. Rikk Kvitek head of CSUMB's Seafloor Mapping Lab. The work that comes out of the SFML has high expectations for quality, which is why Rikk and team lead the way for innovative and technologically advanced work, I hope that my work will live up to the labs' reputation. I know that this line of work is leading the way for future ecological, socio-economical and geomorphological studies that will broaden our knowledge of our unknown water communities aiding the preservation of life on this planet.

Thank you for your time and energy to review this report and its contents.

Sincerely,
Bryan Jones

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Abstract

Marine Protected Areas (MPAs) are established in an effort to manage natural marine resources and limit anthropogenic impacts on marine ecosystems. Assessing the effectiveness of MPAs can be challenging. Monitoring species diversity and abundance between MPAs and control sites (open to standard fishing rules and regulations) of similar physical structure can aid in determining the ecological, as well as socioeconomic, value of MPAs. The goal of this project was to assess the effectiveness of a control by evaluating habitat similarity between designated MPAs and adjacent proposed control sites in the Channel Islands Marine Protected Area Network (CIMPA) off of Southern California. Three priority-mapping sites in the CIMPA network, including the MPA areas and coupled control sites, were selected by California Department of Fish & Game and the California Fish & Game Commission. High-resolution mapping of marine habitats using multibeam and sidescan sonar systems aid in the identification of geologic structure of MPAs and control sites, and help facilitate habitat interpretation of those areas. Statistical analysis was used to support and reject assumptions of similarity of habitat quantity and type between MPA and adjacent control sites.

Introduction

Widespread awareness to the degradation of the world's oceans is calling for advancements in management, maintenance, and restoration of our marine ecosystems (Lubchenco 2003). Exploitation of our oceans resources has led to dramatic changes in the structure and productivity of marine ecosystems (Fogarty 1989). About 45% of U.S. fish stocks whose status is known are either overfished or approaching an overfished condition (NMFS 1999), and between 69-74% of global fish stocks are overfished or fully exploited (FAO 1998). Single species management has contributed to failure of sustainable fisheries because the general scope of regulations does not include the critical ecological linkages between species and the environment (Airame 2003).

Single species management falls under traditional fisheries management techniques, also called general fishing regulations. General fishing regulations are published at the beginning of each year to describe size limit, catch (bag) limit, seasonal closures, and gear restrictions for each sport/commercial species. Individual regulations for each species are designed to protect the future populations of the fishery. The federally regulated Pacific Fishery Management Council (PFMC) defines the basic fishery management structure for each costal state. Local fish and Game authorities can increase the restrictions on individual species based on their research, though they do not have the authority to make the regulations more lenient. The problems with many of these practices is they only target single species and ignore the relationship the species have with their environment (Lubchenco 2003, Grantham 2003). Gislason (2000) noted "It no longer suffices to focus on the sustainable yield of the target species itself; the impacts of fishing on the structure and functioning of the ecosystem have to be considered"

Lubchenco (2003), in a report to congress, stated that by protecting geographical areas, marine reserves offer an ecosystem-based approach to conservation or fisheries management, in contrast to traditional focus on singe species conservation or management. Lubchenco (2003) went on to describe the multiple benefits reserves possess: protection of habitat; conservation of biodiversity; recovery of depleted stocks of exploited species. This relevant and abbreviated list highlights the need for fisheries management within marine reserves.

Marine reserves or no take zones have been proposed as an effective and inexpensive way of preserving biodiversity (Halpern 2003). Marine reserves protect marine communities by using zonal closures rather than single species limitations. Marine Protected Areas (MPAs) house different types of restrictions and levels of marine reserves, which can address these problems by managing human activities in certain areas. MPAs are internationally recognized as a means for conserving natural, historic, and cultural marine resources (NOAA). Through MPA management, certain commercial, recreational, and navigational usage may be restricted in order to fulfill the specific mission of that MPA. Until recently marine reserve boundaries were defined without prior consideration of existing biota or habitat (Halpern 2003).

Ocean conservation is a relatively new concept. Defining boundaries of water as reserves, or parks, is a product of this century. In fact, it was not until 1970s and 1980s when several bodies of water were classified as reserves and then later elevated to Sanctuaries (Ugoretz, 2002). NOAA in 1980, with many other organizations defined the boundary for the 1,252 square-nautical-mile Channel Island National Marine Sanctuary (Ugoretz, 2002). The Sanctuary includes the five most northern Channel Islands: San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara. The Sanctuary continues to set conservation standards and acts as a major support for further conservation efforts.

In October of 2002, CDFG and the CFGC jointly established the largest network of marine reserves housed in the Channel Island National Marine Sanctuary off the US west coast. A total of twelve areas designated, as MPAs were set around the northern Channel Islands, imposed by the California Department of Fish & Game (CDFG) and the California Fish & Game Commission (CFGC) encompass 465 square km within the Channel Island National Marine Sanctuary (Ugoretz, 2002). Now that the CDFG has established the MPA network, resource managers and stakeholders expect to see major benefits in the short term, *E.g.* a 5-year timeframe was proposed do determine efficacy of no-take zones in the Channel Island Marine Sanctuary (Gerber 2002). The MPAs were ranked from one to twelve in order of interest (Ugoretz, 2002). The top three MPAs were given control sites that are directly adjacent to the MPA. Each of the three control sites remain true to standard fishing rules and regulations, unlike their MPA. The DFG is attempting to measure the long-term effects of habitat and ecological biodiversity of the MPAs and compare these data to similar habitat locations in the control sites.

