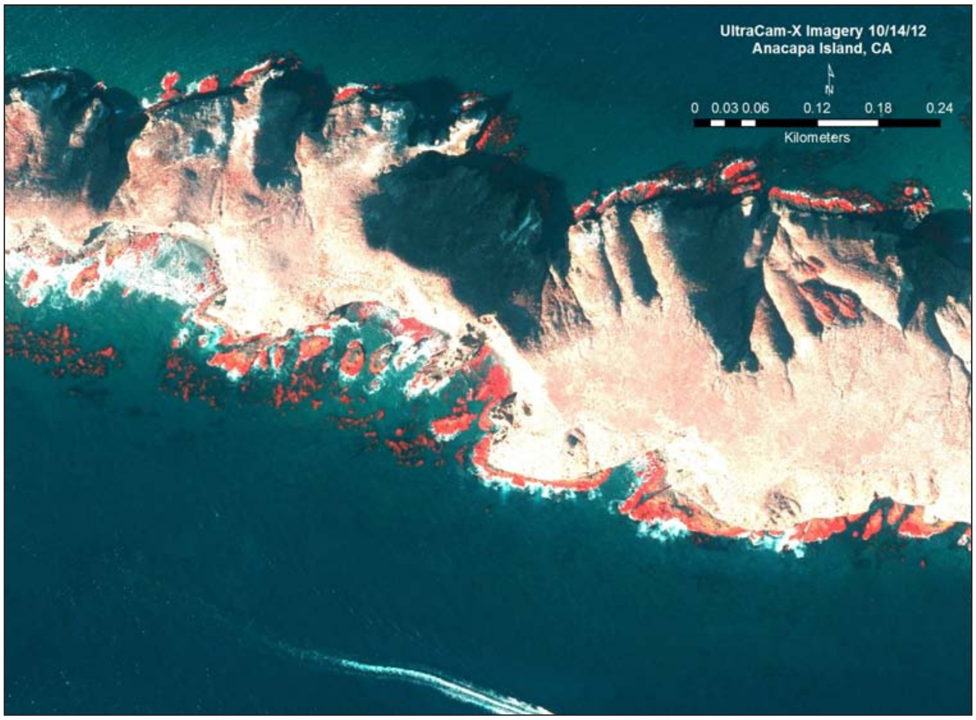
Nearshore Substrate Mapping Change Analysis Using Historical and Contemporary Multispectral Aerial Imagery.

FINAL REPORT

Sea Grant
California

Grant No: MPA 10-049
CA Sea Grant Account #: SEA 2153
Project Number: R/MPA-30

30 September, 2014
Revised 4 March, 2015



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Executive Summary

Marine Protected Areas (MPAs) in California's South Coast Region (SCR) encompass numerous ecosystem types, including Beach, Rocky and Soft-bottom Intertidal, and Kelp ecosystems that have been identified as prime focuses for the region's MPA monitoring program. These resources cover very large areas and the utilization of field sampling and measurements to establish a baseline characterization database over their entirety at relatively high spatial resolution is economically and logistically impossible. At the same time, a high resolution, accurate subtidal, intertidal and estuarine bottom cover database is of great importance for establishing the existing locations and spatial extents of various ecosystem and species types, and for use as a base layer by researchers studying the distributions and abundance of invertebrates and vertebrates with specific habitat requirements. Therefore, a baseline database covering areas both within and outside the MPAs is important for enabling future spatial and temporal comparison studies evaluating the long-term effects of the recently created MPAs.

Multispectral remote sensing provides a highly cost-efficient means for classification of ground and bottom substrate. The highest spatial resolution is achieved using imaging sensors from aircraft. The objective of this project was to create a very high spatial resolution (1-2m) intertidal to subtidal substrate distribution map database covering nearly all of the MPAs in the California SCR, and significant areas outside of the MPAs. This was accomplished using multispectral aerial imagery classified for substrate type using algorithms trained, in part, with field sample data collected specifically for this project by Ocean Imaging staff, but also with field data provided by the South Coast Baseline Project (SCBP). The region of coverage included coastline between Point Conception, CA and Imperial Beach, CA as well as all of the Channel Islands, Santa Barbara Island and Santa Catalina Island. The cumulative stretch of coastline imaged and mapped sums to 556 km.

Three remote sensing datasets were utilized to create the final substrate map products: 1) 4-banded imagery collected in June, October and November of 2012 by Keystone Aerial Mapping with its Microsoft UltraCam-X (used for 2012 intertidal and kelp mapping); 2) 4-banded imagery collected in December of 2011 by Ocean Imaging using its DMSC MK II sensor (used for 2011 kelp mapping); 3) Light Detection and Ranging (LiDAR) topographic data collected by Fugro Earth Data in March, 2010. The LiDAR dataset (providing high resolution topographical data of the intertidal zone) proved to be less useful for intertidal zone delineation than for the North Central California Coast (NCC). This was due to data format issues and some obvious errors in the SCR dataset in the lower intertidal to subtidal zones. However, the LiDAR dataset was used whenever possible. Field data and photographs collected for this project between 2013-2014 were also utilized to divide the terrestrial, intertidal and subtidal areas into subzones helping to create subzone-specific training sets used in the supervised classification procedure. Each subzone classification was then manually edited in order to ensure the highest accuracy product possible, and then mosaicked together into subregions of the overall SCR. The habitat classes this process confidently identified and mapped using the multispectral imagery for the sub/intertidal zones were:

1 - Whitewash/Undefined
2 - Water
3 - Sandy Beach
4 - Mixed Red/Brown Algae
5 - Shadow
6 - Terrestrial Vegetation
7 - Unvegetated Rock
8 - Beach Wrack
9 - Kelp/Brown Algae
10 - Blue-Green Algae
11 - Mixed Rock/Mussels/Barnacles/Anemone
12 - Cobble
13 - Man-made/Artificial
14 - Driftwood
15 - Surf Grass
17 - Eel Grass
21 - Green Algae
22 - Submerged Sandy Bottom
23 - Submerged Rock/Reef
24 - Deep Water

The accuracy of the produced map products was evaluated with Congalton Matrix statistics, using a field sample dataset from SCBP's Biodiversity Point Contact Surveys specifically reserved for this purpose. The evaluation yielded 65% overall accuracy. The attached figures show samples of the original multispectral imagery and resulting final substrate classification of the Farnsworth SMCA. Due to the fine scale resolution of the assessment reference data when compared to 1 meter pixels in the classification product along with the fact that the field reference data were acquired from the most diverse and varied environments compared to the overall SCR as a whole, it is estimated that the actual accuracy of the intertidal classification maps are closer to 80%-85%.

The clear waters in the SCR allowed for classification well into the subtidal zone for most of the SCR OI-Aerial subregions, and so the classes with the overall highest percentage of area covered were the offshore ones such as "Submerged Sandy Bottom" and "Submerged Rock/Reef". The more ecologically significant classes therefore covered a relatively small percentage of our SCR study areas and the MPAs. Since the MPAs were created to purposefully encompass areas holding rich and varied ecological resources, the remote sensing-derived database was expected to reflect the greater abundance of such habitats within as opposed to outside the MPAs. The percentages of ecologically important classes, however, were very similar within the MPAs and outside of the MPAs. For example, the important classes Mixed Red/ Brown algae covered 0.72% of the classified area within the MPAs and 0.67% outside of the protected zones. Kelp/Brown Algae covered 2.21% of the classified area within the MPAs and 2.60% outside of the protected zones and while surf grass covered 0.55% of the total area within the MPAs and 0.58% outside of them. Conversely, sandy beach and unvegetated rock substrates were almost twice as abundant outside the MPAs. These baseline similarities and differences must be considered in future studies comparing closely located MPAs.

The project also utilized historical archived aerial imagery and newly acquired imagery to produce kelp canopy classifications for the designated SCR subregions from 2011 and 2012 as well as to compute its persistence over the period 1999 to 2012. The analyses showed a high degree of inter-annual variability which must be considered in future assessments of the state of this important resource. In general, kelp beds closer to shore showed a higher level of persistence over the time period and offshore beds tended to exhibit a higher degree of inter-annual variability. A sample of this analysis from the San Miguel Island subregion is included at the end of this summary.

Additionally, a change detection analysis for the SCR subregions covering from Dana Point, CA south to Imperial Beach, CA was performed using multispectral imagery-derived intertidal habitat classifications created in 2002 and compared to the 2012 classifications generated for this project. Significant changes between substrate coverage were revealed over the 10-year time period. The dramatic changes between sand covered bottom and vegetated rock over the 10 year period in areas such as the Cabrillo SMR, however were most likely not due to changes in the actual bottom cover, but rather the over-classification of submerged, vegetated rock on the 2002 data set. We found that the differences in the multispectral imagery used, 2002 vs. 2012 data classification methods and technology, along with environmental conditions at the time of data collection provided the best explanation for extreme changes in substrate cover, rather than large scale changes to the environment during the 10-year time period. Lack of a consistent gain or loss pattern between regions, in the case of surf grass for example, indicate, however that the differences are not entirely due to non-environmental factors and there is merit in using synoptic, thematic maps derived from remotely sensed data to compare intertidal baseline data over many years. This highlights the fact that for future studies and assessments, it is critical that the type of imagery used, classification methodology applied and conditions at the time of data collection are as close as possible between datasets.

Any future remotely-sensed derived databases to be used for comparison to the 2012 sub/intertidal

