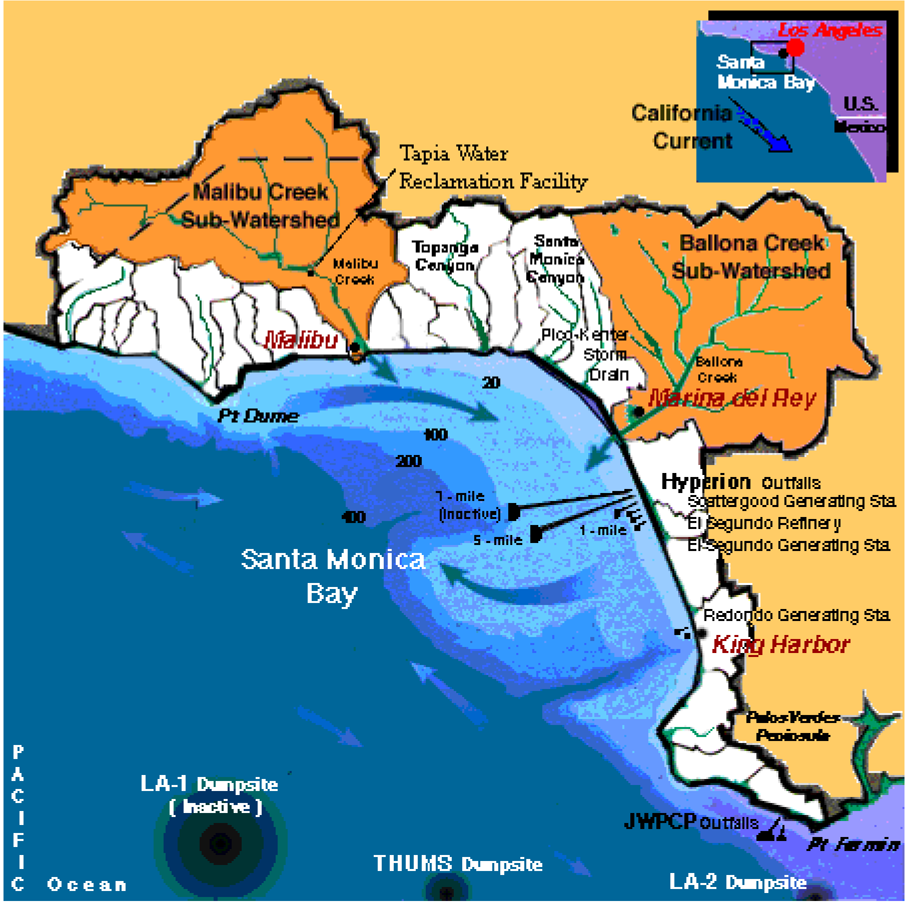
Coastal watershed development, erosion, marine habitat loss and kelp forest decline in Santa Monica Bay, California.

Prepared for the California State University Monterey Bay Seafloor Mapping Lab
Along with the Santa Monica Bay Restoration Project and Foundation



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Abstract

Extensive development and erosion of coastal watersheds have long been suspected of negatively impacting coastal marine habitats. The purpose of this study is to test the hypothesis that the dramatic decline in the kelp forests of Santa Monica Bay (SMB), California, can be attributed, in part, to sediment deposition and the resultant loss of near shore rocky habitat. Geographic Information Systems (GIS) tools were used to compare kelp coverage from 1893, 1912, 1989 and 1999 SMB surveys to identify areas of significant kelp loss over time. The current distribution of rocky habitat was determined using acoustic remote sensing (multibeam bathymetry, sidescan sonar and sub-bottom profiling) and video substrate verification. These data were used to determine whether or not rocky habitat still exists for kelp recruitment in areas where kelp is no longer found.

Introduction

Extensive development and erosion of coastal watersheds have long been suspected of negatively impacting coastal marine habitats. Although natural coastal erosion and sedimentation patterns can shift as a result of changing currents, sea level, wave energy, or storm patterns, more significant factors are likely to be land use (e.g. deforestation, agricultural practices, dredging, coastal construction) (Smith and Buddemeier, 1992). Population growth to coastal cities is the main reason behind many, if not most, coastal problems (Kay and Alder, 1999). Studies of future populations are estimating that in 30 years more people will live in the world's coastal zones than are alive today (NOAA, 1994).

Coastal areas offer people more economic, social and recreational opportunities than inland areas, which are main reasons for the influx in population (Golberg, 1994). Waterfront expansion can be economically advantageous for coastal cities; it can also be very threatening to coastal resources if environmental issues are not addressed (Clark, 1998). Recently the values placed on the coastal resource have expanded to include the value of scenic views, beach access and other aesthetic qualities (Kay and Alder, 1999). Coastal land with ocean views and beach access creates high land values (Kay and Alder, 1999). Because of this strong demand, many people are willing to pay more to enjoy the coast, and are also willing to pay for its protection (Kay and Alder, 1999).

Within coastal environments there are many special habitats, e.g. kelp forests, wetlands, tidal flats, and sea grass beds, which are often damaged or obliterated when shorelines become populated (Clark, 1998). In order to understand the type of impacts our coastal development is having on the near shore marine environment there needs to be some sort of understanding of habitat and species structure within these environments.

In Santa Monica Bay, California (SMB) there has been growing concern over the apparent decline in the once extensive coastal kelp forests, and speculation that the decline may be related to sediment burial resulting from coastal development and erosion.

Kelp beds are common along several continental coasts, extending along the west coast of North America from Alaska south to Baja California and along the temperate shores of South America, South Africa and southern Australia (Abbott and Hollenberg, 1976). Giant kelp grows best in clear, well-mixed, nutrient rich coastal waters. Kelp tends to grow in rocky habitats, using holdfasts to attach to stable rock substrates to resist the energetic forces of waves and swells (Conner and Baxter, 1989). Occasionally, sandy habitats provide a temporary substrate for kelp recruitment and growth (Abbott and Hollenberg, 1976). The massive holdfasts of *Macrocystis Pyrifera* have been known to allow growth over sandy bottoms (Emery, 1960).

Kelp can undergo a variety of disturbances causing large temporal and spatial fluctuations in the size of local kelp populations worldwide, which can include: (1) winter storms, which vary greatly in intensity from year to year (Dayton et al. 1989). (2) episodic sea urchin grazing (Harrold and Reed 1985), Seasonal and aseasonal changes within the environment, which can lead to oceanographic conditions which adversely affect kelp growth and survival (Reed et al. 1996). Sedimentation and rare storms are also key factors drastically effecting kelp recruitment by burying or killing gameophytes and small sporophytes (Dayton et al. 1984). These types of conditions can singly or collectively cause disturbances within kelp populations and create bare patches ranging in size, which can lead to partial or complete loss of a local kelp population.

Giant kelp (*Macrocystis pyrifera*) is a key species in southern California, not only because it's a valuable resource, but also it provides food and shelter for many other species (Schmitt and

Osenberg, 1996). Protections of kelp forests are important due to the substantial diversity of plants and animals that depend on it for survival. Members of the kelp forest community include a variety of very tall to very short kelp species along with a significant amount of invertebrates that are not generally found elsewhere in the continental shelf (Thorne-Miller, 1999). Over fishing, polluted runoff and waste outfall from coastal development, and habitat modification or destruction commonly plague these ecosystems (Thorne-Miller, 1999).