Because the establishment of MPAs is relatively new and there is limited field derived data yet that supports their effectiveness, there are many opponents to the formation of additional MPAs and the restrictions they impose. A mathematical study conducted in 2000 supported the concept of MPA designation. A French environmentalist and an English mathematician were able "to study the influence of protected areas upon fisheries sustainability… using the mathematical concept of invariance kernel in a robust and worst-case context, … a formal modeling analysis [shows] how marine reserves might guarantee viable fisheries" (Doyen, 2003). This study provided compelling evidence for MPA success using repeated computer modeling permutations.

Without knowing the geomorphology that lies within the designated MPA or its control site, the DFG may be trying to compare apples to oranges. Another example shows that areas with diverse marine geomorphology have higher biodiversity (Brodeur, 2001). It is important that the control site have similar structure as its MPA, in order for the control to be a useful comparison tool. The control will allow comparison, if similar to MPA, of like habitat within an area outside the MPA to assess its effectiveness.

Purpose

The purpose of my study was to classify and describe the marine habitats of MPA and control sites for Gull Island (Fig. 1) and South Point (Fig. 2) within the Channel Island Marine Protected Area Network. Habitat type and coverage data will be analyzed to determine level of similarity in habitat distribution and type. Control sites must have similar geologic structure and quantity of habitat as the MPAs to be suitable locations for comparison. Final products were created that determined seabed habitat within MPA and control structure via GIS, multibeam and Sidescan analysis. Statistical analysis using a random point generator, allowed us to establish electronic quadrats to query data and test for similarities.

Methods

The California State University, Monterey Bay (CSUMB) Sea Floor Mapping Lab (SFML) led by Rikk Kvitek, carried out survey operations from the National Park Service's R/V Pacific Ranger in June 2003. Multibeam bathymetry data was collected using a Reson 8101 Seabat multibeam sonar system. Survey transects were plotted in Hypack 8.9 navigational software. A Trimble 4700 global positioning system (GPS) and ProBeacon receiver generated vessel locations for data post-processing. A TSS POS/MV motion sensor accounted for data variations due to vessel movement: roll, pitch and heave (heading accuracy $\pm$ 0.02^0, heave accuracy + 5^{0}cm). Water density was measured with a Sound Velocity Profile (SVP), which was applied to the data to correct for speed variations in the soundings. Tide corrections were also applied to the data using NOAA software that inserts predicted tidal changes.

The processing of all data was done in the SFML facilities using Caris Hips and Sips hydrographic software. Erroneous data points such as vibrations in the boat, debris in the water, animals in the water, etc were flagged as 'noise' and were removed during post-processing. Edited data was then exported and displayed using ArcMap allowing spatial analysis of produced Digital Elevation Models (DEMs).

ArcMap 8.3 allowed visual and mathematical analytical functions to show differences in slope and texture by creating different DEMs. Functions were run against the DEMs to measure the slope and rugosity of the overall rocky habitat and again at specific depth ranges. The DEMs created have a cell size of 3m. Slope takes an individual cell and compares its value to the elevation of its surrounding eight neighbors and returns a value between 0 and 90 degrees. Rugosity is the roughness, or texture of a surface. Rugosity was calculated by measuring actual surface area of an individual cell and divided that value by the planer equivalent value for the same cell. That ratio describes the texture for that cell and the value produced was greater than one and less than infinity. It is important to note that the values for rugosity that were greater than 6 were most likely erroneous data and were not included in the calculations. Areas of texture are analyzed as Rocky substrate *vs.* sandy habitat, which has no apparent texture.

Side Scan Sonar (SSS) imagery illustrates different intensity levels (from the acoustic return) and displays those levels as a black and white image. Areas of high intensity will show as darker black from strong reflection off of the sea floor, usually from a harder surface *i.e.* rock. Low intensity areas will be a light grey to white depicting soft sediment or shadow. SSS can be used as a tool for ground truthing and also displays areas that might be of great interest. SSS is also a helpful tool in describing habitat features.

Geomorphic analysis delineated submarine features within the MPAs and control sites. Geologic descriptions of terrestrial features were taken from Dibblee Maps and literature and were stretched into the marine environment to evaluate the type of habitat.

The terrestrial geologic processes gave support when describing the rocky habitats off shore.

A statistical approach was developed to describe representative samples of each zone within GI Control and Gull Island. Models were created either including the entire depth range within both MPA and control or a limited depth range within 20m to 60m representing prime Abalone habitat. A random point generator that was downloaded off of the ESRI arc scripts site, which was used to create a set of points bound within each of these zones in question, then these points were buffered with a 250m radius to represent multiple sampling quadrats. Hereon, the survey area refers to the amount of area within the quadrats. Then the area of available habitat is compared to a list of relevant species found in the project area.

Geomorphology

The Geology in northern Channel Islands is quite unique. The northern Channel Islands about 18 million years ago pointed north and were located on the Baja coast. They slowly migrated north to its current location, ramming into the North American Plate that spun the islands to the East-West direction today. During this spin, which is still occurring, multiple little faults started appearing. The very active Santa Cruz fault splits the island in a manner similar to the transverse ranges. Santa Rosa Island has a similar fault that is no longer as active. This spin is evident in the Islands' left-lateral faults compared to the counter direction of the San Andreas' right-lateral fault. The distinctive difference between the north and south sides of the islands are divided along the fault, which created the eroded canyon Canada del Medio on Santa Cruz Island. Presented on the Dibblee Geologic Maps for the Islands, the north part of Santa Cruz Island is mostly comprised of volcanic rock that runs pretty deep. The south end of the island is a collage of rock types. Evidence of serious faulting and folding creates some uplifting and erosion that exposes such variety of rock, making analysis of rock easier on land. Analyzing sub-marine patterns of rock are easiest when the patterns on land are extended into the marine environment.