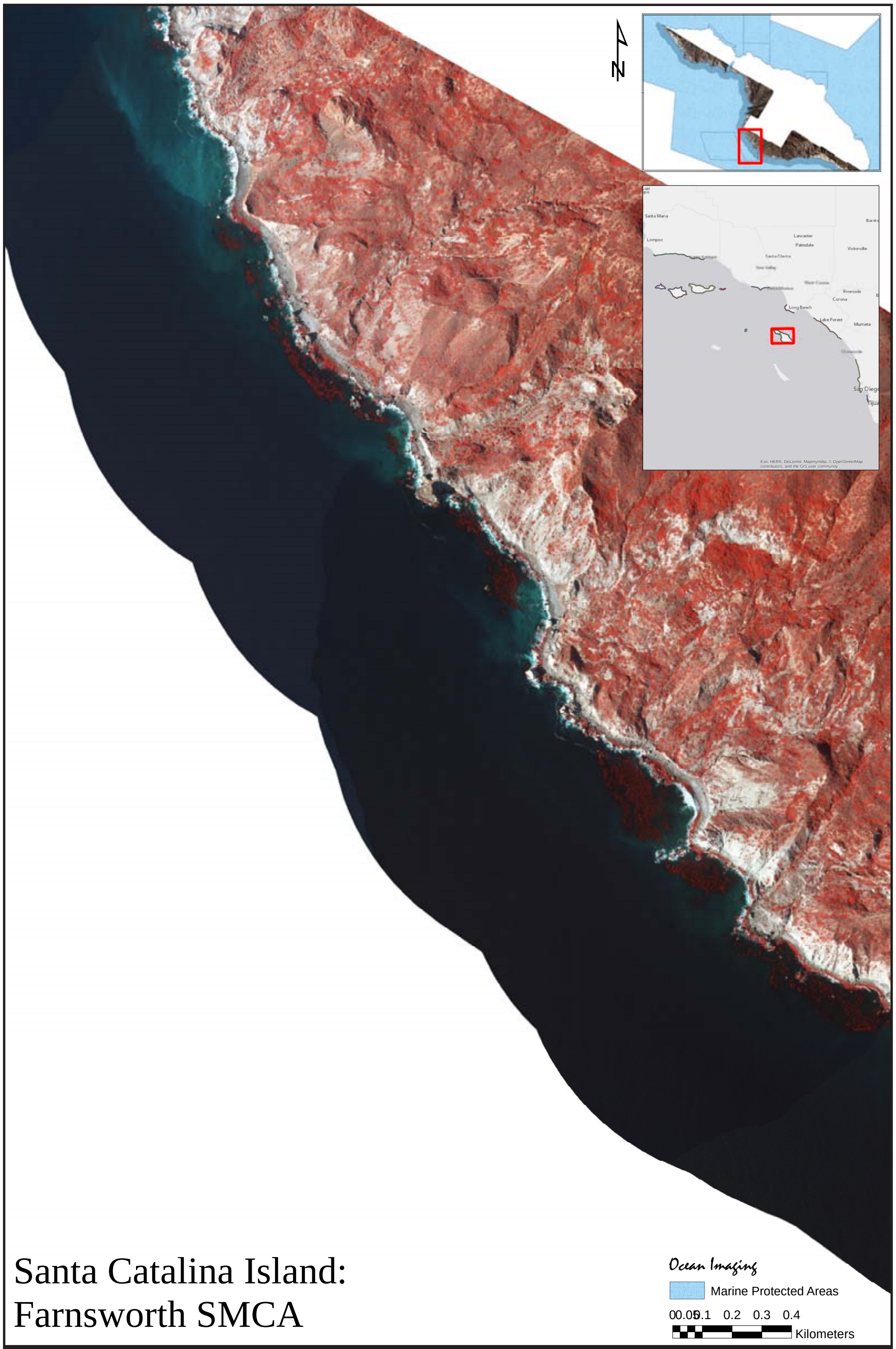


Figure ES1.

Sample multispectral imagery of Santa Catalina Island: Farnsworth SMCA.

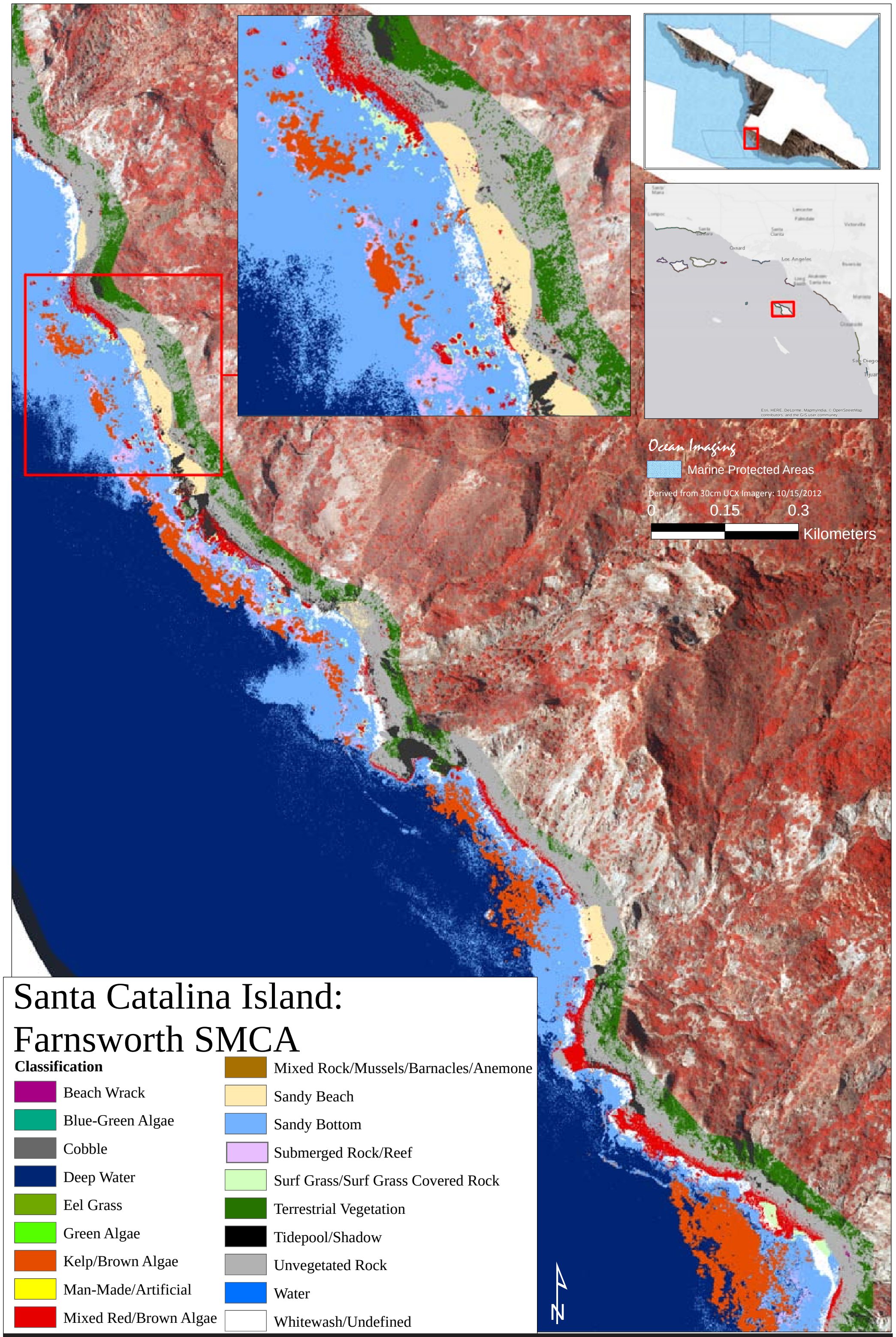


Figure ES2.

Sample intertidal habitat classification of Santa Catalina Island: Farnsworth SMCA.

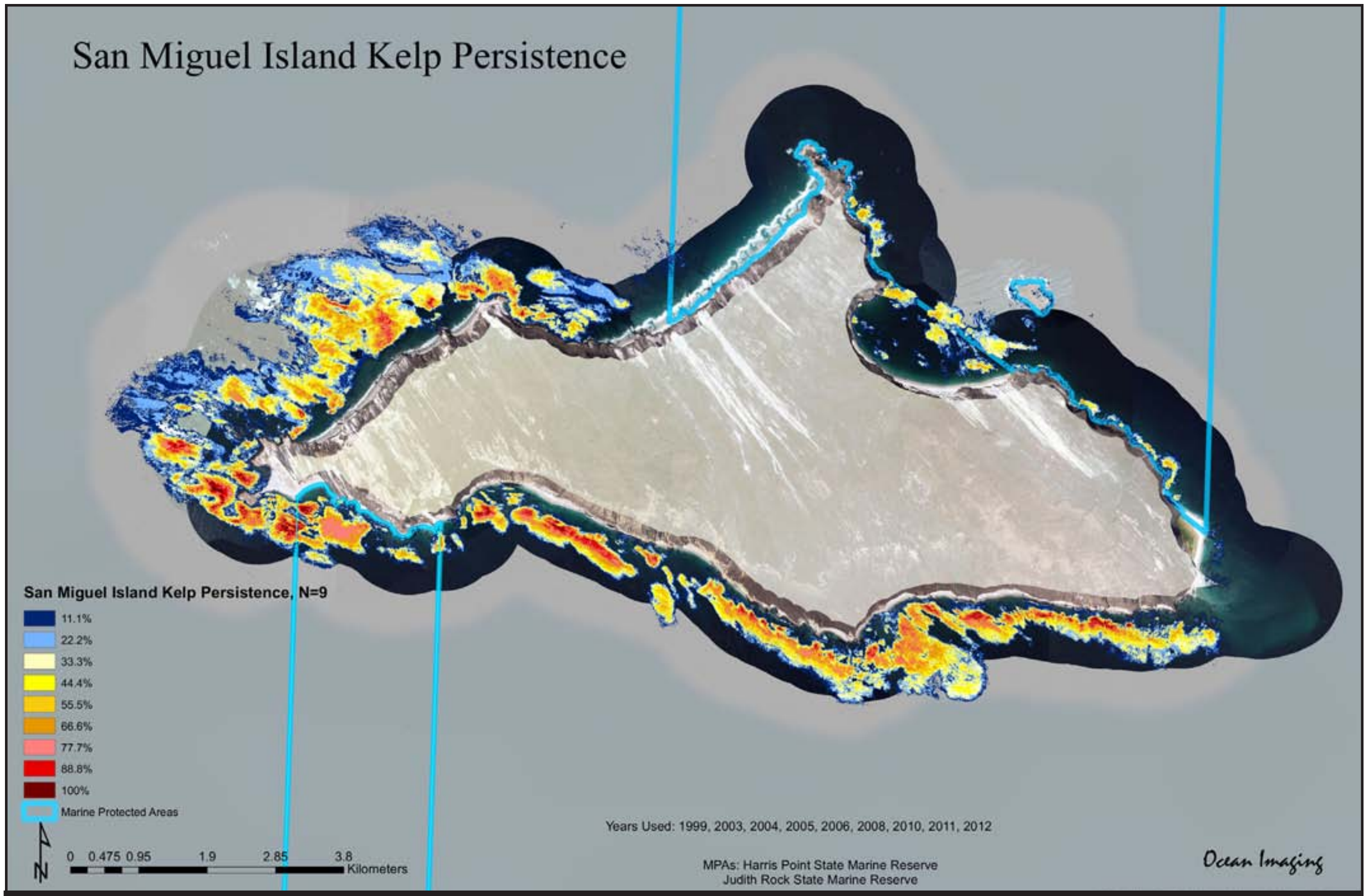


Figure ES3.

Sample kelp persistence analysis of San Miguel Island.

and kelp databases generated as part of this study should be as close as possible to the 2012 data in regards to:

1) The multispectral camera system used
2) The time of year the data are acquired
3) The tidal and environmental conditions at the time of data collection
4) The processing techniques used to create the image mosaics
5) The classification techniques utilized to create the thematic maps

As was illustrated in the change detection analysis performed as part of this project, even small differences in the above factors can lead to diminished confidence in the analysis of the environmental/habitat change over the time period being studied. Any long term monitoring plan which aims to take advantage of the synoptic, comprehensive habitat map products generated from remotes sensing data should take this into serious consideration.

Final classification and analysis product files were delivered to Sea Grant and OceanSpaces in both GeoTIFF (.tif), ESRI shapefile and PDF formats in September of 2014.

1. Introduction

1.1 Project Background and Justification

Marine Protected Areas (MPAs) in California's South Coast Region (SCR) encompass numerous ecosystem types including Estuarine, Beach, Rocky and Soft-bottom Intertidal and Shallow Subtidal, and Kelp ecosystems. These specific ecosystems cover vast areas and have been identified as prime focuses for the region's MPA monitoring program. The utilization of field sampling and measurements to establish a synoptic baseline characterization database over their entirety at relatively high spatial resolution is economically and logistically impossible. At the same time, a high resolution, accurate subtidal and intertidal vegetation, substrate and bottom cover database is of great importance for establishing the existing locations and spatial extents of various ecosystem and species types. These data will be used as a "base layer" by researchers studying the distributions and abundance of invertebrates and vertebrates with specific habitat requirements. Such base data may also be used by researchers studying the socioeconomic impacts of the MPAs, e.g. shifts in fishing activities from the MPA areas to other locations including kelp beds and related rocky substrate areas outside the MPAs. The inclusion of areas outside the MPAs will provide data over possible "control" sites for future studies.