This study tests and evaluates the main hypothesis that the decline in kelp populations within SMB can be attributed in part to sediment deposition and the resultant loss of near shore rocky habitat. My general approach used GIS to identify areas of kelp loss in by comparing historical to current kelp distributions to determine areas of kelp loss. Kelp loss was then compared to areas with availability of rocky habitat in four levels of condition: 1) healthy (available for kelp recruitment), 2) degraded (dusted with sediment), and 3) present but not available (completely buried by sediment), and 4) no evidence of rocky habitat. This assessment will be done using bathymetric models and sub-bottom profiling.

H0: There is no spatial relationship between areas of kelp loss and the condition of rocky habitat
H1: Kelp has been lost in areas where rocky habitat has been degraded or potentially degraded.
H2: Kelp has been lost in areas where rocky habitat is still available and clear.
H3: Kelp has been lost in areas where there is no evidence of rocky habitat (sediment)

The results from this research will assist resource agencies in identifying which coastal watersheds may have contributed most to nearshore habitat degradation in SMB, and where restoration and erosion control efforts should be focused.

Methods

Study Area and General Approach

The two study areas include the regions from Point Dume to Topanga Canyon, and Flat Rock Point to Point Fermin on the Palos Verdes Peninsula (Fig. 1). Study areas covered approximately thirty miles of coastline with depths ranging from 5-50 meters. The general approach for this report was to map the near shore marine habitat using acoustic remote sensing along with identifying those areas of kelp loss and suggesting what habitat areas would be suitable for kelp recruitment and kelp habitat restoration.

Kelp Loss

A Geographic Information System (GIS) was used to compare kelp cover results from 1893, 1912, 1989 and 1999 surveys to identify areas of significant kelp loss in the Santa Monica Bay over time. These data were obtained from National Oceanographic and Atmospheric Administration (NOAA) and the California Department of Fish and Game (CDFG). The current distribution of near shore marine rocky habitat was mapped using acoustic remote sensing (multibeam bathymetry, sidescan sonar and sub-bottom profiling) and video substrate verification, which was collected using the hydrographic survey vessel the R/V MacGinitie, a 30 ft vessel.

Habitat Mapping

Multibeam and Sidescan Sonar Acquisition

The MacGinitie is equipped with a hull mounted Reson 8101 SeaBat multibeam sonar system. The 240 KHz SeaBat 8101 multibeam measures discrete depths, allowing complex underwater features to be mapped with precision. The system enables dense coverage utilizing up to 3,000 soundings per second for a swath of up to 7.4 times the water depth. The SeaBat has a depth range of 1-300 m and can operate in either standard (150-degree swath) or wide (210-degree swath) mode when the need to obtain shoreline data or other features all the way up to the waterline is needed. The SeaBat allowed for collection of xyz data at 1m horizontal resolution. Multibeam and sidescan sonar data was used to create DEM's, contours, and substrate maps of the survey areas.

The vessel is equipped with instrumentation to successfully correct the sonar for vessel movement. A Trimble 4700 provides GPS positioning and differential correction is provided by a Trimble ProBeacon receiver. Heave, pitch, heading, and roll data are provided by a TSS HDMS heading and motion sensor (+/- 0.02 degree accuracy). An AML SV+ sound velocity profiler creates water column sound velocity profiles, to correct the acoustic data for changes in water column densities.

Coastal Oceanographics Hypack software was used for survey design and execution. Triton-Elics International Isis Sonar data acquisition system, which was used for data logging. The multibeam data was processed using CARIS HIPS hydrographic data cleaning system software and sidescan data was processed using ISIS and Delph Map software programs.

Sub-bottom Profiling Survey

Sub-bottom profiling was collected using an EdgeTech SB-424 Full-Spectrum sub-bottom chirp profiler, which allowed for determination of seafloor sediment and rock layer thickness (Fig. 5). The Sub-bottom data was used to determine the thickness of overlying sediment. The SB-424 has a frequency range of 4-24 KHz, with +/- 4cm vertical resolution and a typical penetration ranging from 3m in calcareous sand, to 40m in clay. The SB-424 uses Triton-Elics International Delphi Seismic Data acquisition system to record the profile data and the Seismic-GIS software to process the data. Sub-bottom and ground truthing were accomplished by driving transect lines and collecting samples along the transect, within each block site (Fig. 5).

Groundtruthing (video analysis)

Video analysis was performed not only as a ground truthing tool, but also as a tool to analyze the substrate. Video analysis was accomplished by haphazardly selecting still frames of the video footage. Each frame was incorporated into the habitat maps within ArcGIS 8, which were used to analyze the substrate within the study areas. Video frames were used to qualitatively compare the substrate to the bathymetry, generalizations were made regarding the substrate based on qualitative comparisons. This was done due to the minimum amount of video points available to analyze the substrate. From these generalizations habitat interpretations were designated.

Habitat Interpretations and Classifications

Using ArcGIS 8, final products for each study site were created including a high-resolution 3D digital terrain models, habitat raster image of SMB near shore marine environment, historical kelp abundance and habitat type maps (Figs. 3,3a,3b,3c). These maps were used to assess the three different habitat conditions (rock, degraded rocky, sediment) within SMB. These habitats were used to suggest what areas could be suitable for restoration and kelp recruitment.

A combination of substrate maps from multibeam and sidescan sonar, GIS kelp layers, Sub-bottom profiling, and Video footage was used to assess the main hypothesis that the decline in kelp populations can be attributed in part to sediment deposition and the resultant loss of near shore marine habitat (Figure 3,3a, 3b, 3c).

The kelp layers were combined into two categories: historical kelp data (1893 and 1912) and current kelp data (1989 and 1999), that allowed for maximal extents of kelp within those time periods (Figure 1, 1a, 1b).

Results

Kelp Loss

GIS kelp layers from 1893, 1912, 1989, and 1999 obtained from CDFG suggest that there has been a significant kelp decline in the last 100 years (Fig. 2, 2a, 2b). The extent of the historical kelp beds consisted of 1716.23 Hectares. The area of kelp loss that occurred between historical and current kelp data equaled 1181.60 Hectares (55% loss in kelp) (Fig. 2c).

Sub-bottom Analysis Results

Sub-bottom analysis will be complete during the summer of 2002, due to time restrictions.

Groundtruthing (video analysis)

Video analysis resulted in identical relationships between the video footage and the bathymetry, which allowed for accurate habitat interpretations. The video frames that were used to compare to the bathymetry, were visually identical to the bathymetry.

Habitat Interpretations and Classifications

Bathymetry and video footage was used to determine the three different substrate types (rock, degraded rock, and sediment). These results displayed a large amount of sediment (72%) within the study sites (Fig. 3c)

The three different substrate types were used to determine the area of current kelp and the area of kelp loss that covered over the different substrate types (Fig. 4). The results were conclusive in that there was areas of degraded habitat along with areas of vast sediment that historically displayed kelp. These areas that contain sediment and historically presented kelp, will be analyzed for buried rock using sub-bottom profiling.

Discussion and Conclusion

The results show that there is a significant loss of kelp within SMB (55%) from 1893 - 1999, which could be due to a loss in nearshore rocky habitat caused from sedimentation burying the rock vital to kelp growth (Fig 2, 2a, 2b, 2c).

The study areas that were near the Malibu coastline, displayed significantly more degraded rocky substrate than the Palos Verdes Coastline (Fig. 3, 3a, 3b, 3c). This could be due to the increase in development and erosion from sandy beaches. On the other hand, the Palos Verdes coastline still had a significant amount of clean rocky habitat available for kelp recruitment, but there was also significantly more kelp that was loss in the Palos Verdes area than the Malibu area. This could be caused from sedimentation, but also the areas of kelp loss were in areas of deeper water which could mean that the water clarity has become poorer over the years which doesn't allow for sunlight to reach the bottom and initiate kelp growth.