Results

Gull Island

The MPA surrounding Gull Island is on the southwest side of Santa Cruz Island, located outside Santa Barbara, CA. Santa Cruz island is one of the five islands in the area that encompass the Channel Island MPA Network (CIMPAN). Gull Island MPA (which I will now reference as Gull Island) includes 25.77 Km^2 of surveyed area sampled area depends on the number of buffers. Gull Island bathymetry extends from shore to approximately 260m. Of the sampled area at Gull Island, 19.89% (Table 1) of the area is considered rocky habitat. This Rocky substrate, shown in Table 2, is described the amount of habitat that fell within each buffer. The Gull Island Control (GI Control) site is located to the East side of the MPA and shares a border (Fig. 1). The GI Control includes 23.56 Km2 sampled area depends on number of buffers (Table 1). The available habitat within the depth range 20m to 60m (Table 3) only fit eight buffers within the depth zone. The shaded Rocky substrate image (Fig. 3) visually shows the amount of Rocky substrate both within Gull Island and GI Control. Using GIS analysis tools, a function was inserted into the Raster Calculator in ArcMap combining rugosity, slope greater than 5°, and restricted to depth zones of interest to create rocky habitat (Fig. 7). SSS images (Fig.4) confirm the areas interpreted as rocky substrate.

To measure the similarities between Gull Island and GI Control with confidence, a two-tailed t-test was run yielding values higher than the t-critical for each model. The depth zone that included the entire survey area (260m to shore) calculated a t value of 3.59. The depth zone that was limited to depths between 20m and 60m calculated a t value of 2.42 (t-test run was a two-sample testing, $\alpha = .05$).

South Point

The MPA surrounding the south portion of Santa Rosa Island, California called South Point is located between Santa Cruz Island and San Miguel Island offshore Santa Barbara, California. The South Point MPA (now referenced as South Point) includes 25.4 Km^2 and about 5.99% of that area is sampled to be rocky habitat (Table4). The sampling technique was the done the same as mentioned for the previous site. The maximum number plots without overlap, with a radius of 250m, are randomly placed within the boundaries of the two models. The first model is the entire depth range and the second model is limited to 20m to 60m deep. South Point's depth range extends from near shore to approximately 250m deep. The South Point Control (SP Control) shares a border to the west of the MPA (Fig. 2). The SP Control includes 12.4 Km^2 and 8.71%is considered rocky habitat (Table 4). The shaded rocky substrate image (Fig. 6) visually shows the amount of Rocky substrate both within South Point and SP Control. Using GIS analysis tools, a function was inserted into the Raster Calculator in ArcMap combining rugosity, slope greater than 5°, and restricted to depth zones of the two models to create rocky habitat (Fig. 7).

To confidently state similarities between control and MPA a statistical analysis of both models were run yielding t values lower than t-critical. The first model, which includes the entire depth zone, calculated a t value of 0.89. The second model with restricted depths ranging 20m to 60m returned a t value of 2.24.

Discussion

Gull Island

The goal of this study was to compare habitat similarities between MPAs and control sites by way of bathymetric data and GIS analysis techniques in order to establish a relationship of comparable habitat. In order for the effectiveness of each MPA to be measured, the control sites of these MPAs need to have similar amounts habitat. Using a visual comparison of Gull Island and GI Control, it is observed that there is more exposed rocky substrate within Gull Island than GI Control, but just how much? The statistical analysis gave support to the claim that GI Control has significantly less rocky habitat than Gull Island. The t-test values for both the total area as well as the depth range of 20m to 60m was such that the null hypotheses were rejected (t values were higher that t-critical values therefore must reject null). The null stated that the means of the two populations were statistically similar, but because the null was rejected, the two populations are not similar. Table 1 describes the percent of overall rocky substrate and Tables 2 & 3 give more detail about the habitat distribution at depths between 20m and 60m. Statistically these two models are not similar, meaning there is not enough habitat located in GI Control to have meaningful comparisons of equal amounts of habitat with Gull Island.

The sub-surface terrain appears to be greatly buried under a sediment apron on the southwest side of the surveyed area (Fig. 5). The bulge of smooth surface is to be interpreted as sand or soft sediment, supported by SSS imagery. The darker areas near right center of Gull Island is very blocky pattern resembling of an igneous volcanic rock *i.e.* granite, gabbro, which are associated with areas of high Rocky substrate. On the isolated portion of Gull Island there is very strong support for tilted strata, sediment beds that have been uplifted through folding and faulting. The long linear features exposed at this anticline suggest a compression folding point in which sediment layers are lifted. Sedimentary rock is associated with low Rocky substrate habitat. The GI Control has somewhat less interesting geologic behaviors. This portion of the island also shows evidence of a significant sediment apron that covers majority of the marine habitat. The East portion of the GI Control demonstrates light linear patterns resembling sedimentary layering or a deep marine terrace (areas of low rocky substrate). As fore mentioned (Table 1), the GI Control has significantly less exposed Rocky substrate than that of Gull Island. GI Control has very little evidence of igneous patterns, which describes areas of high rocky substrate. A geologic interpretation of this site recognizes larger amounts of visible habitat in Gull Island and extremely less amounts within GI Control.

Five species of fish were selected from the species of interest page in the *Environmental Document: Marine Protected Areas in National Oceanic and Atmospheric Administration's Channel Island National Marine Sanctuary* (Ugoretz 2002) to allow for a comparison of available habitat at a depth that each species can be found.

Species of Interest	
White Abalone	*Haliotis sorenseni*
Olive Rockfish	*Sebastes serranoides*
California Halibut	*Paralichthys californicus*
Pacific Saddab	*Citharichys sordidus*
Lingcod	*Ophiodon elongatus*

The amount of habitat was compared to the overall area within each depth range. Halibut, Sanddab, Lingcod, and Olive Rockfish have large percentages of preferred habitat in the Gull Island and GI Control. Some species of fish, which prefer to live at narrower depth ranges, *E.g.* White Abalone, could be found in waters typically 20m-60m in rocky substrate.