Most natural resources tend to exhibit inter-annual variability in abundance and spatial distribution due to factors not related to the creation and maintenance of the MPAs. Thus, to elucidate the results of future studies and monitoring projects, historically useful baseline characterizations should consistently include non-MPA variability data. A useful baseline characterization database should also include some measure of habitat or resource variability due to natural or anthropogenic causes not related to the creation and maintenance of the MPAs. Therefore, in addition to the database described above, we utilized image time series analysis to provide a quantitative measure of persistence and/or spatial distribution variability for several important coastal resources including algae covered reef, kelp, surf grass and unvegetated bottom substrate. This was made possible by examining the differences between the 2012 habitat classifications created from 1 meter multispectral data and classifications derived from 2-meter multispectral data acquired by Ocean Imaging (OI) between Imperial Beach, CA and Dana Point, CA in 2002.

Of the most valuable coastal resources are the brown macroalga (Phaeophyceae in the order Laminariales) such as Macrocystis Pyrifera (commonly referred to as Giant Kelp), Laminaria setchellii (commonly referred to as Stiff-Stiped Kelp) and Egregia menziesii (commonly referred to as Feather-Boa Kelp). These species of large brown algae, which for the purposes of this project will be heretofore referred to simply as kelp, are commonly found from the lower intertidal rocks, in protected to moderately wave-exposed areas, extending out past the subtidal zone. Laminaria and Egregia are often found mixed with Macrocystis at the inner edges of kelp beds as well as growing in mixed stands with surf grass (Phyllospadix spp). (Abbott and Hollenberg 1976). Annual aerial-imaging based kelp resource inventories along the SCR mainland coast and islands are much more complete over the past two decades than in the Northern California areas. The surveys include California Department of Fish and Wildlife (CDFW)-sponsored work as well as surveys sponsored collectively by Southern California wastewater dischargers as part of their discharge permit-mandated environmental monitoring. Data covering the Channel Islands include CDFW and Navy-sponsored surveys. OI has utilized these datasets to create a first-ever large-scale database of kelp persistence in the SCR region. The available datasets spanning 1999-2012 were run through a statistical algorithm on a pixel by pixel basis to create a GIS layer of kelp persistence rendered as persistence classes representing the numbers of years kelp was present in each pixel location in the analysis during the time period. In addition, future researchers may be interested in any growth/persistence trends for individual kelp beds. For this reason an additional database has been created which lists each available year's total kelp canopy area within each MPA.

1.2 Project Goals and Objectives

This project had two primary objectives:

1) Create a baseline database of shallow subtidal and intertidal bottom substrate and kelp canopy at very high spatial resolution

(40cm-2m) covering all Marine Protected Areas (MPAs) in the California South Coast region (SCR). Select kelp canopy and inter-to-subtidal substrates were also mapped in areas outside the MPAs, resulting in a spatially broad database for the SCR region.

2) Conduct change-detection and persistence analysis utilizing similarly collected data from the past 10-12 years to assess any changes in the shallow subtidal and intertidal substrates and persistence trends in kelp canopy prior to the establishment of the new MPAs.

This comprehensive goal was to be accomplished in a very cost-efficient manner by utilizing state-of-the art aerial imaging and multispectral image processing technologies. Substrate classification accuracy was carefully validated with field sample data provided by other collaborating research teams as well as new sampling done specifically for this project.

For the second goal, comparing prior collected data would help assess any changes in the shallow subtidal and intertidal substrates and persistence trends in kelp canopy prior to the establishment of the new MPAs.

Both objectives directly address the establishment of databases for Rocky and Soft-bottom Intertidal Ecosystems, and Kelp, Shallow Rock and Shallow Soft Bottom Ecosystems. These remote sensing-derived baseline characterization databases and the resource persistence/variability analyses allow coastal decision makers to attain valuable insights useful for evaluating these novel technologies for possible implementation and enhancement of a long-term monitoring plan.

2. Technical Approach and its Modifications to Achieve Best Deliverable Products

The overall technical approach for this project was to obtain multispectral aerial imagery over the target areas and then process the data with multispectral digital image classification algorithms to obtain bottom substrate and kelp coverage map database products. Field sampling data obtained over specific areas were to be utilized in part to help train the classification algorithms and also (from a separate sample set) to generate classification accuracy statistics for the final datasets.

Initially the intertidal imagery were scheduled to be collected during the early fall of 2011 and the kelp imagery during both the fall of 2011 and 2012. A delayed project start date of 09/01/2011, lack of data acquisition windows during the early fall season (low sun angle and tidal conditions required), combined with subsequent poor weather during that time period, pushed the intertidal imagery acquisitions into 2012. However, the kelp imagery data collections held to the fall of 2011 and 2012 schedule for reasons explained below.

2.1 Geographical Extent of Data Coverage and Analysis

Intertidal and Kelp Imagery/Classifications: Figure 1 shows the proposed and actual extents of the intertidal and kelp mapping areas within the SCR. Data along the entire coastline of the Channel Islands, Catalina and Santa Barbara Islands were acquired. Also imaged and processed were all proposed MPA coastline areas from Point Conception, CA south to Imperial Beach, CA, with significant portions of the neighboring coastline included for control area purposes. The total length of coastline data acquired summed to 556 km.

The intertidal imagery data were acquired at 30cm spatial resolution (Ground Sampling Distance – GSD). The kelp data imagery were acquired at 30 cm – 1 m GSD. In previous projects of this nature in the SCR region, OI has found 1-meter resolution to provide very high spatial detail and substrate identification accuracy, while maintaining a sufficiently wide imaging swath to cover the targeted zone in a continuous flight line (hence offering best flight time cost efficiency). Centered on the intertidal zone, this scan width of 30 cm was sufficient to cover all targeted areas and provide additional coverage of the shoreline (useful for georeferencing corrections) and subtidal areas. In coastal sections requiring a wider swath width, multiple side overlapping lines were flown and the data seamlessly merged.

The 2011 and 2012 kelp imagery cover the same geographical subregions shown in **Figure 1**, but extend farther offshore (~1-3 km depending on extent of kelp) in order to capture all of the offshore beds. Kelp coverage for some OI-Aerial subregions is incomplete due to weather complications and or flight plan restrictions imposed by the US Navy. Data coverage for the imagery and corresponding kelp classifications are shown below in **Figures 2A and 2B**. Further discussion on the data acquisition and processing follows in section 2.2.

Kelp Persistence Analyses: The kelp persistence analyses were also performed for each subregion shown in **Figure 1** at the spatial resolution of 2 meters. Most of the CDFW kelp canopy products were only available at 2 meter GSD and thus the 2011 and 2012 kelp imagery were subsampled to 2 meters to fit the GSD of the analyses. Also, some of the CDFW and OI kelp data did not include 100% complete coverage of the project's study areas, however all of the MPA's were covered by the datasets used for the kelp persistence analysis. Additional discussion is below.

Change Detection Analysis: The 2002 multispectral imagery-derived intertidal classifications used for the habitat change detection analysis comparing to the 2012 substrate classifications generated for this project covered from Dana Point, CA south to Imperial Beach, CA. **Figure 3** shows the coverage areas for the 2002 and 2012 substrate classifications and the resulting area of the change detection analysis performed. Additional data from Orange County, Santa Barbara Island and Santa Catalina Island were proposed for use, however, further examination of that multispectral imagery proved the data to be of insufficient quality and spatial resolution to obtain substrate classifications comparable to the 2012 data. The 2002 substrate classification was created at a spatial resolution of 2 meters and so for this analysis, the 2012 intertidal classifications were subsampled to 2 meters to match the GSD of the 2002 data.

2.2 Data Acquisition and Processing

Inter/subtidal imagery acquisitions: The originally proposed work plan included the use of Ocean Imaging's (OI's) DMSC-MkII aerial system for these image data acquisitions. Subsequently, in 2011 OI had the opportunity to utilize a Microsoft UltraCamX aerial sensor, albeit at a higher acquisition cost. OI decided to seize this opportunity and financed the increased cost (approximately $16,000) internally as co-funding.

Digital multispectral data were acquired using a Microsoft UltraCamX Digital Sensor (UCX). This sensor is a 16-bit, 4000x4000 pixel, 4-channel instrument imaging in the red (580-700nm), green (480-640nm), blue (380-540nm) and near-infrared (680-960nm) wavelengths flown in tandem with a high accuracy airborne geographical positioning system (ABGPS) and inertial measurement unit (IMU) to achieve high geolocation accuracy and precision. The data were acquired at a ground sampling distance (GSD – i.e. horizontal spatial resolution) of 30 cm during specific tide, sun angle and weather conditions. This reduces the possibility of sun glint contamination and ensures an acceptable level of solar illumination during times when the substrate/vegetation in the intertidal zone is maximally exposed. Requirements dictated the data be collected during periods of seasonally low tides within a 3 hour time window, +/- 1.5 hours from the mean low water level (MLW). In most cases, the data were acquired +/- 1.5 hours of the mean lower low water lever (MLLW) which is lower than the required level.

Imagery from the UCX sensor was used in place of the proposed DMSC sensor for several reasons. The bit depth of the UCX is 16-bit as opposed to the DMSC's 12-bit sensitivity which offers greater spectral fidelity and hence improved ability to classify substrates. Given the wide swath width of the UCX, 30 cm spatial resolution can be collected for the entire study region compared to the proposed 1 meter and 40 cm data which would have been collected with the DMSC. This did provide more detailed and precise imagery resulting in a better classification product. Finally, geolocation capability of the UCX is superior to that of the DMSC, delivering more geographically accurate imagery and data products.

100% of the imagery covering the MPA regions as defined in the proposal was collected. 90% of the data were acquired between 06/07/2012 and 10/16/2012. The remaining datasets were collected on 11/12/2012 and 11/13/2012. The November 2012 imagery was collected during low tide levels and favorable weather and so, like the rest of the data, are of very high quality and show excellent spectral and spatial definition. Water penetration in areas of calm seas were more than sufficient in most areas to classify submerged substrate into the subtidal zone as depth and water clarity permitted.

All of the UCX imagery was orthorectified, georeferenced and projected to a WGS_1984_UTM_Zone_11N geographic projection preserving the 30 cm spatial resolution. The imagery were then cross-checked for geographic accuracy and manually corrected to achieve a horizontal spatial accuracy of at least +/- 1 meter RMSE. The image tiles were then mosaicked into logical subregions along the SCR coast and islands based on UCX flight lines, local city/region names and MPA locations within each subregion as shown in **Figure 1**. These subregions are referred to as the OI-Aerial subregions throughout this report. This work was performed using both the ERDAS Imagine and ESRI ArcGIS software packages. The image mosaics were then subsampled to the proposed 1 meter delivery product and the corresponding metadata were associated with each mosaic. The resulting files in GeoTIFF (.tif) format were then set aside for use in the substrate classification process as well as moved to hard drive media for delivery to the California Ocean Science Trust (OST) and OceanSpaces.org.