Kelp loss and current kelp coverage with relation to substrate type clearly display that the areas where kelp loss has occurred are primarily areas where only sediment is found, which suggests that there is buried rock beneath those layers of sediment where kelp could have being growing previously (Fig. 4). Sub-bottom profiler will display those areas where buried rock is beneath layers of sediment. This part of the study will be analyzed during the future months.

There are many possible reasons for kelp loss within Santa Monica Bay, and many researchers are analyzing other possibilities. One study is being done, to see if maybe there isn't enough large sediments coming from the coastal watersheds such as large boulders and rock which kelp needs to grow upon. This could be adding to the problem of sedimentation, there is not only an increase or constant flow of fine sediment coming from the watersheds from development and erosion; there isn't enough large substrate materials flowing into the nearshore marine environment to sustain or equal the amount of fine sediment coming from the watersheds.

There are many studies that need to be done, in order to minimize the amount of sedimentation and erosion that occurs within the watersheds. One study that is vital is to understand the sediment budget, and the amount of fine sediment that is depositing into the nearshore marine environment. Once this sediment budget is established, watershed restoration efforts can be implemented to reduce the amount of sedimentation that is occurring. Watershed restoration agencies can also use the results from this study to look at the areas that have received the most sedimentation and display the most degraded rocky habitat and then analyze those parts of the watersheds to determine the cause of the sediment runoff.

Another study that would be beneficial would be to look at seasonal changes in the habitat, is there certain times of the year where sediment is flushed from the system and is there certain years where sediment is imputed into the system. This would help agencies and researchers understand when and where the sediment is coming from within the watersheds.

In conclusion, the study should be helpful to restoration agencies, researchers and other research institutes to obtain a better idea of the possible effects of coastal development and erosion on nearshore marine habitat. The data from this study will assist agencies in where to focus their restoration efforts first and give them and other researchers a better understanding of the nearshore marine habitat.

To better understand if sedimentation is the cause of kelp loss within Santa Monica Bay, there needs to be an in depth understanding of the inputs and outputs into the nearshore marine system in order to better understand the cycle the system goes through. This will allow for a complete understanding as to whether sedimentation is the key factor in kelp loss within Santa Monica Bay.

Acknowledgements

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Figures

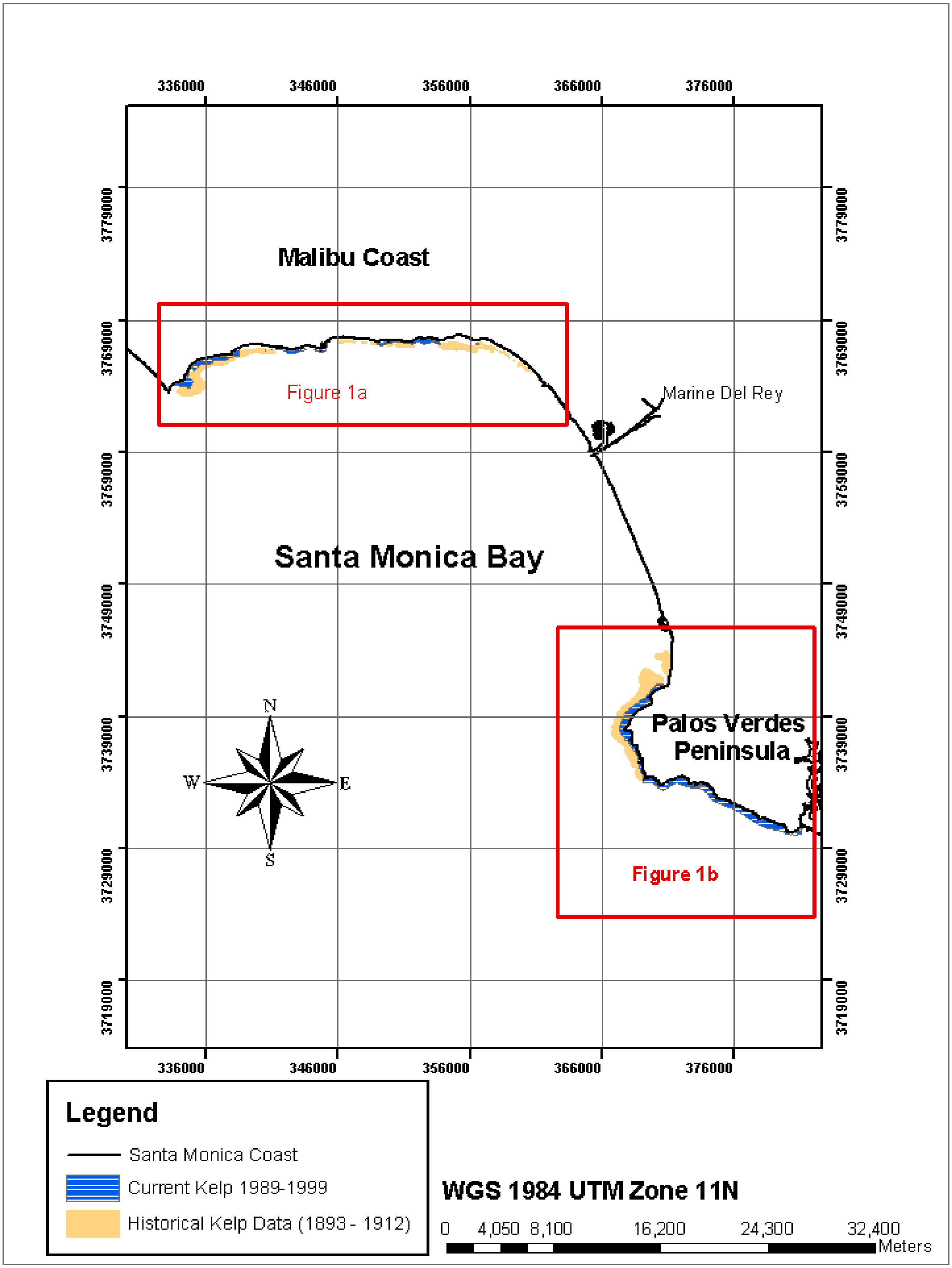

Figure 1 - Santa Monica study sites (Malibu coast and Palos Verdes Peninsula, along with current and historical kelp coverages.