White Abalone has limited habitat to choose from. The amount of available preferred habitat within Gull Island is roughly 2.95% of the area included at its depth range, compared to GI Control that has about 0.03% available habitat. With the exception of the soft sediment habitat fish, GI Control does not have much to compare to Gull Island.

South Point

The goal of this study is analogous to that of Gull Island. The amount of available rocky habitat at different depths in the control needs to be similar in the MPA. Our data shows that the distribution of rocky habitat is very similar in South Point as in SP Control. The t-test values were lower than the t critical which fails to reject the null hypothesis that the two population means are statistically similar. The t value associated with the first model has a higher probability of significance due to the small size of the value. The t value that was returned on the 20m-60m-depth range was close to the t-critical value and does not have high probability that these means are truly similar. With this sample data set the null just could not be rejected.

The geologic formations are very similar off the south coast Santa Rosa as they are on the south coast of Santa Cruz Island. There are also similarities in the terrestrial features. Both Islands have left lateral faults that split the islands geologic formations up the middle of the islands. Off shore Santa Rosa there is also evidence of large beds of sediment aprons. The one thing that holds these two locations apart is the amount of exposed rocky habitat that is constant within each the SP Control and South Point.

The amount of rocky habitat in both control and MPA will support the five species of interest mentioned earlier well. A diverse mixture of sandy and rocky habitat spread throughout the MPA and control will allow for species to move freely form the MPA to the control when populations become too dense. There is good potential for spill over outside the parameters of the MPA and into the control or beyond.

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	Km^2	Percent Cover
Gull Island rocky habitat	0.7810	19.8875%
GI Control rocky habitat	0.0022	0.0569%

Table 1. A comparison of overall rocky habitat within Gull Island and GI Control buffers. Percent cover describes the amount of habitat that fell within the buffered areas.[2]

Distribution of Data			
Gull Island		GI Control	
Buffer number	Habitat within Buffer m^2	Buffer number	Habitat within Buffer m^2
0	271.61	10	2228.7872
1	2119.99	13	6.1622
2	53574.27		
3	130.45		
4	1762.27		
6	32791.23		
7	6575.19		
8	798.27		
9	7843.07		
10	13431.60		
12	74197.99		
13	105850.52		
14	81512.21		
15	8849.76		
16	114488.26		
17	135792.66		
18	138200.03		
19	2789.09		

Table 2. The figures above are representative of the plots that were placed in Gull Island and GI Control. A total of 20 randomly placed plots were in each area. Missing plots are omitted if no habitat fell within the plot.

Distribution of Data at depths of 20m to 60m			
Gull Island		GI Control	
Buffer number	Habitat within Buffer m^2	Buffer number	Habitat within Buffer m^2
0	10981.80	1	55.71
1	226.36	2	60.06
3	102.73	4	285.96
4	15381.91	5	34.35
5	552.82		
6	15755.01		
7	3313.41		

Table 3. The figures above are representative of the plots that were placed in Gull Island and GI Control between the depths of 20m and 60m. A total of 8 randomly placed plots were in each area. Missing plots are omitted if no habitat fell within the plot.
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	Km^2	% Cover
Total rocky Habitat SP Control	.2905	8.71%
Total rocky Habitat South Point	.2000	5.99%

Table 4. Area (Km^2) represented in this table displays the values associated with the area of the buffers (Sample plots, quadrats).

	South Point	SP Control
Buffer number	Habitat within Buffer m^2	Habitat within Buffer m^2
0	7246.7710	25755.1322
1	13275.0865	5371.5686
2	4828.0755	1049.6879
3	388.5406	15601.2869
4	38379.8359	34737.7666
5	403.5260	3509.1225
6	24588.8456	3515.7948
7	2292.6424	3002.1747
8	220.0738	34968.7217
9	256.6430	20274.9815
10	4889.9743	14175.8492
11	3789.0477	7146.0239
12	25383.2179	37330.7016
13	294.3665	1022.1692
14	48455.1210	6883.0770
15	8018.7312	79.1813
16	17312.3610	76150.8338

Table 5. The figures in this table represent a wide distribution of habitat spread through the depth ranges. The habitat within buffer is understood to be the amount of habitat that overlapped with the 17 total quadrats.

	South Point	SP Control
Buffer number	Habitat within Buffer m^2	Habitat within Buffer m^2
0	8293.6837	2048.9895
1	585.3994	24307.0963
2	2634.9005	35113.9732
3	2152.2151	3666.3157
4	339.1870	6961.9209
5	356.5766	34516.0039
6	1581.7923	21495.0762
7	27000.1937	15998.8247

Table 6. The depth zone of 20m-60m had 8 quadrats in each the control and the MPA.