2011 and 2012 Kelp Imagery Acquisition and Processing: Kelp imagery and classifications were originally proposed for delivery in the fall-winter of 2012 and 2013. CDFW did not renew its contract with OI in 2013. Consequently, kelp data for 2013 were not available to OI and data from the fall of 2011 were substituted for 2013 instead. All kelp imagery for the years 2011 and 2012 were acquired during the mid to late fall of 2011 and 2012. The 2011 imagery were collected on 11/22/11, 12/07/11 and 12/08/11 at a ground sampling distance (GSD – horizontal spatial resolution) of 2 meters using OI's DMSC MK II multispectral imager configured with the four bands at 451, 551, 710 and 850 nm. OI owns and operates a 4-channel aerial imaging sensor - the DMSC - manufactured by SpecTerra, LTD in Australia. The unit incorporates 4 synchronized, progressive scan 1024x1024 CCD cameras with spectral range capability from 350-990nm. Data is captured in 12-bit format. The unit is integrated with a DGPS for synchronous frame location logging. The channel wavelengths are customized by the use of narrow-band (10-20nm) interference filters. Spectral sensitivity is also customizable through software controlled shutter speed. The DMSC is a portable system suitable for mounting on a variety of aircraft. It acquires successive image frames at a rate automatically computed from the DGPS-derived ground speed and user-specified frame-to-frame overlap margin. OI also owns an Inertial Movement Unit (IMU) which collects precise location, altitude, roll, pitch and heading of the DMSC. The IMU was run in tandem during image collection and data collected will be used in the post-processing of the imagery.

Upon completion of each flight, image data were downloaded from the DMSC onto an in-house computer hard drive. Back-up copies were burned on DVD's. Pre-processing included a two-step procedure to eliminate slight band-to-band misalignment. This was done using customized software to first compute an overall x-y direction shift of bands 1, 3 and 4 relative to band 2. Each of the 4-band shifted image frames was then run through a Fast Fourier Transform (FFT)-based pattern recognition routine, which tiles the image into 80 pixel sections and computes a secondary, regional pixel shift on each band. The pre-processed imagery was then run through an in-house, customized software package to auto-georeference each of the pre-processed frames based off of the DGPS time stamp from the DMSC and the time stamp from the IMU. Once auto-georeferenced, frames were manually georeferenced and assessed for quality using Microsoft's 1-meter VirtualEarth data as a reference layer. Adjusted frames were then projected to a

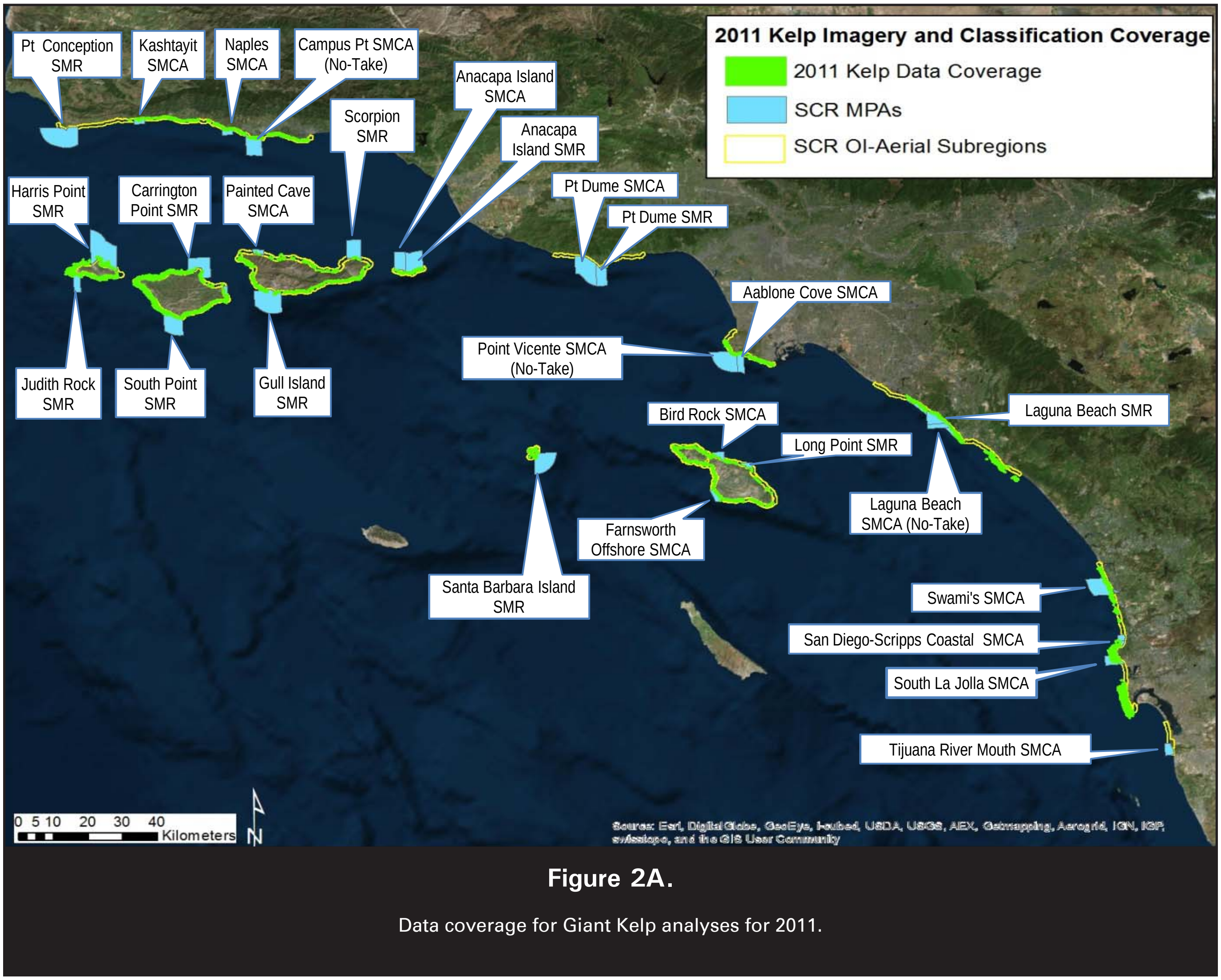
Intertidal & Subtidal Kelp Survey Area	OI-Aerial Subregion Name	Data Product and Analysis Subregions & Corresponding MPAs (SMRs and SMCAs)
1	Anacapa Island	Anacapa Island SMCA, Anacapa Island SMR
2	Coal Oil Point	Naples SMCA, Campus Point SMCA
3	Dana Point-Laguna Beach	Crystal Cove SMCA, Laguna Beach SMR, Laguna SMCA, Dana Point SMCA
4	Encinitas-La Jolla	Swami's SMCA, San Diego-Scripps Coastal SMCA, Matlahuayl SMR
5	Imperial Beach	Tijuana River Mouth SMCA
6	La Jolla-Point Loma	South La Jolla SMR, Cabrillo SMR
7	Point Conception	Point Conception SMR, Kashtayit SMCA
8	Point Dume	Point Dume SMCA, Point Dume SMR
9	Point Vicente	Point Vicente SMCA, Abalone Cove SMCA
10	San Miguel Island	Judith Rock SMR, Harris Point SMR
11	Santa Barbara Island	Santa Barbara Island SMR
12	Santa Catalina Island (East)	Lover's Cove SMCA, Casino Point SMCA
13	Santa Catalina Island (North)	Long Point SMR, Blue Cavern SMCA, Arrow Point to Lion Head Point SMCA
14	Santa Catalina Island (West)	Farnsworth Onshore (Catalina Island) SMCA, Cat Harbor SMCA
15	Santa Cruz Island (North)	Painted Cove SMCA
16	Santa Cruz Island (Northeast)	Scorpion SMR
17	Santa Cruz Island (South)	Gull Island SMR
18	Santa Rosa Island (North)	Carrington Point SMR, Skunk Point SMR
19	Santa Rosa Island (South)	South Point SMR, Skunk Point SMR

Figure 1. Survey areas for South Coast Region (OI-Aerial) Subregion Imagery and Analyses.

MPA South Coast Baseline Program: Ocean Imaging Aerial (OI-Aerial) imagery, data product and analysis coverage subregions and corresponding MPAs. Latitude - Longitude coordinates defining each of the areas listed above are provided in an Excel file included on the portable disk drive located in the “Support” folder with the delivered data as well as in the metadata files for each image and anlysis product.

WGS_1984_UTM_Zone_11N geographic projection preserving the 1 meter spatial resolution and mosaicked into logical subregions along the SCR coast and islands based on DMSC flight lines, local regions and MPA locations within each region as shown in **Figure 1**. This work was performed using both the ERDAS Imagine and ESRI ArcGIS software packages. The image mosaics were then subsampled to the proposed 2 meter delivery product and the corresponding metadata were associated with each mosaic. The resulting mosaics conform to an accuracy level of +/- 2 meters RMSE. The MPAs covered in each of the OI-Aerial kelp regions are listed in **Figure 1**. The resulting files in GeoTIFF (.tif) format were then set aside for use in the kelp classification process as well as moved to hard drive media for delivery to The California Ocean Science Trust (OST) and OceanSpaces.org.

The 2012 imagery were collected between 10/14/12 – 12/10/12 using a RGB-NIR Microsoft UltraCam-X digital imager at a GSD of 30 cm. Details on this instrument and the acquisition details are described above. The 2012 data were acquired using the UCX in place of the DMSC for the same reasons as described in section 2.2 above. All of the UCX imagery was orthorectified, georeferenced and projected to a WGS_1984_UTM_Zone_11N geographic projection preserving the 30 cm spatial resolution. The imagery were then cross-checked for geographic accuracy and manually corrected to achieve a horizontal spatial accuracy of at least



Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

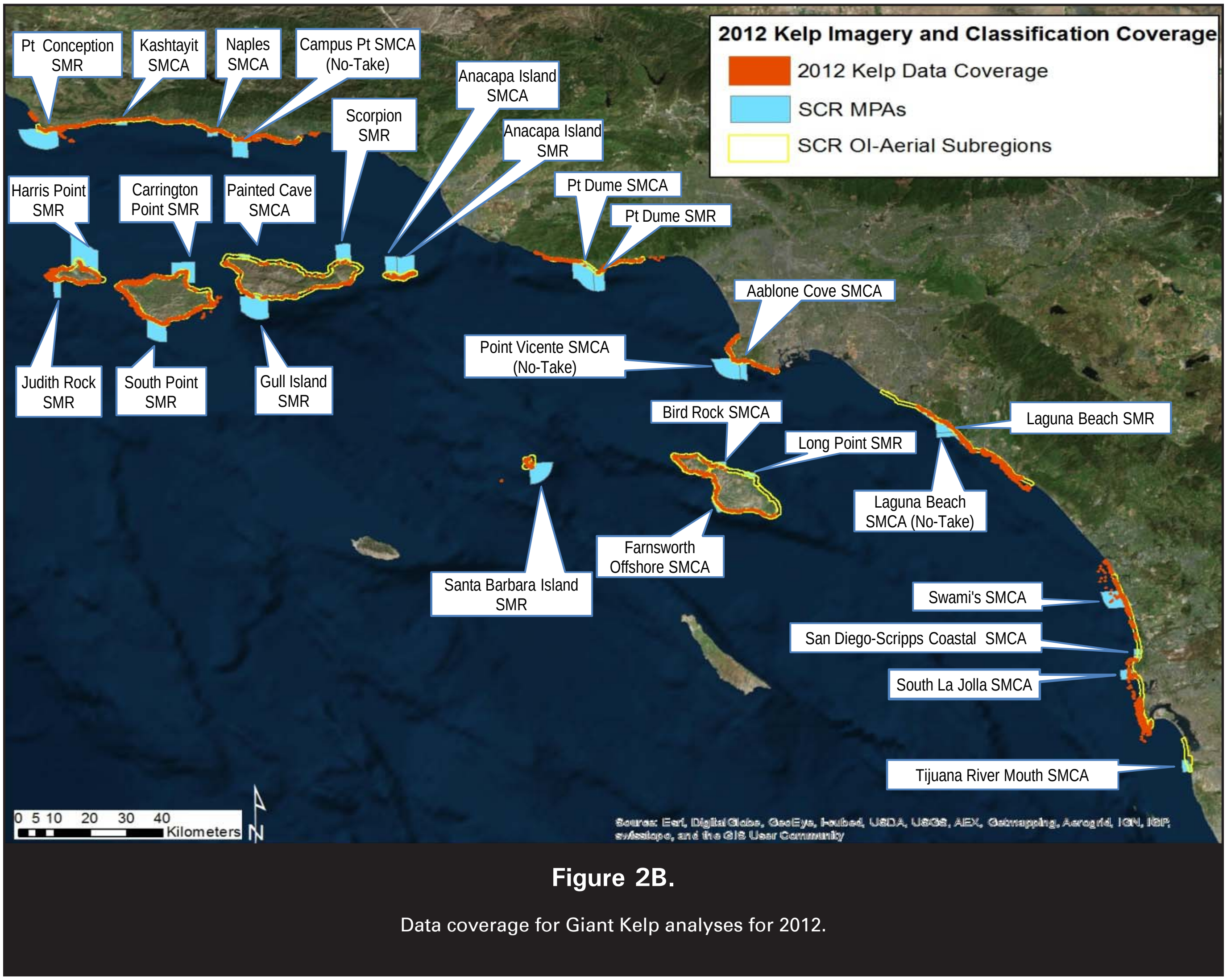
Figure 2A.