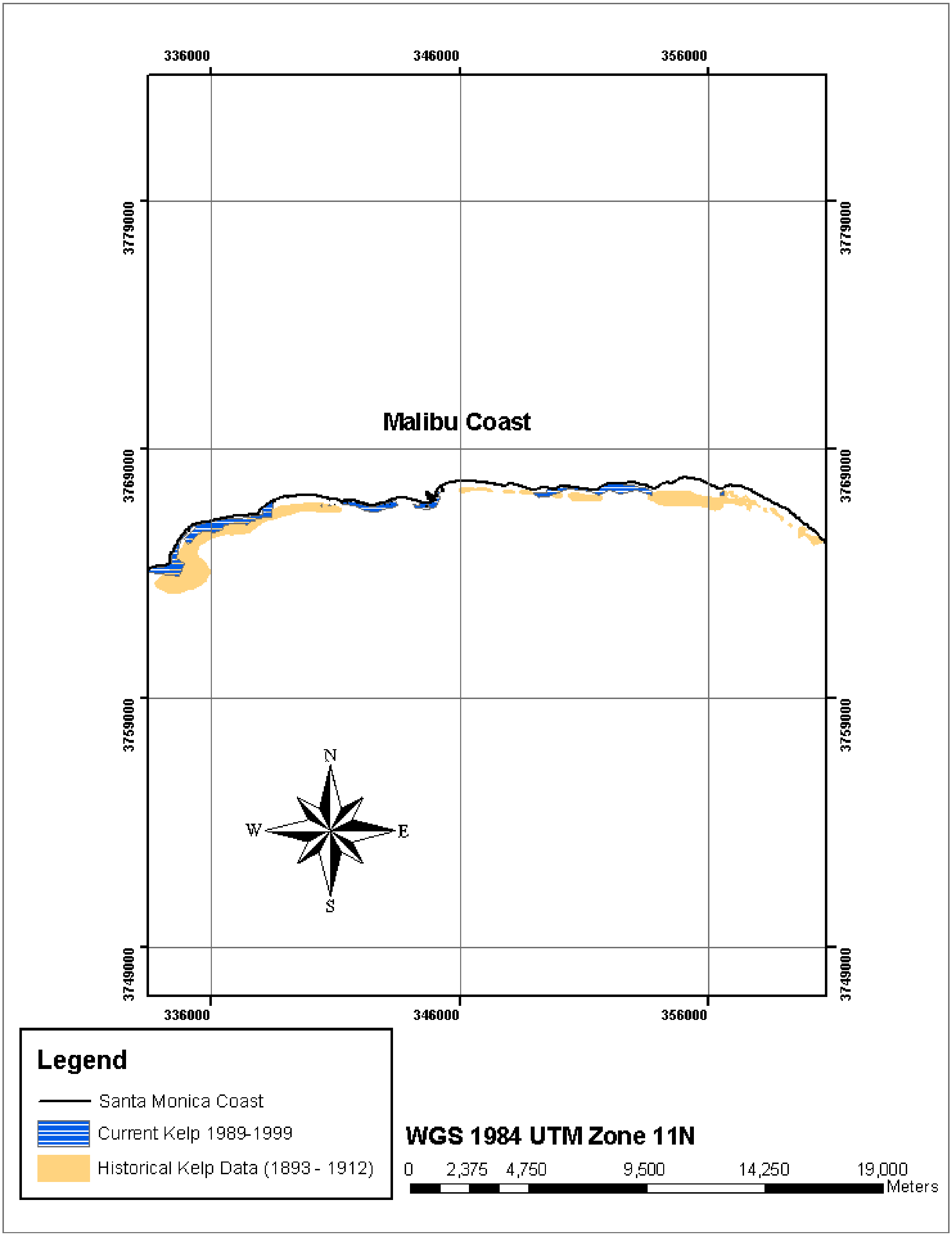

Figure 1a - Northern study site along the Malibu coast, displaying current kelp and historical kelp coverages.

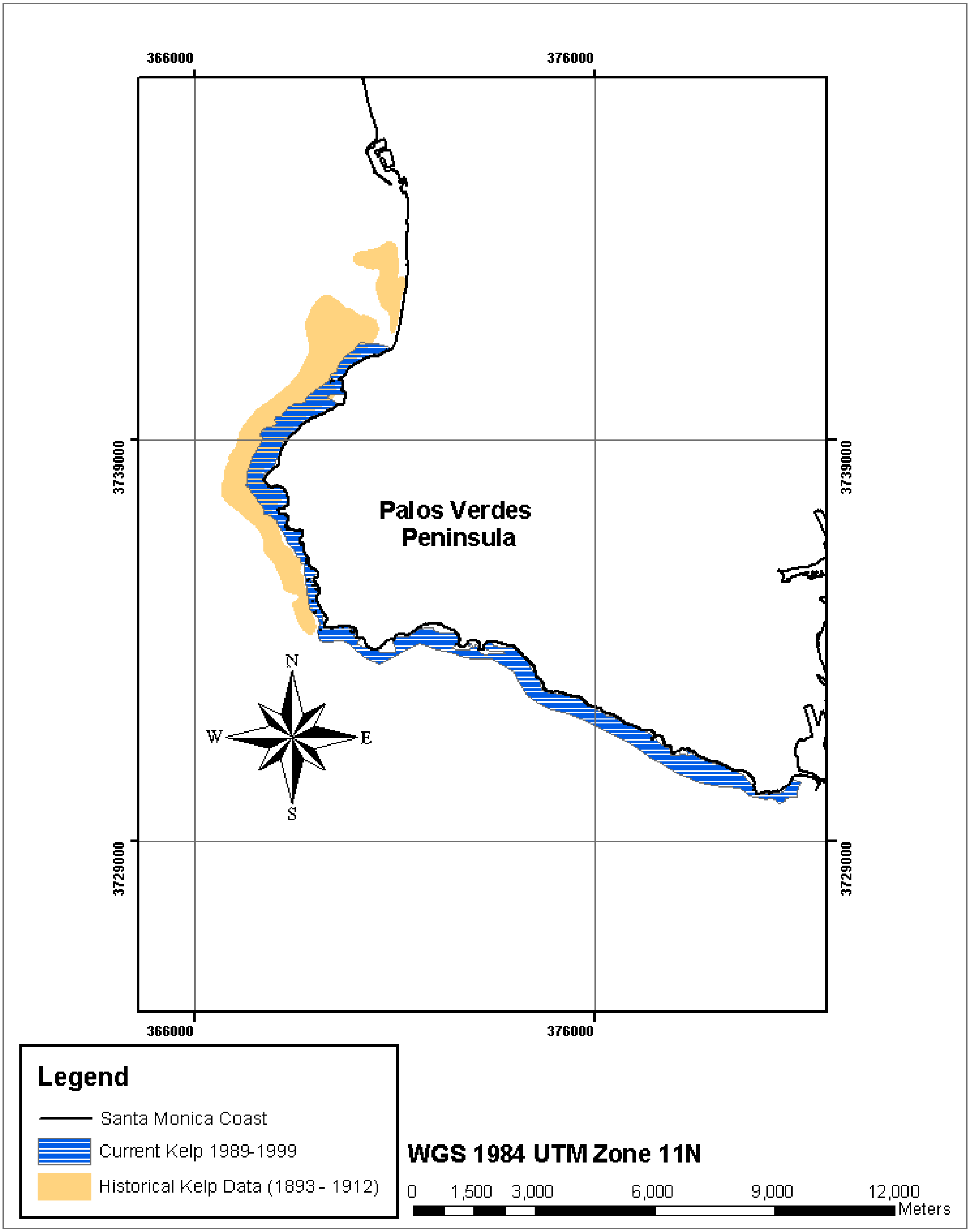

Figure 1b - Palos Verdes Peninsula study site, displaying current kelp and historical kelp coverages.