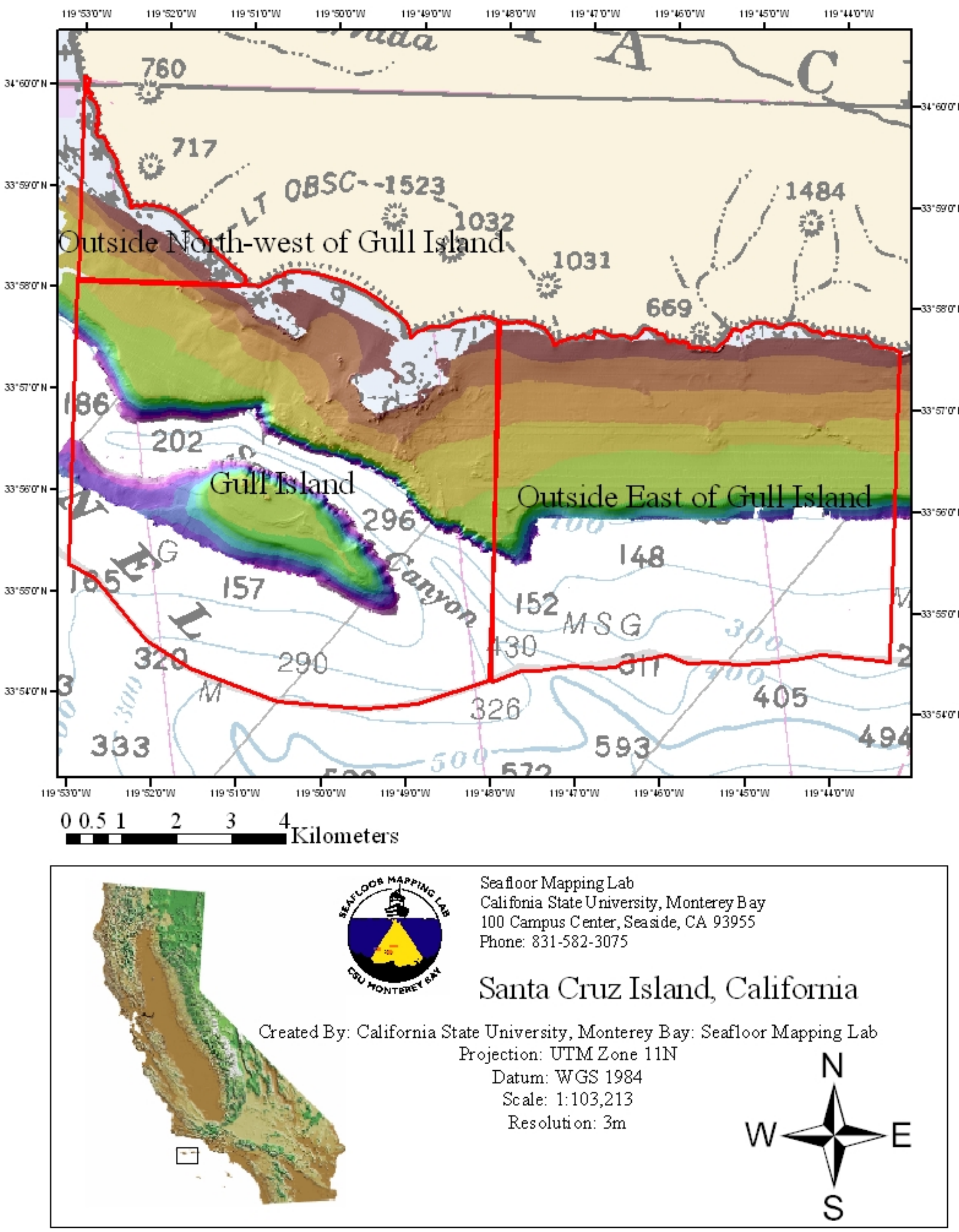

Fig. 1: The red boxes above are the outlined MPA, called Gull Island, and the areas in which to survey in June 2003.