Data coverage for Giant Kelp analyses for 2011.

+/- 2 meters RMSE. The image tiles were then mosaicked into the local subregions along the SCR coast and islands based on UCX flight lines, local regions and MPA locations within each region as shown in **Figure 1.** This work was performed using both the ERDAS Imagine and ESRI ArcGIS software packages. The image mosaics were then subsampled to the proposed 2 meter delivery product and the corresponding metadata were associated with each mosaic. The resulting files in GeoTIFF (.tif) format were then set aside for use in the kelp classification process as well as moved to hard drive media for delivery to the OST and OceanSpaces.org.

Kelp Persistence Data Acquisition and Processing: The kelp persistence analysis dataset is a thematic representation of kelp persistence between the years of 1999-2012 along SCR's intertidal to offshore areas within in the OI-Aerial subregions shown in **Figure 1.** In that time period, kelp data from years 2000, 2001 and 2007 were unavailable and so the persistence analyses were created using data from eleven years: 1999, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011 and 2012. Originally we intended to include the year 1989, however subsequent analysis on the use of this year determined the ten-year gap to be too temporally distant from the other eleven years' data.

For some years the coverage for the OI-Aerial regions is incomplete. **Table 1** shows the years used in the persistence analysis for each of the SCR



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 2B.

Data coverage for Giant Kelp analyses for 2012.

Table 1.

Years used for the 1999-2012 kelp persistence analysis.
Green "YES" means data were available for that year in corresponding the OI-Aerial subregion.
Red "NO" means that no data were available for that year.

SCR OI-Aerial Subregion	1999	2002	2003	2004	2005	2006	2008	2009	2010	2011	2012
Anacapa Island	YES	NO	YES	YES	YES	YES	YES	NO	YES	NO	YES
Coal Oil Point	YES	YES	YES	YES	YES	NO	YES	NO	NO	YES	YES
Dana Point Languna Beach	NO	NO	NO	NO	NO	NO	YES	YES	NO	YES	YES
Encinitas LaJolla	YES	NO	YES	NO	YES	NO	YES	YES	NO	YES	YES
Imperial Beach	YES	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO
LaJolla Pt Loma	YES	NO	YES	NO	YES	NO	YES	YES	NO	YES	YES
Point Conception	YES	YES	YES	YES	YES	NO	YES	NO	NO	NO	YES
Point Dume	YES	NO	YES	YES	YES	YES	YES	YES	NO	NO	YES
Point Vicente	YES	NO	YES	YES	YES	YES	YES	YES	NO	YES	YES
San Miguel Island	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
Santa Barbara Island	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES
Santa Catalina East	YES	NO	YES	YES	YES	YES	YES	NO	NO	YES	YES
Santa Catalina West	YES	NO	YES	YES	YES	YES	YES	NO	NO	YES	YES
Santa Catalina North	YES	NO	YES	YES	YES	YES	YES	NO	NO	YES	YES
Santa Cruz Island NorthEast	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES
Santa Cruz Island North	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES
Santa Cruz Island South	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES
Santa Rosa Island North	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES
Santa Rosa Island South	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES

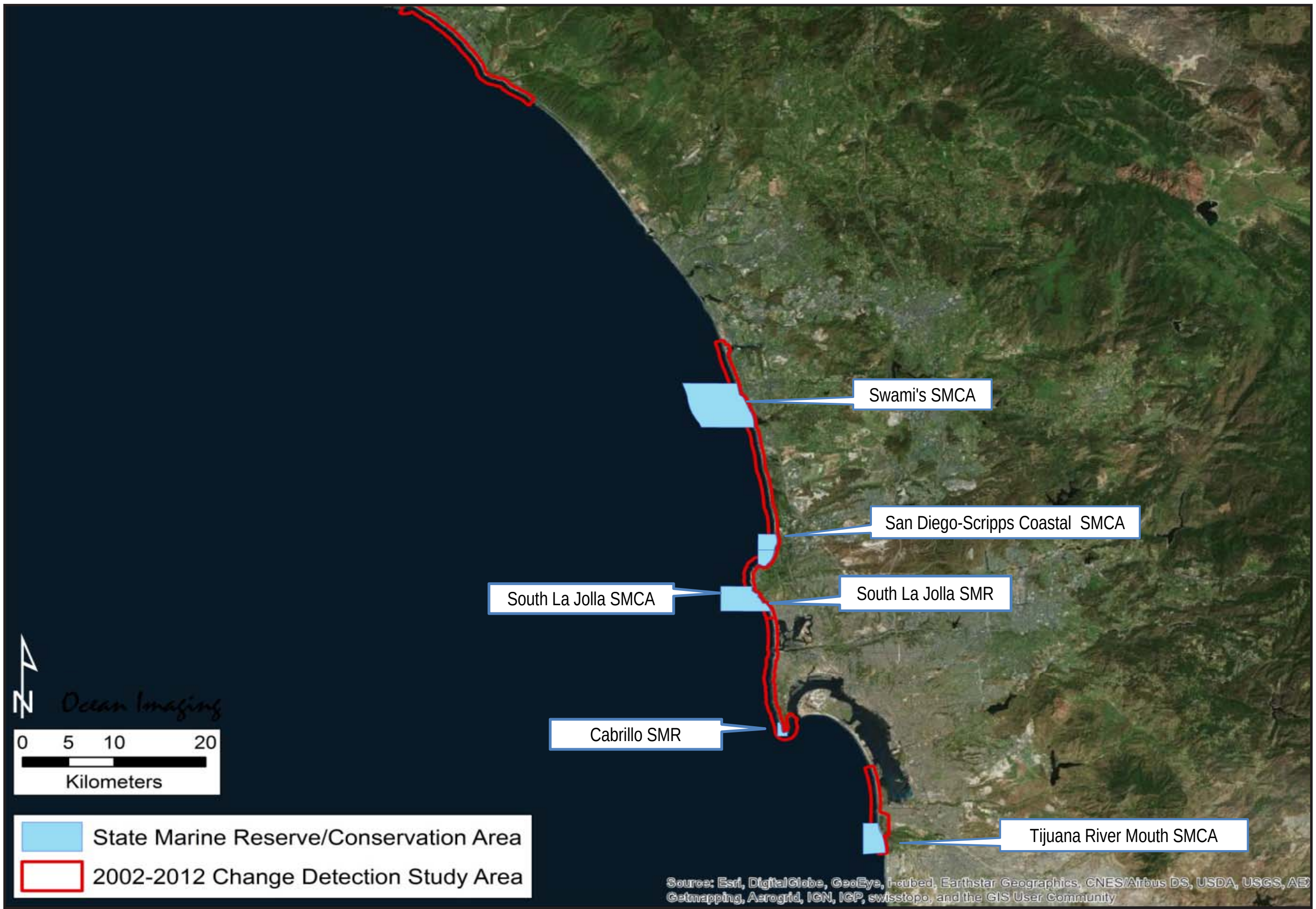
OI-Aerial subregions. The acquisition and processing of the kelp data for years 2011 and 2012 used in the analysis are described in this document. Kelp classifications in the form of ESRI shapefiles were acquired from the California Department of Fish and Wildlife (CDFW) server (http://www.dfg.ca.gov/marine/gis/downloads.asp) for the years of 1999, 2002, 2003, 2004, 2005, 2006 and 2008 and 2009. Kelp classification shapefiles for 2010 were used from OI's kelp database generated for the US Navy's NAVAIR Range Sustainability Office. All of the kelp shapefiles were mosaicked into the OI-Aerial subregions and then converted to 2 meter GeoTIFF raster images. The pixels showing kelp (both submerged and exposed) were assigned the value of 1 and all other pixels assigned the value of 0. Discussion continues below on the methods of creating the persistence analysis.

Data Used for 2002 vs. 2012 Inter/Subtidal Change Detection Analysis: The goal of this analysis was to characterize and analyze the decadal-long change in several sub/intertidal, general substrate/vegetation classes. The classes were identified in habitat classifications created as part of 2001-2002 work completed for the San Diego Association of Governments (SANDAG), and compared to the same classes identified and mapped during 2012 as part of this project. Data acquisition and processing work for 2002 was very similar to that used for the 2011 kelp data. For the 2001/2002 project, OI configured the DMSC with 10nm bandwidth filters corresponding to 450, 550, 600 and 643 center wavelengths. These filters were chosen based on previous submerged substrate mapping experience to allow good water penetration while providing sufficient spectral differences for separation of anticipated substrate types both in the intertidal and subtidal regions. The DMSC was flown aboard a Partenavia twin engine aircraft, specially equipped for aerial imaging. The pilot utilized a separate video camera system to precisely follow the coastline. In areas where the coast angle changed too rapidly to allow horizontal change of aircraft direction (i.e. without banking which would introduce excessive spatial distortion in the image data), the plane looped back and resumed data acquisition in the new direction.

Data were acquired over the entire area shown in **Figure 3** on the afternoon of 10/4/02 during moderately low tide. The coastline from North Pacific Beach to Dana Point was re-flown on 10/6/02. The flight was timed to coincide with the day's peak low tide (-1.2") in order to provide better imagery of the intertidal zone where some wave and whitewater interference was experienced on 10/4. The duplicate data were combined to eliminate whitewater interference from the final product. The 10/6 flight was also completed to produce final, post-flight processed data with 90cm resolution vs. the 120cm resolution of the data collected on 10/4. The 90cm resolution provided the greater detail deemed necessary for better substrate classification at some of the north county reef and intertidal areas. Additional details regarding the acquisition and data processing of the 2002 classification dataset used for the change detection analysis can be found in the supplemental document entitled "SANDAG_ThalesFinalRep.doc." This document can be found located in the "Support" folder on the data product hard drive delivered to OST and OceanSpaces.