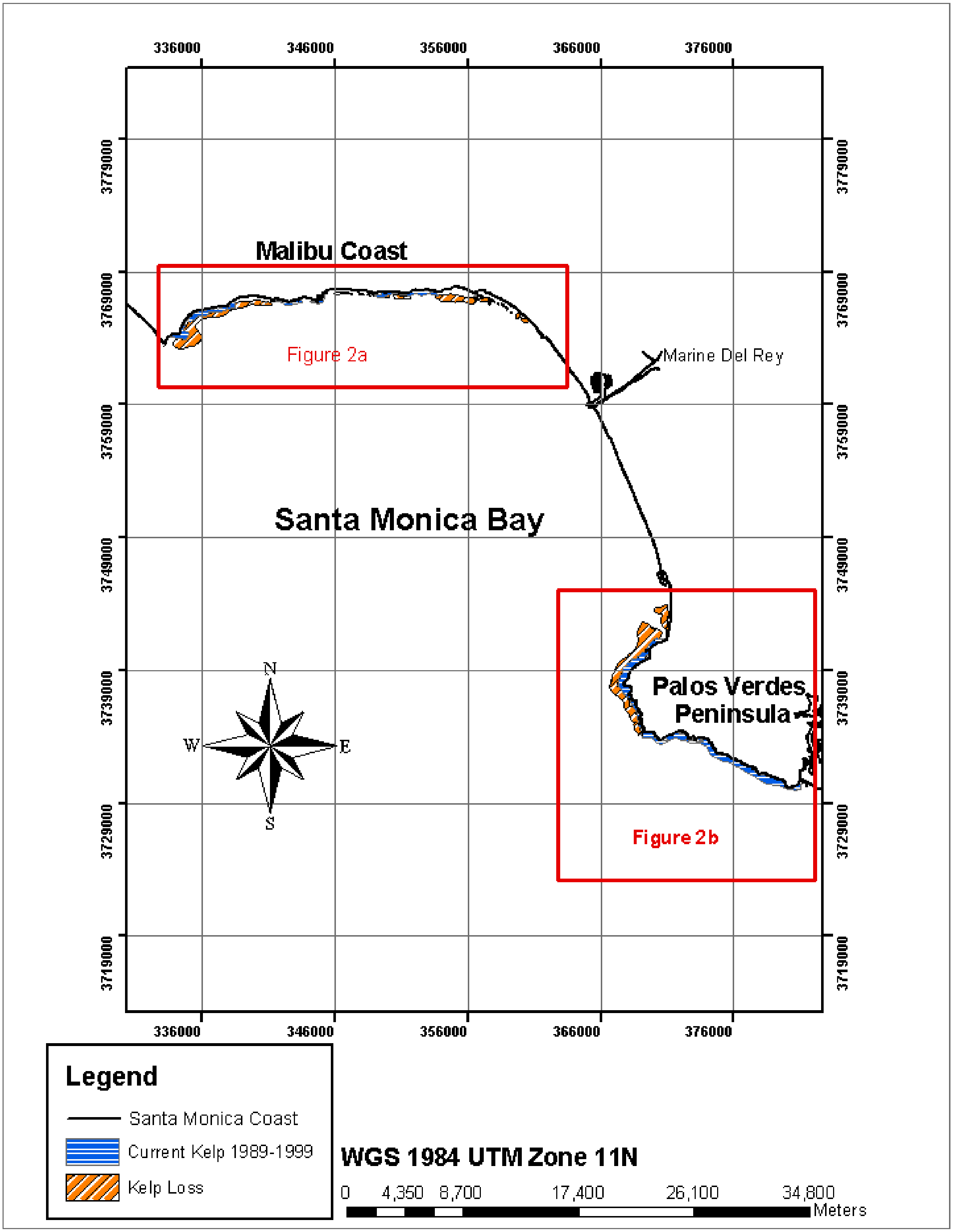

Figure 2 - Santa Monica study sites (Malibu coast and Palos Verdes Peninsula, along with current and kelp loss coverages.

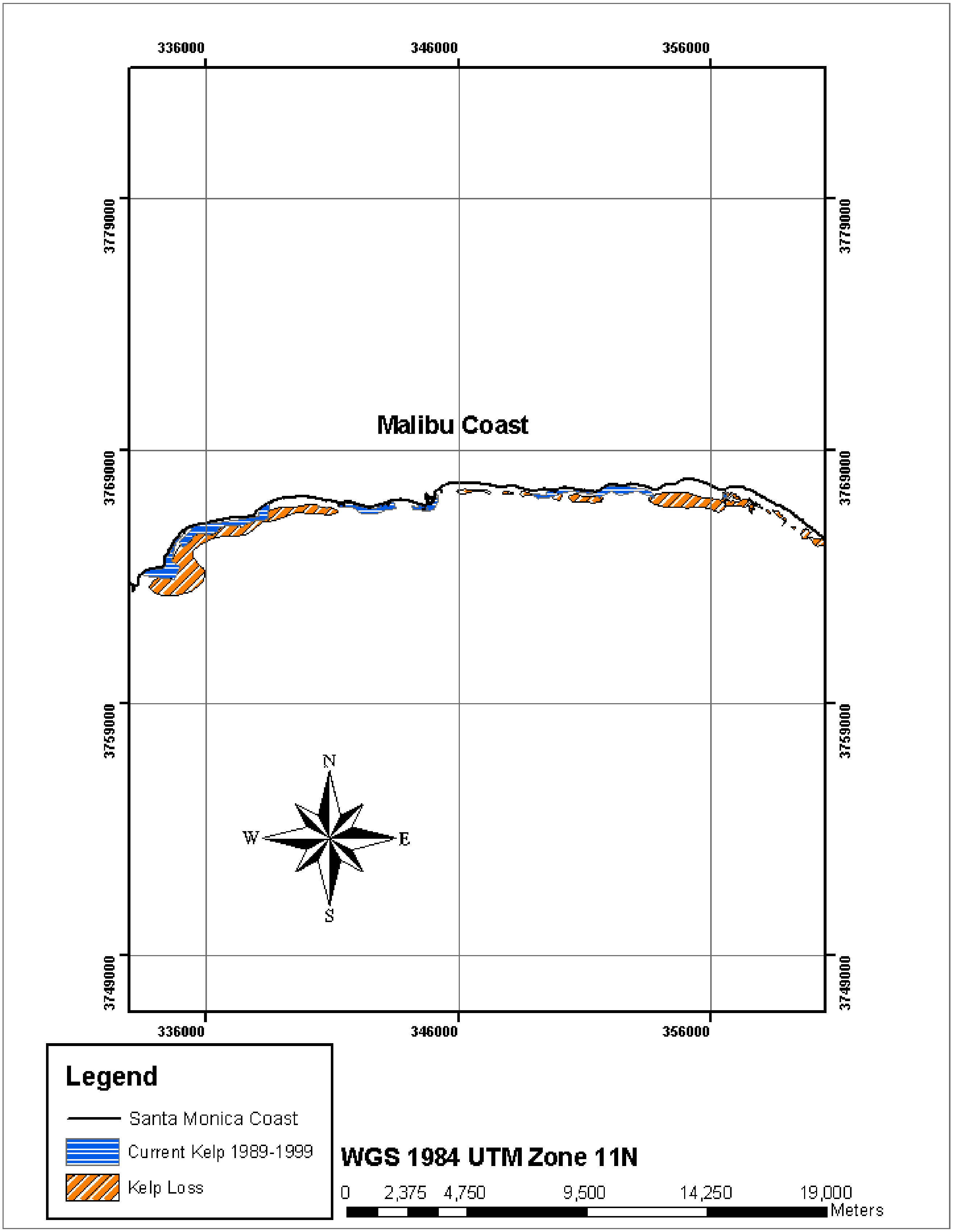

Figure 2a - Northern study site along the Malibu coast, displaying current kelp and kelp loss coverages.