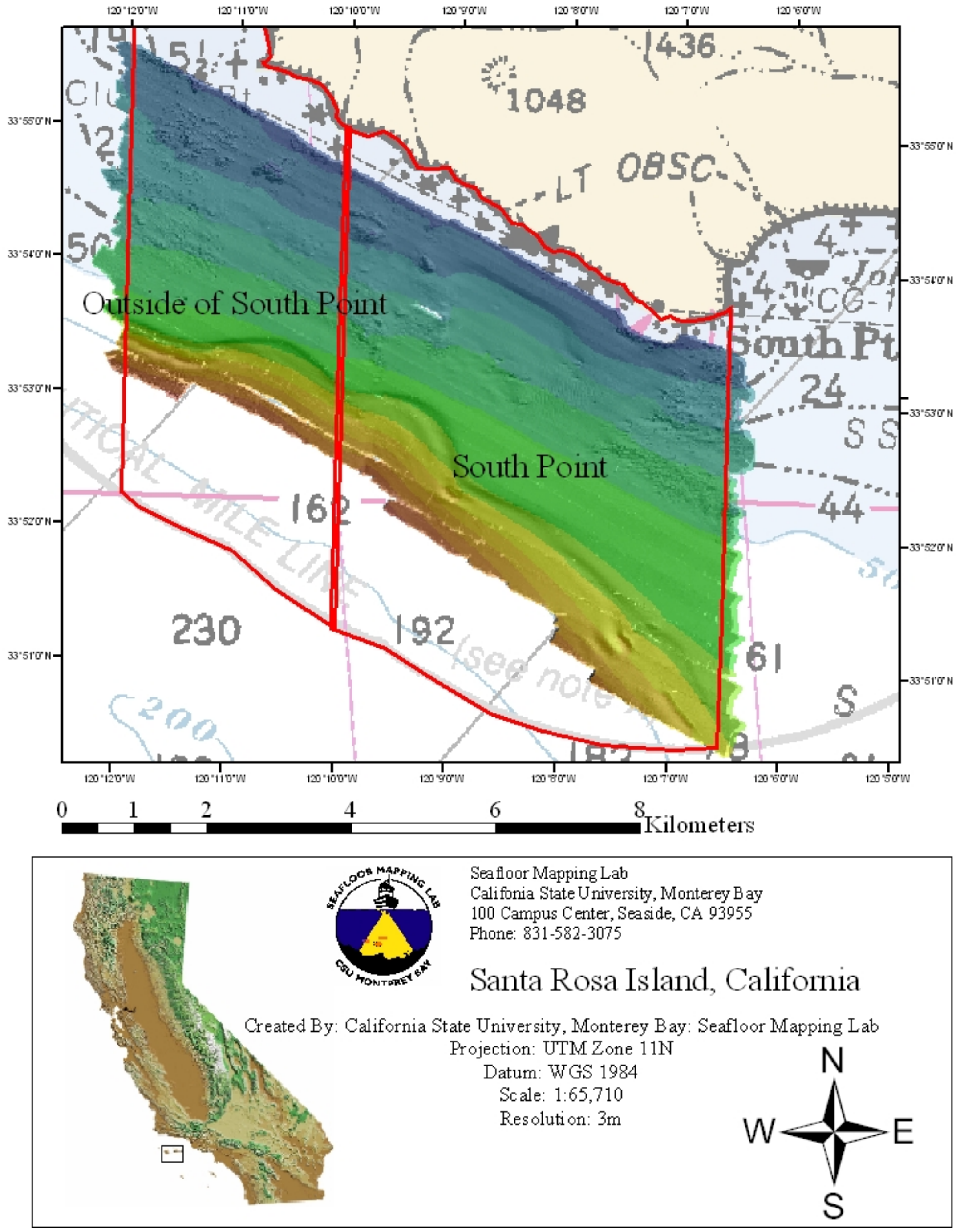

Fig. 2: The red boundary above outlines the MPA, called South Point, and surveyed areas south of Santa Rosa Island, Santa Barbara CA.

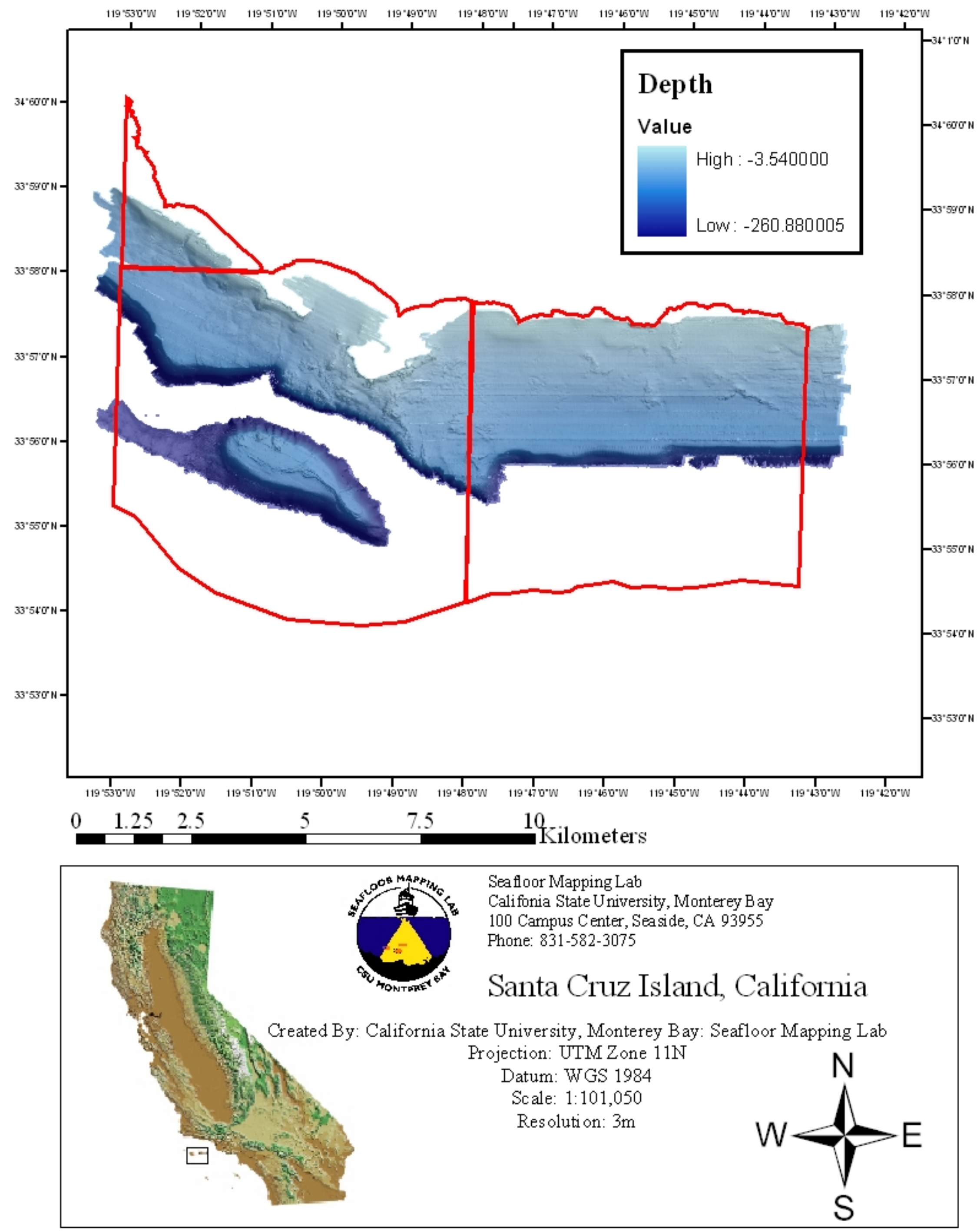

Fig. 3: Shaded Relief models allows for interpretation of substrate within marine environments.