2.3 Habitat Classification and Analysis Approach

Intertidal Habitat Classification Methods: Following the creation of image mosaics from the georeferenced, orthorectified, four-banded, UCX, RGB-NIR multispectral imagery, thematic maps were created from the 30 cm and resampled 1 meter data to characterize specific vegetation and substrate types in the SCR intertidal zone. The mosaics created were segregated into the local, coastal and island regions



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AE
Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3.

Intertidal change detection analysis study area and MPAs within the area.

as described above encompassing the SCR MPAs for more efficient classification and data management using ERDAS Imagine and ESRI ArcGIS software applications. The basic principle of the habitat classification processing is to utilize a multispectral algorithm that compares reflectance differences from the 4 available wavelengths and assigns each pixel to one of a number of classes, based on the reflectance relationships. Because of the large size of the SCR image set, it was important to develop an algorithm rigorous enough to be applicable, with acceptable consistency and accuracy, over large sections of the coastline. The ultimate goal is to assign each cell (pixel in the image) of the AOI to a known class (supervised classification) or to a cluster (unsupervised classification). In both cases, the input to classification is a signature file containing the multivariate statistics of each class or cluster. The result of each classification is a thematic map that partitions the study area into known classes, which correspond to training samples, or naturally occurring classes, which correspond to clusters defined by clustering. Classifying locations into naturally occurring classes corresponding to clusters is also referred to as stratification (ESRI, 2011).

For this project, depending on the target region and habitat types, both supervised Maximum Likelihood and unsupervised Iso Cluster classification techniques were used. The Geoprocessing Tools in the Environmental Systems Research Institute (ESRI) ArcGIS 10.1 and 10.2 software were applied for this purpose. Other methods such as Fuzzy Ratio and Principle Component Analysis were tested, however, the Maximum Likelihood and Iso Cluster algorithms yielded the best results when compared to the field reference data. In general, the steps to perform these two classification methods are (ESRI 2011):

<u>Supervised classification</u>

1. Identify the input bands.
2. Produce training samples from known locations of desired classes.
3. Develop a signature file.
4. View and edit the signature file if necessary.
5. Run the classification.

<u>Unsupervised classification</u>

1. Identify the input bands.
2. Define the number of clusters to be created.
3. Develop a signature file.
4. View and edit the signature file if necessary.
5. Run the classification.

Iso Cluster performs clustering of the multivariate data combined in a list of input bands. The resulting signature file can be used as the input for a classification tool, such as Maximum Likelihood Classification, that produces an unsupervised classification raster. The ArcGIS Iso Cluster Tool combines these steps using a modified iterative optimization clustering procedure, also known as the migrating means technique. The algorithm separates all cells into the user-specified number of distinct unimodal groups in the multidimensional space of the input bands. It then performs the classification to generate a classification raster showing the number of clusters (classes) the analyst specifies (ESRI, 2011). In the classification raster, each cluster is represented by its own color. Since the optimal number of classes to yield the most accurate result is unknown, the analyst usually enters a conservatively high number of clusters to begin with, analyzes the product and then reruns the function until the desired number of classes is obtained.

For the unsupervised classification method implemented by OI, an arbitrary number of classes were chosen for the first run of the algorithm. The results were then compared to field data, historical data and known class locations within the AOI. If more than one known class was represented by a single cluster, the function was re-run with a higher number of output clusters in order to separate known, distinct substrates and vegetation types into their own clusters. Once all of the desired classes were individually represented in one or more clusters, the clusters were then combined to pare them down into each of the final, target classes. This is an iterative process by which the analyst compares the result of each cluster combination to the field data and known locations of specific substrates/vegetation types to ensure that the each step in the paring process does not lump more than one class into a single cluster/color and does not create misidentification of a class. A more detailed description of the Iso Class algorithm/method can be found here: http://resources.arcgis.com/en/help/main/10.1/index.html#/How_Iso_Cluster_works/009z000000q8000000/.

Collection and Incorporation of Photogrammetric, LiDAR and Field Photo Data: The processed imagery is of very high quality and shows excellent spectral and spatial definition. Water penetration in areas of calm seas was sufficient to classify submerged substrate including subsurface, offshore kelp. To maximize the efficiency and substrate class resolving power of the multispectral classification algorithms, it is best (and sometimes necessary) to first isolate the intertidal zone (i.e. the area of interest) from the many multispectral signature terrestrial targets further inland. So, as was done for the Northern California classification work (also funded by Sea Grant R/MPA-17 Grant No 09-015), the intertidal region was first segregated into elevation sections within and above the intertidal zone in order to eliminate cross correlation of reflectance values for marine and terrestrial vegetation with similar radiometric signatures. The different elevation segments are then classified and ultimately merged together into a final product. The definition of these classification zones was done either by manually digitizing the coastline's different zones, examining other photogrammetric imagery and field photos or, when available, using Light Detection and Ranging (LiDAR) topographic data collected by Fugro Earth Data in March, 2010. The LiDAR dataset (providing high resolution topographical data of the intertidal zone) proved to be less useful for the NCC region due to data formatting issues and inaccurate topography data in the lower intertidal to sub tidal zones. Ocean Imaging staff also utilized the multispectral imagery and field photos to identify the upper limit of the intertidal zone within each shoreline section (as best as possible based on vegetation and ground substrate type), then matched these determinations with the multispectral data to create the "coastline" boundaries. This boundary was then used to isolate the region of interest for the multispectral classification.

Over 325 photographs were taken by Ocean Imaging staff covering several subregions along the SCR coast including Point Conception, Coal Oil Point, Point Dume, Point Vicente, Dana Point-Laguna, and Encinitas-La Jolla. Many of these photographs were either linked to GPS coordinates and/or to locations on printed versions of the UCX imagery. Notes and additional field data were collected along with the photographs. The field data and photographs were further utilized to create training sets used in the supervised classification procedure for each subzone. An example linking the imagery and field data is shown in **Figure 4**.

Incorporation of Biodiversity Point Contact Survey Data: Several attempts to obtain additional field data from SCR partners to link the imagery and create classification training sets, as well as for use in accuracy assessment resulted in only one response. Fortunately, the South Coast Baseline Project (SCBP) (Baseline Characterization of the Rocky Intertidal Ecosystems of the South Coast Study Region) did offer the use of an extremely valuable dataset. OI was provided a set of Biodiversity Point Contact Survey data from 31 sampling sites within the SCR.

Point Contact sampling consists of recording the diversity and abundance of invertebrates and algae, by recording what is found directly underneath or in the near vicinity of 100 points on each transect. Algae and invertebrate species, hosts and epiphytes, layering, and substrate characteristics are all taken into account (http://oceanspaces.org/monitoring/regions/south-coast/collecting-data#baseline, http://www.eeb.ucsc.edu/pacificrockyintertidal/methods/index.html#bio-method). Over 38,000 survey points were included in this extensive dataset. For this project we selected 17 of the 31 sites to both aid in the creation of classification training sets and for the accuracy assessment described below. Each of the sites contained up to 1,100 biodiversity sampling points gridded inside survey bolts which were located in the OI imagery and classifications using GPS locations provided by the SCBP. The field data were digitized as points in ArcGIS using the GPS locations of the survey site boundary bolts noted above, transect line data, base maps and field photographs to match to the corresponding locations in the mosaicked, georectified imagery and

Figure 4.

Example of multispectral imagery, the resulting habitat classification and the corresponding locations of field sampling targets obtained by Ocean Imaging in the Point Conception SCR OI-Aerial subregion (Kashtayit SMCA) for this project.

classification rasters. Conveniently, the points are spaced roughly 33cm apart which is a close match in spatial resolution to the 30cm imagery used to generate the classification products. The selection of the 17 sites was based on the field data sampling dates, the location, the grid/matrix set up of each site, and how the transects overlaid on the classification data. This resulted in over 18,000 points available for use in training the classification algorithms and for the accuracy assessment. Roughly half of the survey data (approximately 8,450 points) were set aside for the accuracy assessment work. The other half were used to guide the classification training sets (See below for discussion on the accuracy assessment process and the results). The field data were spatially compared to the image-derived classes. The comparison results were then used to re-train the classifications to produce a more accurate product. Since 100% of the data from one of the survey sites (Frenchy's Cove) was used for training set creation, it was not used for the accuracy assessment. **Figure 5** shows the locations of the remaining 16 survey sites used and **Figures 6A-6D** illustrate how the biodiversity data were used to help train and improve the habitat classifications.

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5.

South Coast Baseline Project Biodiversity Point Contact Survey sites used for classification training set enhancement and accuracy assessment. The names of the sites are the SCBP intertidal site names.

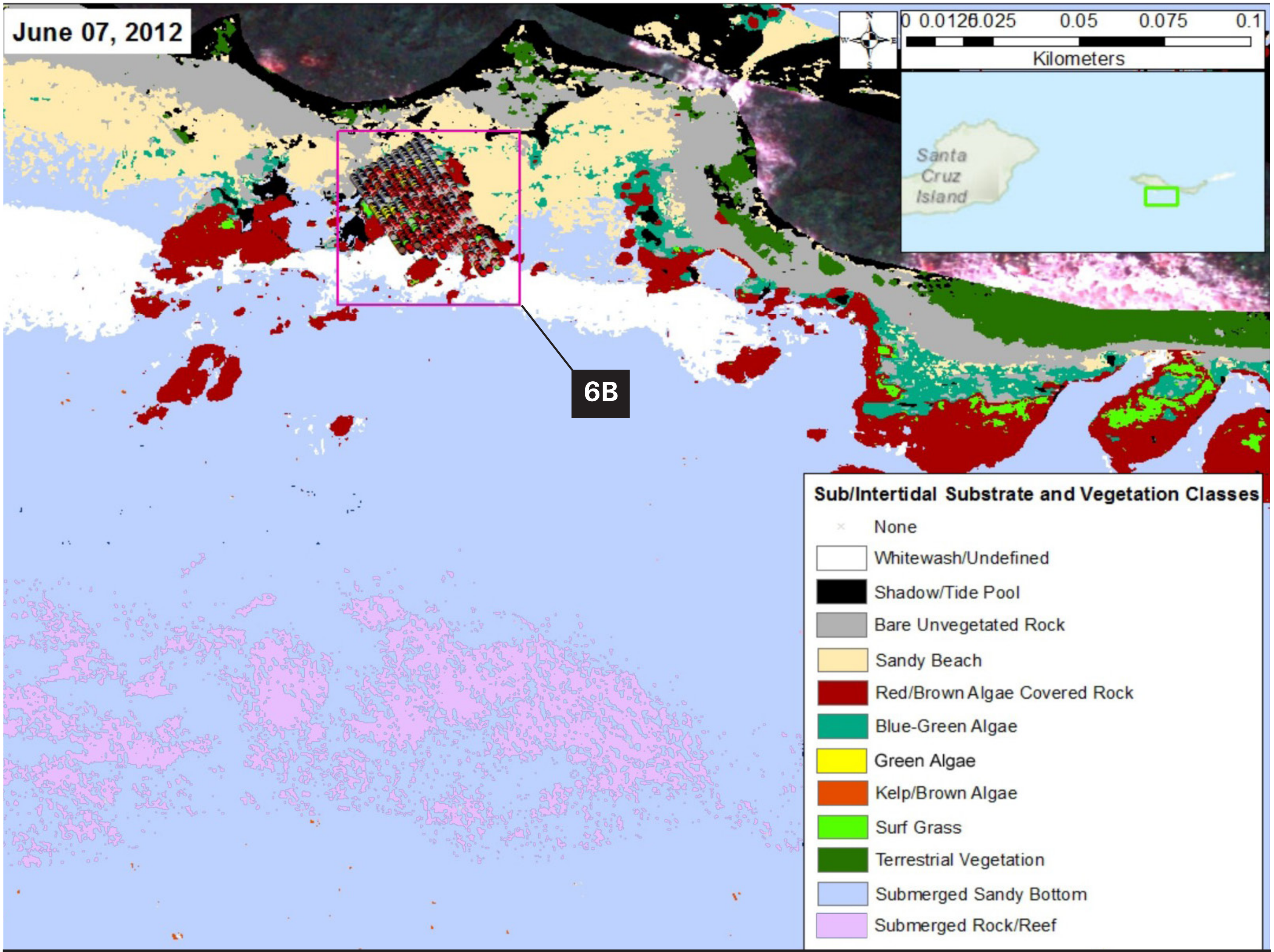


Figure 6A. Initial Subtidal / Intertidal Classification (Pre-Training)

Example of image-derived Sub/Intertidal Classification of the south side of Anacapa Island. Biodiversity Point Contact Survey field data points are overlaid in "Frenchy's Cove" area (pink square). These points were used to help correct the classification thereby improving the class accuracy.