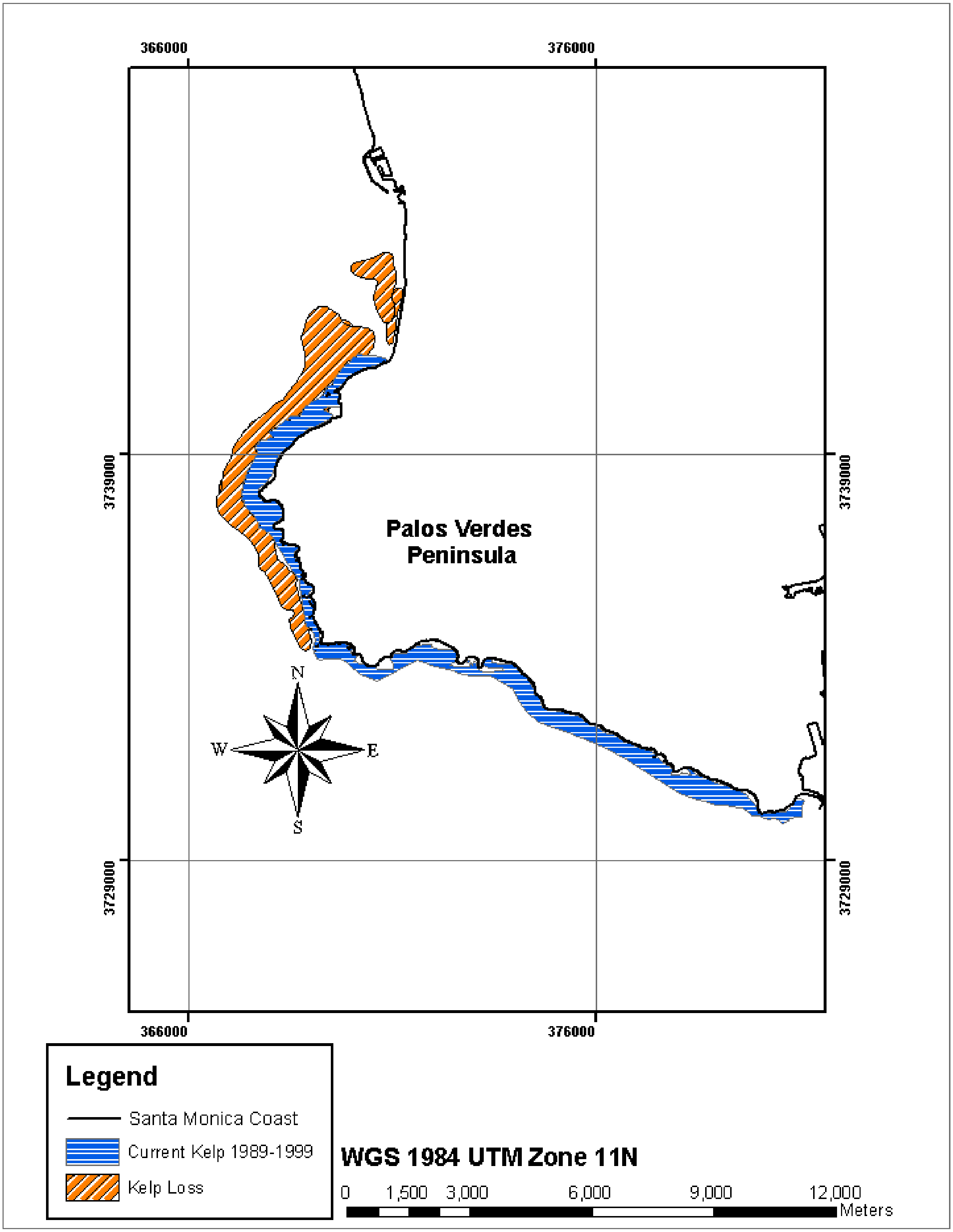

Figure 2b - Palos Verdes Peninsula study site, displaying current kelp and historical kelp coverages.

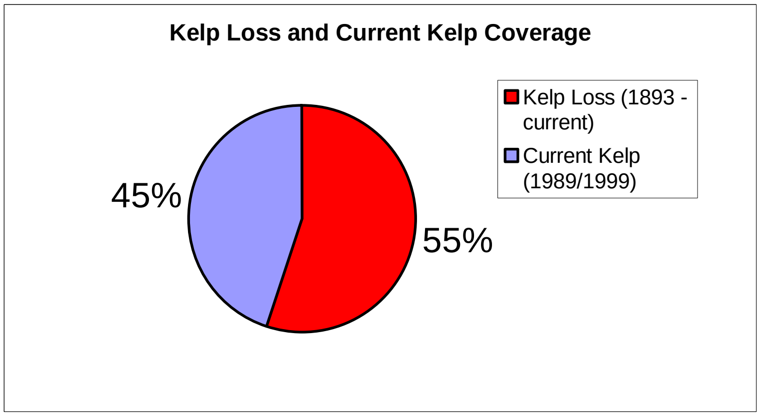

Figure 2c - Percentages for each type of coverage.

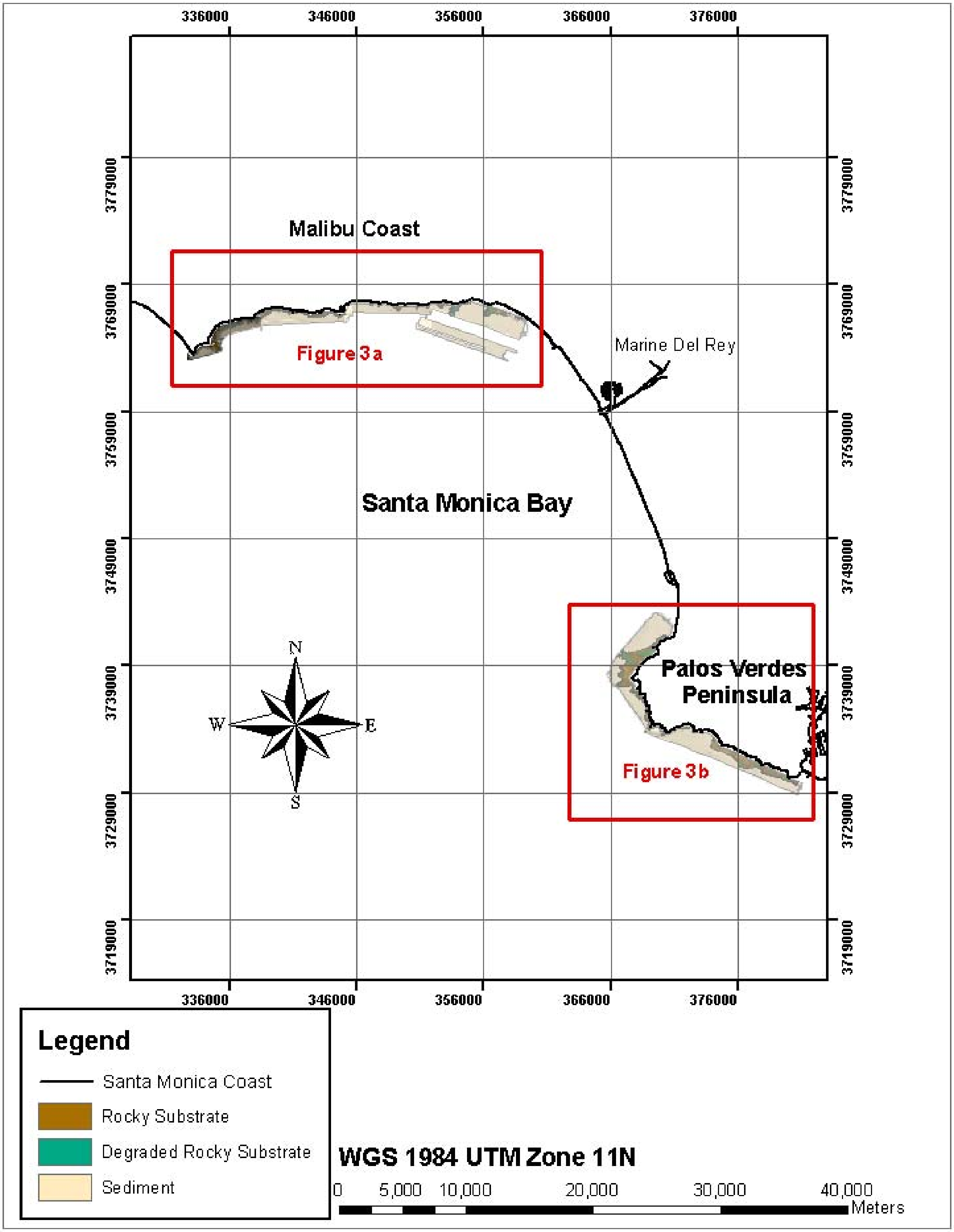

Figure 3 - Santa Monica study sites (Malibu coast and Palos Verdes Peninsula), with the three different substrate types along with gray scale bathymetric images.