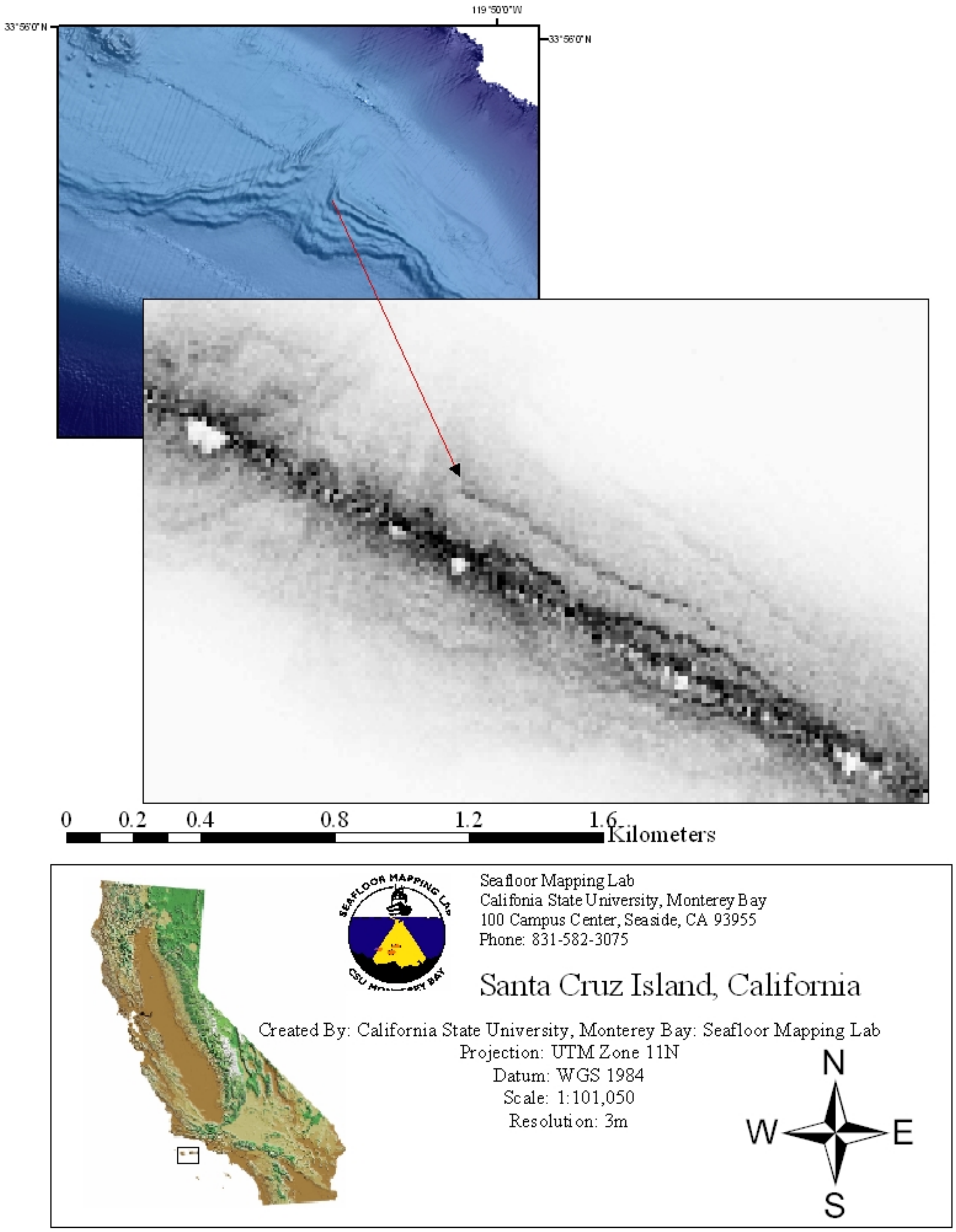

Fig. 4: Side Scan Sonar describes the intensity of the sounding return allowing for sediment type classification. The south tip of the Gull Island data displays shale bed ridges.