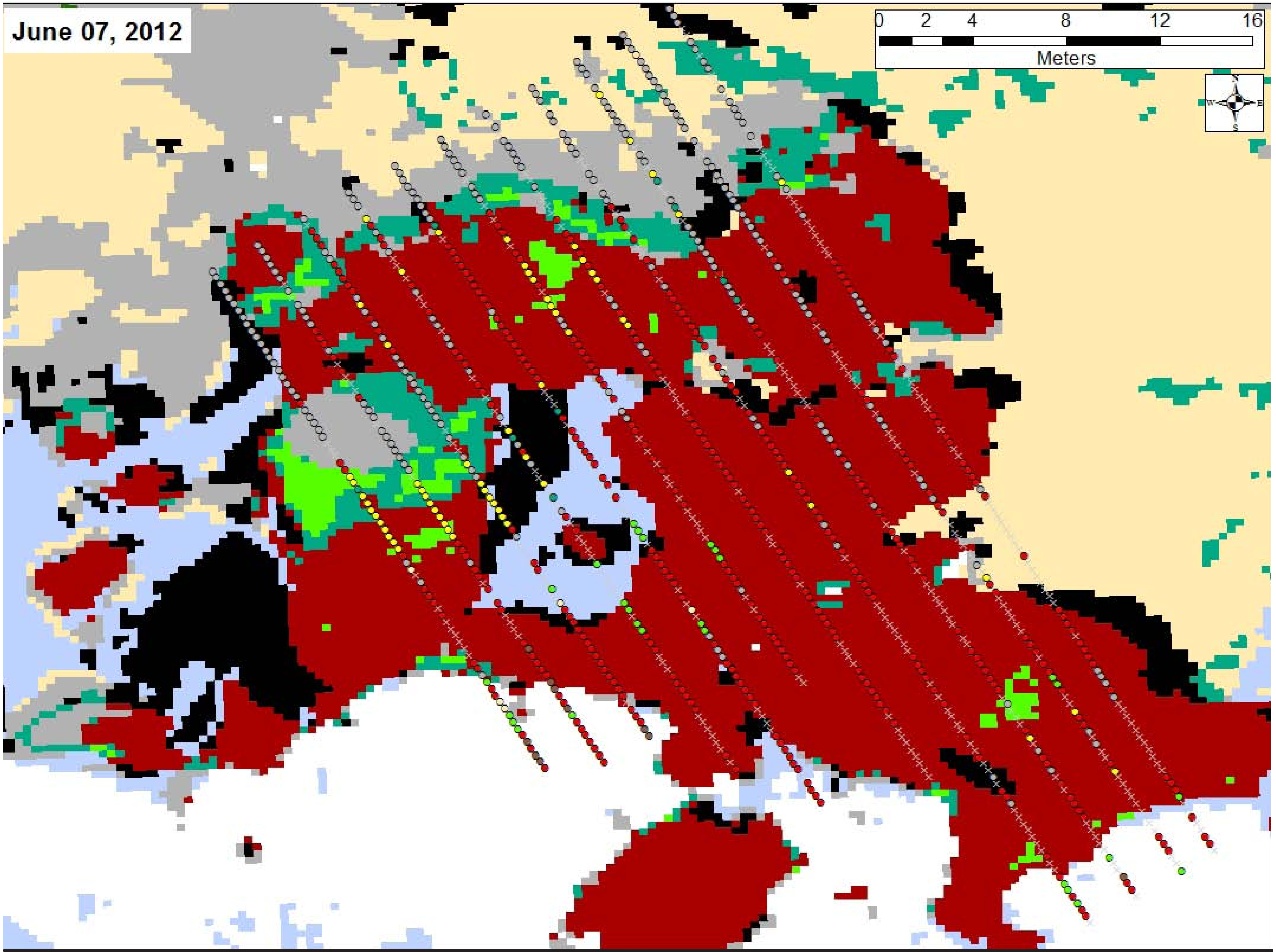


Figure 6B. Close Up of the Initial Classification with Overlaid Field Sample Point Analysis

Each field sample was grouped into the same classes as the image-derived classification. The field samples are displayed as colored circles indicating the initial image-derived classes. A small 'x' represents points at which there were no field samples taken or the substrate identified was of an unknown class.

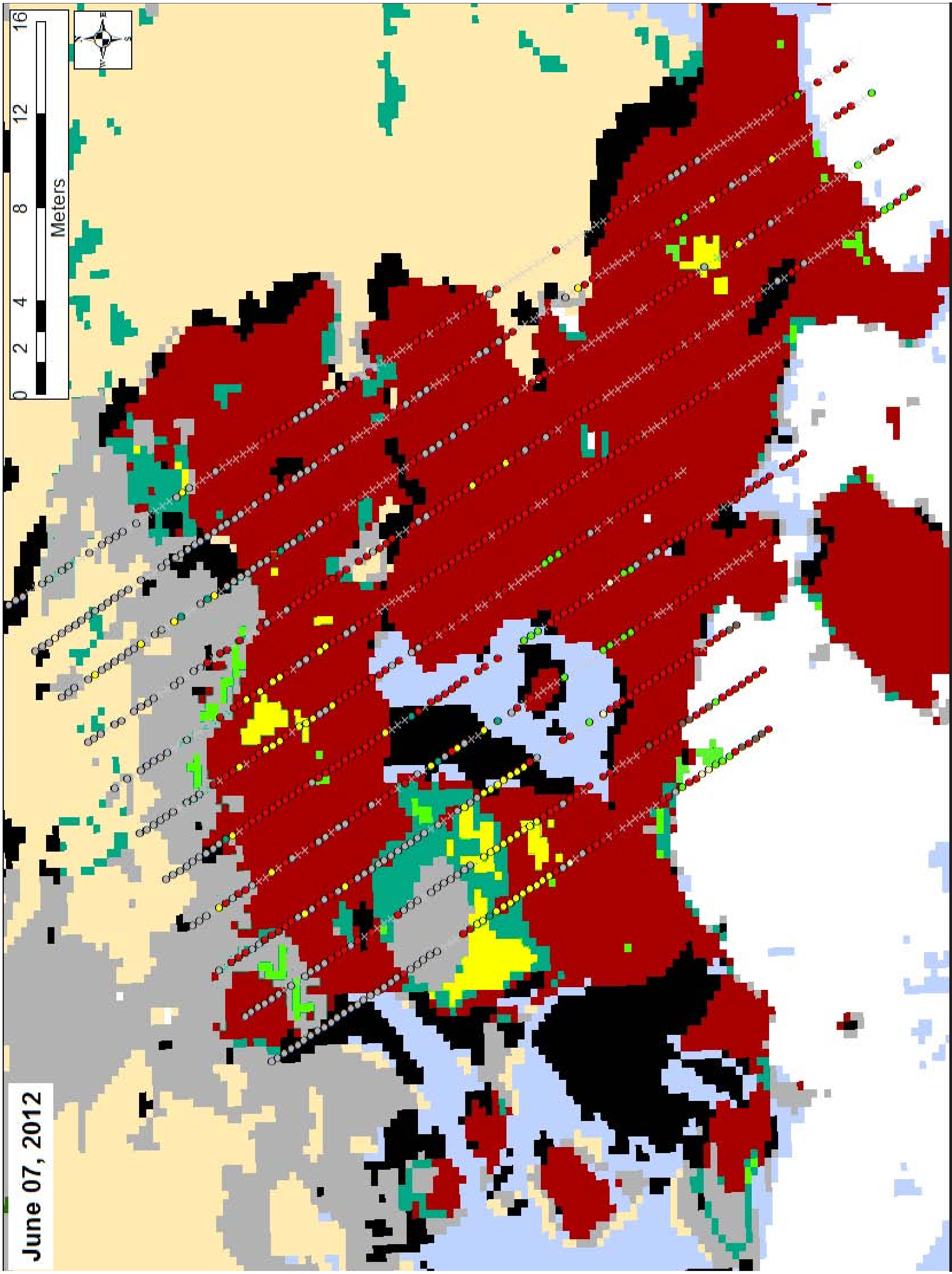


Figure 6C. Re-training the Classification

The field data are then used to re-train the initial image classification resulting in this adjusted classification.