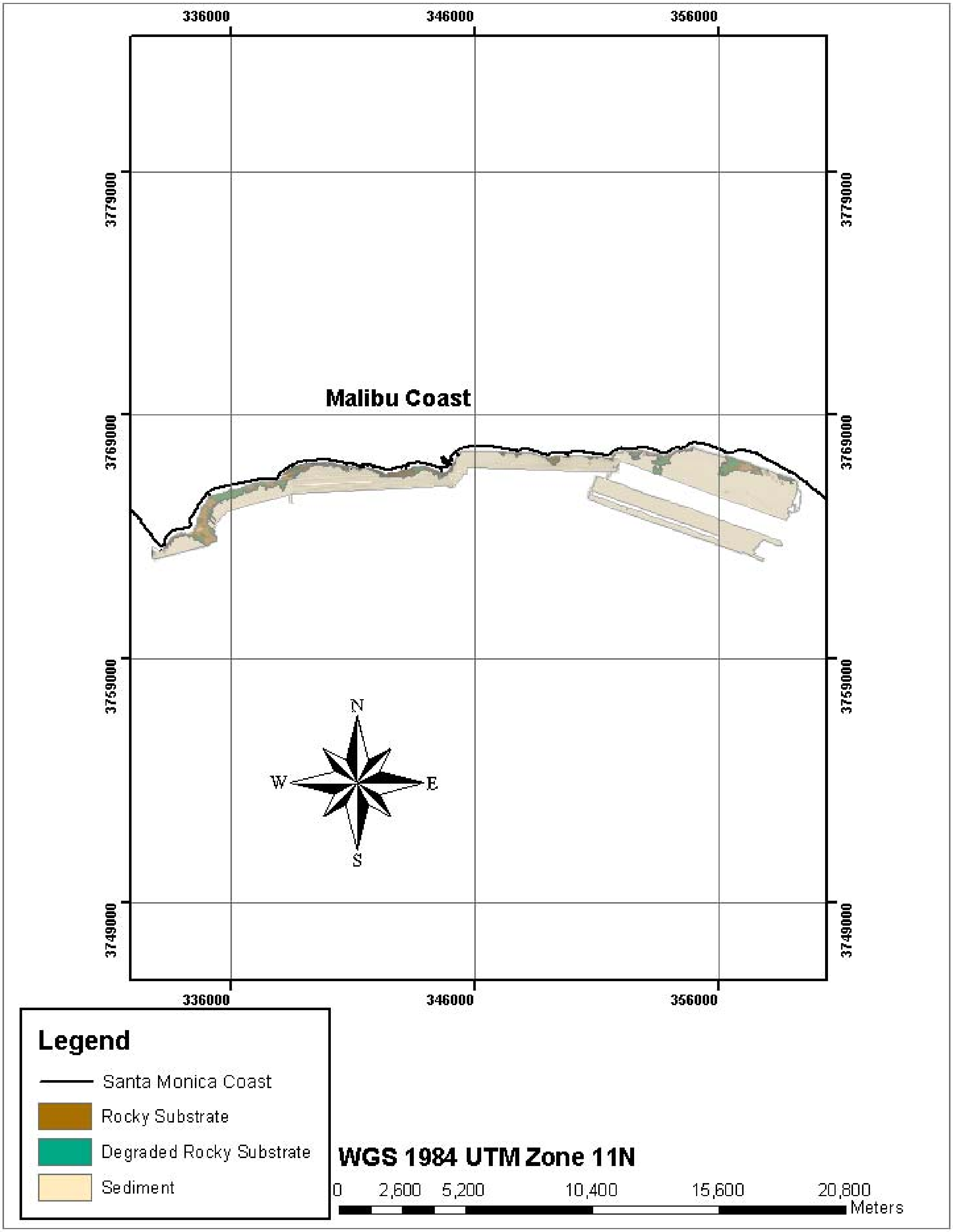

Figure 3a - Malibu coast study site, with the three different substrate types along with gray scale bathymetric images.

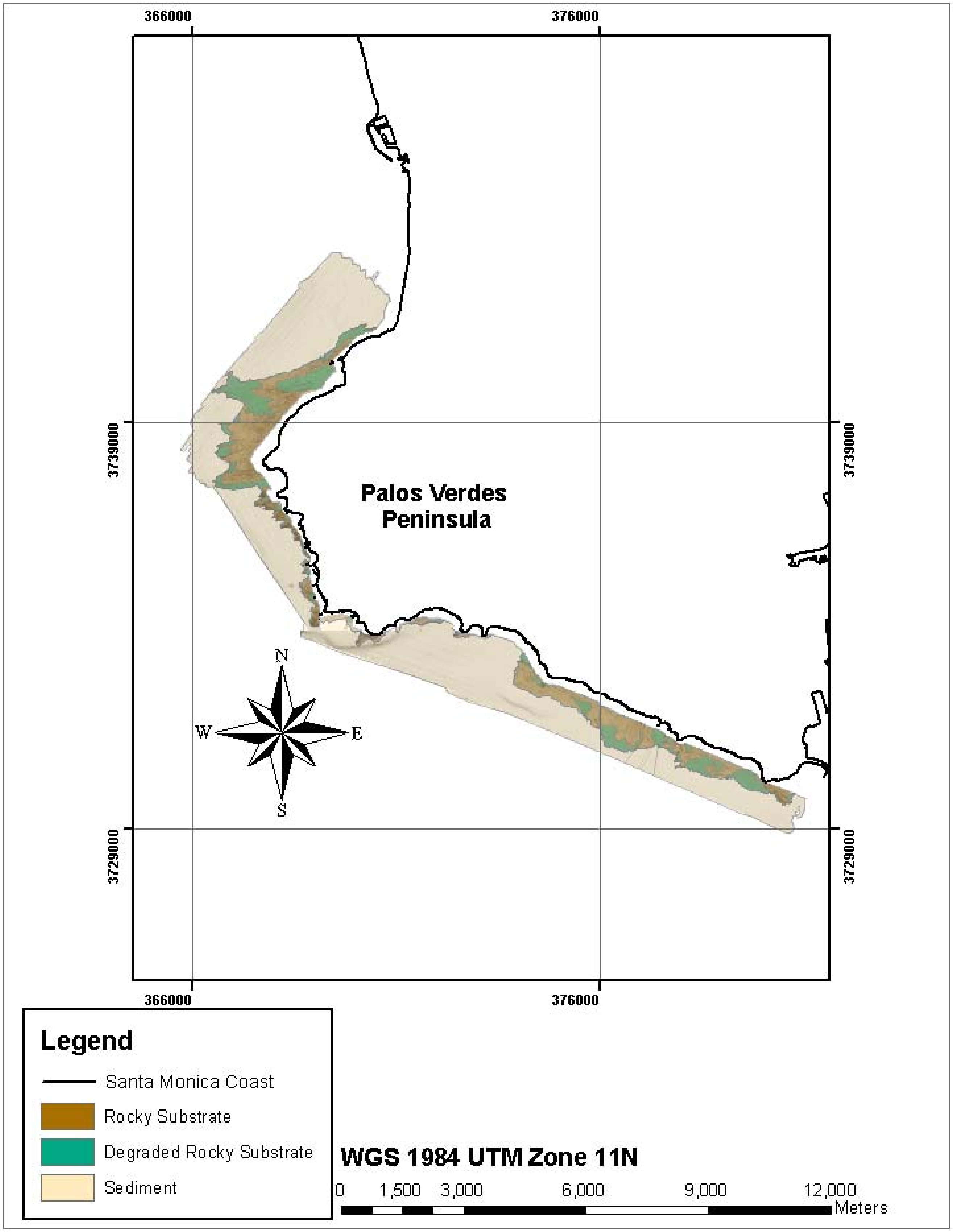

Figure 3b - Palos Verdes Peninsula study site, with the three different substrate types along with gray scale bathymetric images.