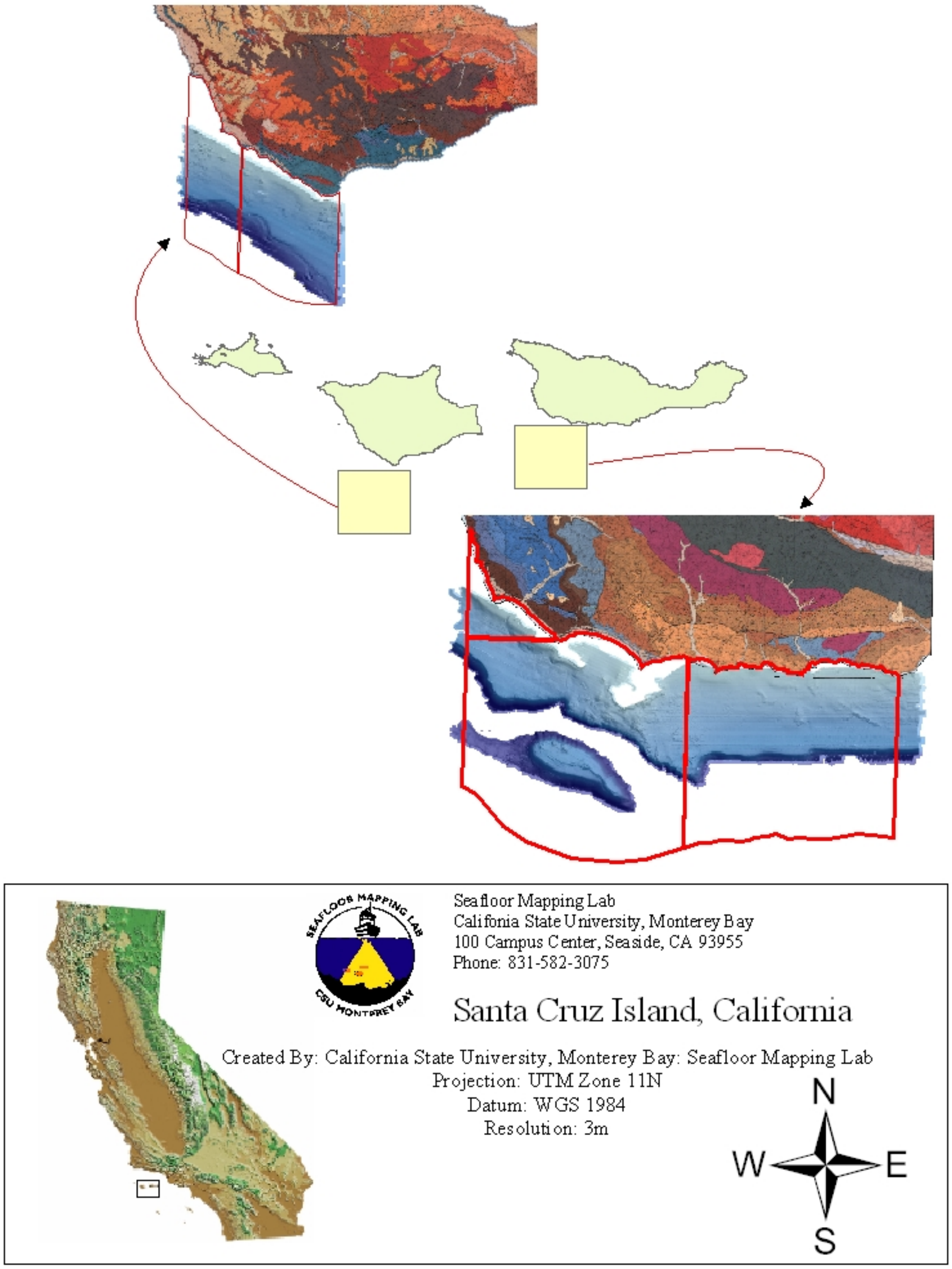

Fig. 5: Georeferenced geologic maps were used to help describe the type of rock features that are evident in the bathymetry maps.

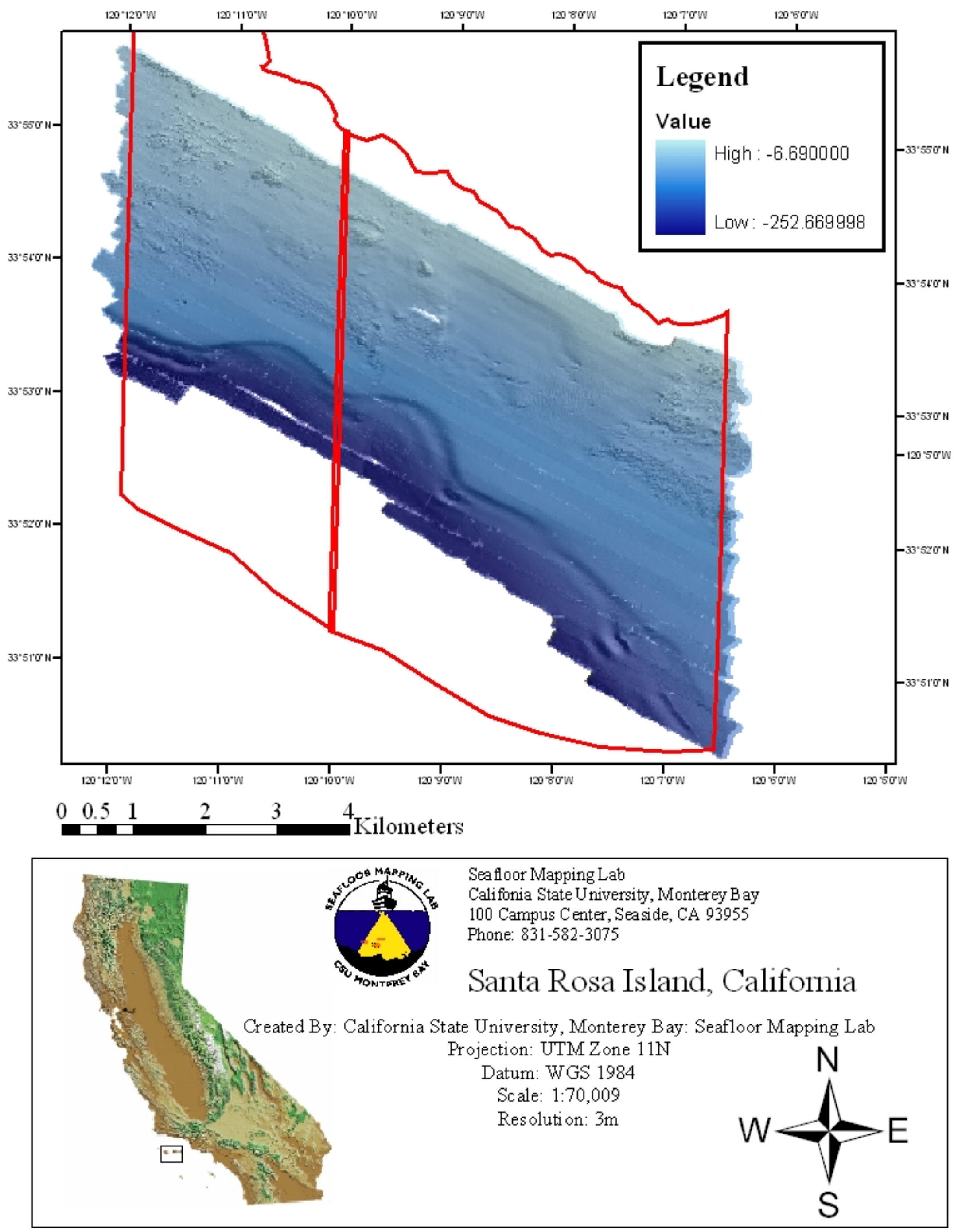

Fig. 6: Shaded Relief models allows for interpretation of substrate within marine environments.