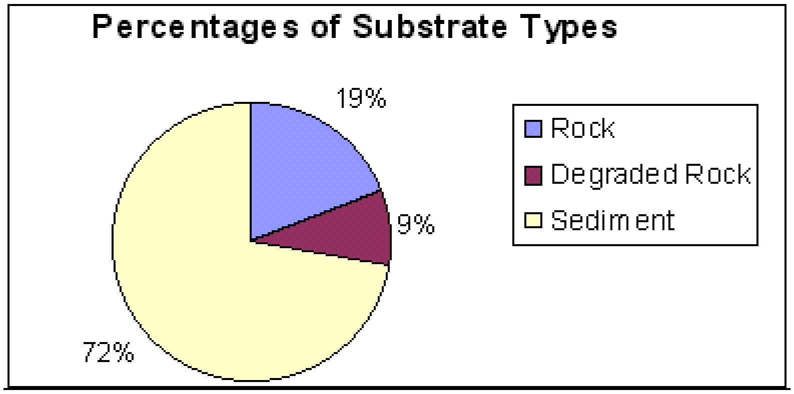

Figure 3c - Percentages for the three different substrate types.

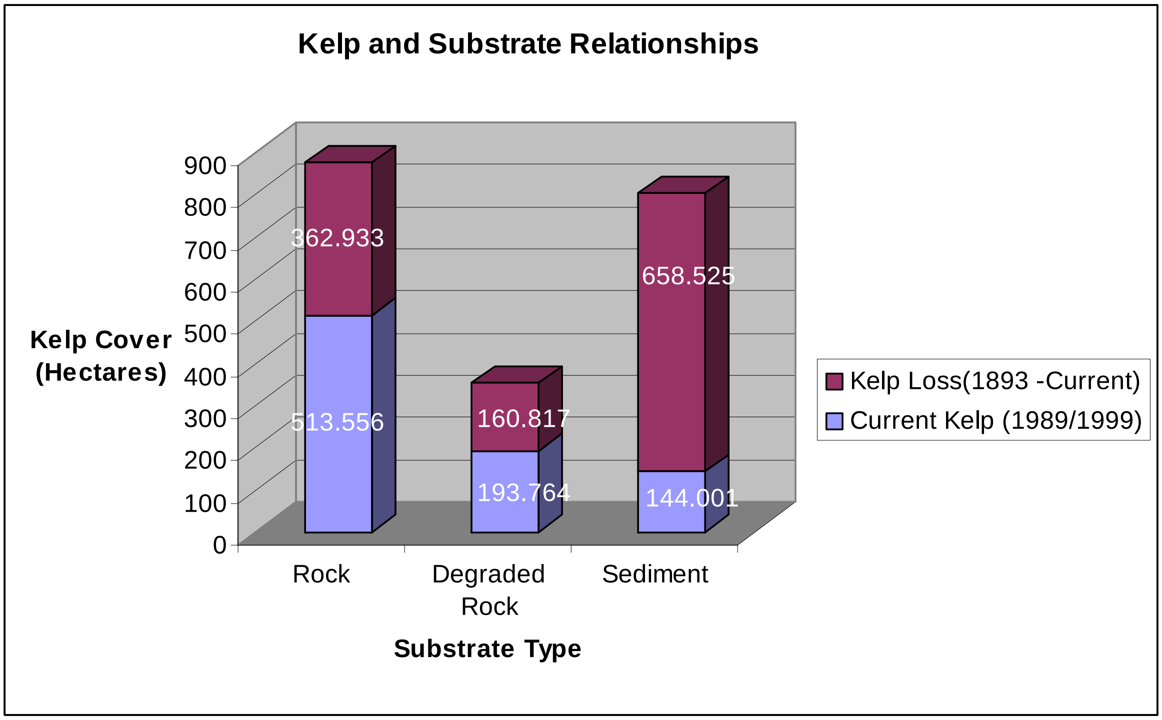

Figure 4 - This figure displays the kelp and substrate relationships in terms of area (hectares), it shows how much kelp coverage is over the three different substrate types.

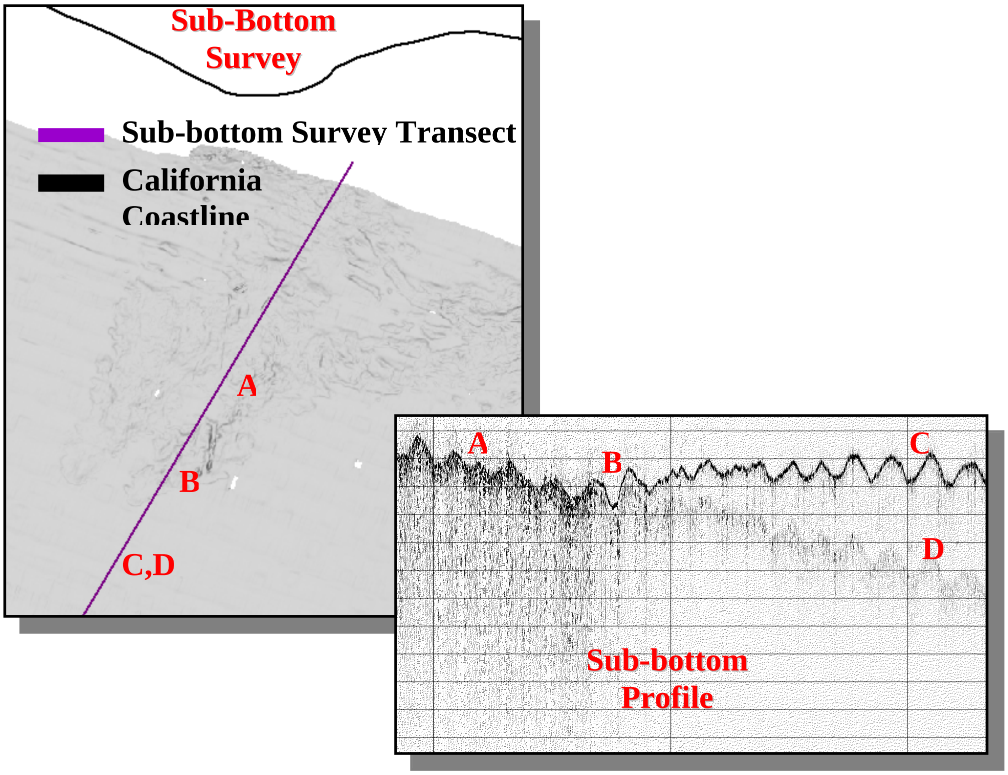

Figure 5: Sub-bottom profile survey line across rocky reef, rock-sediment transition, and sediment flat (left). Acoustic Sub-bottom profile data (below) showing exposed rocky habitat (A), transition (B), surface sediment (C), and buried rocky habitat (D).

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