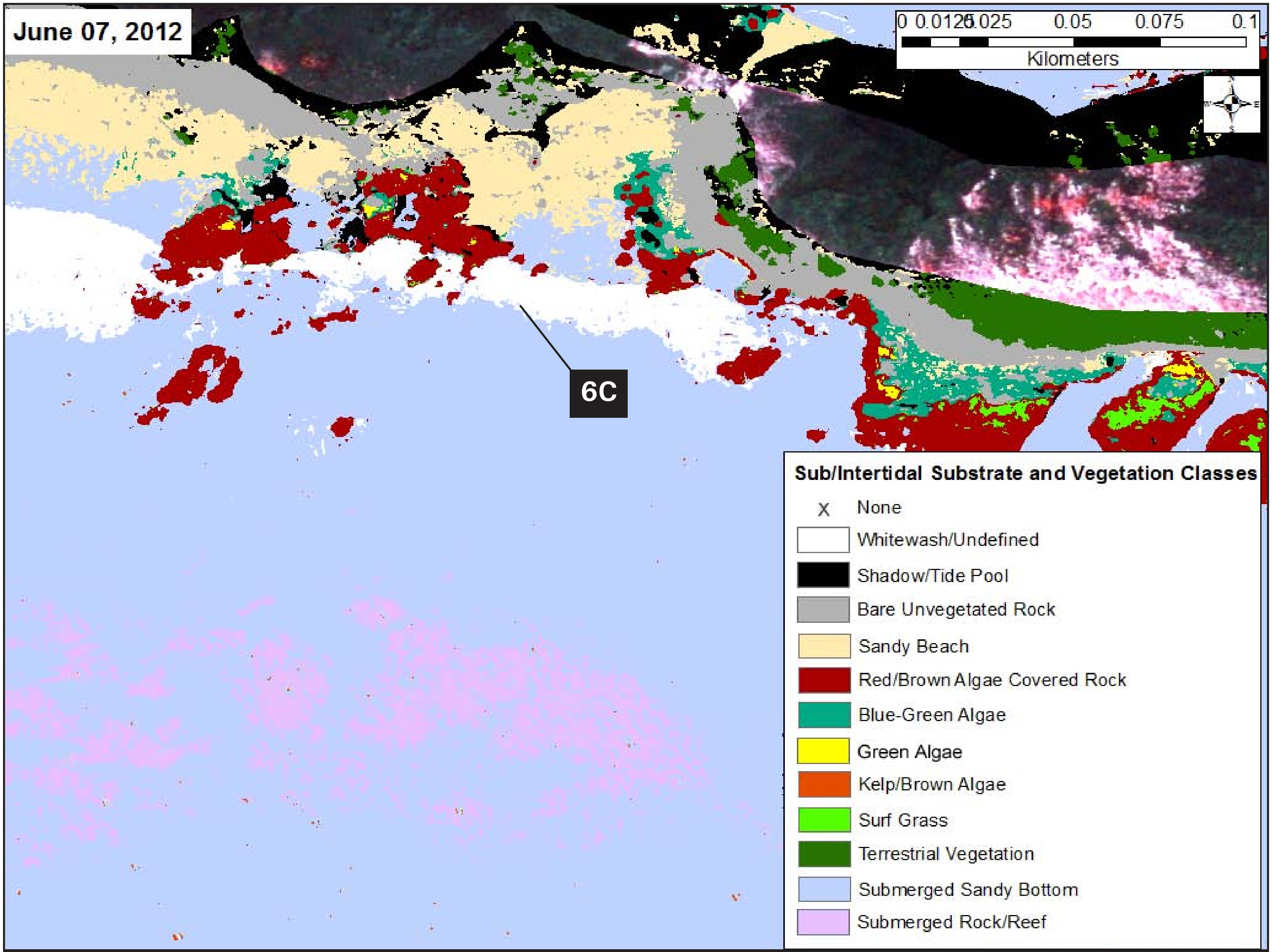


Figure 6D. Trained Classification

Considering the correlation of the spectral signatures of the points and the field samples, as well as the height of the sample in the intertidal zone, the corrections are then applied to a larger area surrounding the survey area.

Following the initial classification work, each subzone's resulting thematic map data were then manually edited in order to ensure the highest accuracy product possible and then mosaicked together into the SCR OI-Aerial regions for delivery. The habitat classes this process was able to confidently identify and map using the UCX multispectral imagery were:

1 - Whitewash/Undefined
2 - Water
3 - Sandy Beach
4 - Mixed Red/Brown Algae
5 - Shadow
6 - Terrestrial Vegetation
7 - Unvegetated Rock
8 - Beach Wrack
9 - Kelp/Brown Algae
10 - Blue-Green Algae
11 - Mixed Rock/Mussels/Barnacles/Anemone
12 - Cobble
13 - Man-made/Artificial
14 - Driftwood
15 - Surf Grass
17 - Eel Grass
21 - Green Algae
22 - Submerged Sandy Bottom
23 - Submerged Rock/Reef
24 - Deep Water

Final classification product files have been delivered to OST and OceanSpaces in both GeoTIFF (.tif) and ESRI shapefile formats. ESRI Layer (.lyr) files are available with the shapefiles which provide information on classes. Adobe Acrobat .PDF files are also provided on the delivery drive for non-GIS users. A sample intertidal/subtidal classification of the west side of Catalina Island is shown in **Figures 7A and 7B. Figure 7A** (left) shows a subsection of the western side of the island which is outside of any MPA. **Figure 7B** (right) shows a section of the Farnsworth SMCA (MPA).

2011 and 2012 Kelp Classification Methods: The kelp classifications were originally proposed to show both the submerged and exposed kelp canopy as two separate classes. The 2012 kelp classification does include these two classes, however, the 2011 classification only includes one kelp class combining the submerged and exposed kelp. This is because the 2011 classifications, already created as a single-class product, were included as a substitute for the planned 2013 data which were unavailable due to reasons explained above. Therefore, thematic maps showing combined submerged and exposed kelp were created from the 2011 2 meter DMSC mosaics, and maps showing both exposed and submerged kelp separately were created from the 2 meter UCX mosaics. As discussed above, both datasets were mosaicked into SCR OI-Aerial coverage subregions. In the case of the kelp maps, the supervised Maximum Likelihood classification technique was used for both 2011 and 2012 datasets. Each kelp classification was manually edited in order to ensure the highest accuracy product possible. Comparisons were made to photographs as well as kelp classifications from prior years and ERSI base layer photogrammetric imagery to help ensure the quality and accuracy of the end products. A sample 2012 kelp classification product is shown in **Figure 8.** Finally, metadata were added to the GIS files and the final classification product files have been delivered to OST and OceanSpaces in both GeoTIFF (.tif) and ESRI shapefile formats as well as non-GIS PDF files.

Kelp Persistence Analysis Methods: This dataset is a thematic classification of kelp persistence between the years of 1999-2012 in the South Coast's intertidal to offshore region from Point Conception to Imperial Beach. As stated above, in that time period, kelp data from years 2000, 2001 and 2007 were unavailable and so the persistence analyses were created using data from eleven years: 1999, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011 and 2012. All of the kelp shapefiles were mosaicked into the OI-Aerial coverage areas and then converted to 2 meter GeoTIFF raster images with pixels showing kelp (both submerged and exposed) assigned the value of 1 and all other pixels assigned the value of 0. The rasters for each OI-Aerial region were subsequently summed to show the number of years during the 1999-2012 time period for which each pixel showed the presence of kelp. Since the thirteen-year time period as well as the geographical coverages were incomplete from year to year, the persistence is represented as a percentage of the total number of years used in the analysis for that particular OI-Aerial data subregion. Persistence maps in PDF form and digital persistence classification products in GeoTIFF (.tif) and ESRI Shapefile formats along with corresponding ESRI layer files (.lyr) were created for each SCR OI-Aerial subregion shown in **Figure 1** and delivered to the OST and OceanSpaces. A sample of the persistence analysis result is shown in **Figure 9**.

2002 vs. 2012 Inter/Subtidal Change Detection Analysis Methods: Once the sub/intertidal classifications were finalized from the 2012 SCR imagery, the substrate/vegetation classes were reduced to roughly the same general classes identified using the 2002 data:

1 - Bare/Unvegetated Rock
2 - Vegetated Rock (exposed and submerged)
3 - Surf Grass
4 - Eel Grass
5 - Kelp
6 - Beach and Sandy Bottom (exposed and submerged)
7 - Man-Made/Artificial
8 - Whitewash/Turbidity
9 - Cobble
10 - Beach Wrack
11 - Shadow/Tide Pool
12 - Deep Water/Unknown

Figure 10 illustrates the class-merging process and the resultant change analysis. The prime focus was to identify any significant changes in the total area of vegetated hard bottom vs. sand-covered bottom and unvegetated rock (i.e. loss of gain of algae habitat) as well as decadal changes in surf grass bed distributions within and around the proposed MPA areas. Kelp change analyses were delivered in the form of the kelp persistence analyses discussed in section 3.4. The change in coverage area for specific species were computed for the 10-year time period. Thematic analyses for each SCR subregion showing where a substrate remained the same and where each substrate class changed into a different substrate were also generated in order to illustrate how the intertidal and subtidal habitats changed (or did not) over the time period. These change detection analyses were created in both GIS-compatible ESRI Shapefiles as well as PDFs.

2.4 End-Product Accuracy Assessment Methods

SCR Sub/Intertidal Habitat Classification Accuracy Assessment: Accuracy assessment methodologies as outlined by Congalton, 2001 & 2009 were used to determine the classification accuracy of the coastal intertidal thematic maps. For this project the Biodiversity Contact Survey data discussed above were used as the field reference data in the Congalton matrix.

First, since the Contact Survey points were much more specific in their identification of the substrate or vegetation type, the names/classes were grouped to match the equivalent class in the remote sensing-derived habitat classification. Next, over 8,450 of the Biodiversity Contact Survey points selected were spatially joined to the habitat classification raster in ArcGIS, for each survey site. This represented roughly half of the points for each site – the other half having been used in the classification process. Once the two databases were joined, the field data points falling into each pixel cell were grouped together to match the 1-meter cell size and geographical location of each pixel. This resulted in one-to-several field data points per cell. Then, from each cell's group, a random field sample was extracted to represent the reference data corresponding to each pixel in the classification. This resulted in 4,671 pairs of data points entered into the Congalton matrix to show the accuracy of the reference data to the image-derived classifications. Having a limited number of OI-collected photographs and field samples relative to the 4,671 field sample points provided by the SCBP offered both a unique and extremely valuable dataset to aid in the assessment of the OI-Aerial habitat classification products. The Congalton method is outlined in detail in Congalton, 2001 and Congalton and Green, 2009.

3. Results and Discussion

3.1 End-product Accuracy Assessment Results

The Congalton accuracy assessment yielded 65% overall classification accuracy. The complete Congalton error matrix and accuracy summary is shown in **Table 2**. A few observations on the results: Accuracies for terrestrial vegetation show a 0% Producer's and User's Accuracy, because there were zero instances in the reference data which classified a point as a type of terrestrial vegetation. In the case of green algae, the classification misidentified a bright green reflectance in the imagery characteristic with green algae, however the field data indicated that these spots were either a red algae possibly with a green color (not unusual) or unvegetated rock. Given the time difference between the acquisition of the imagery and the collection of the field reference data, as well as the potential for green algae to rapidly disappear from rocks in the upper intertidal zone, this is not entirely unexpected. The misidentification of kelp as either red/brown covered or unvegetated rock in the classifications is also not unexpected. In most cases the kelp identified in the field data is not of the Macrocystis Pyrifer variety, but rather Egregia menziesii which tends to grow in the lower intertidal and intermix with rocks covered in different algal types. With the multispectral imagery at 30cm - 1m

Table 2.

Congalton accuracy assessment matrix for Sea Grant California, South Coast Region (SCR).

		REFERENCE DATA									
	Remote Sensing-Derived Data	**Mixed Rock/Mussels/Barnacles/Anemone**	**Unvegetated Rock**	**Mixed Red-Brown**	**Surf Grass**	**Terrestrial**	**Sandy Beach**	**Kelp**	**Blue-Green Algae**	**Green Algae**	
CLASS DATA	Mixed Rock/Mussels/Barnacles/Anemone	550	183	157	0	0	8	0	0	0	898
	Unvegetated Rock	216	791	164	4	0	8	83	0	2	1268
	Mixed Red-Brown	160	147	1350	40	0	45	83	0	59	1884
	Surf Grass	0	0	38	73	0	0	0	0	0	111
	Terrestrial	0	9	0	0	0	0	0	0	0	9
	Sandy Beach	49	30	13	0	0	143	0	0	29	264
	Kelp	10	10	19	0	0	0	29	0	0	68
	BlueGreen Algae	7	12	0	0	0	0	0	25	6	50
	Green Algae	9	12	22	2	0	6	0	0	68	119
		1001	1194	1763	119	0	210	195	25	164	4671

		Producer's Accuracy	**User's Accuracy**
SUMMARY CLASS	Mixed Rock/Mussels/Barnacles/Anemone	54.9%	61.2%
	Unvegetated Rock	66.2%	62.4%
	Mixed Red-Brown	76.6%	71.7%
	Surf Grass	61.3%	65.8%
	Terrestrial	N/A	0.0%
	Sandy Beach	68.1%	54.2%
	Kelp	14.9%	42.6%
	BlueGreen Algae	100.0%	50.0%
	Green Algae	41.5%	57.1%

Overall Accuracy	
Total Accuracy	3029
Overall Accuracy	64.8%

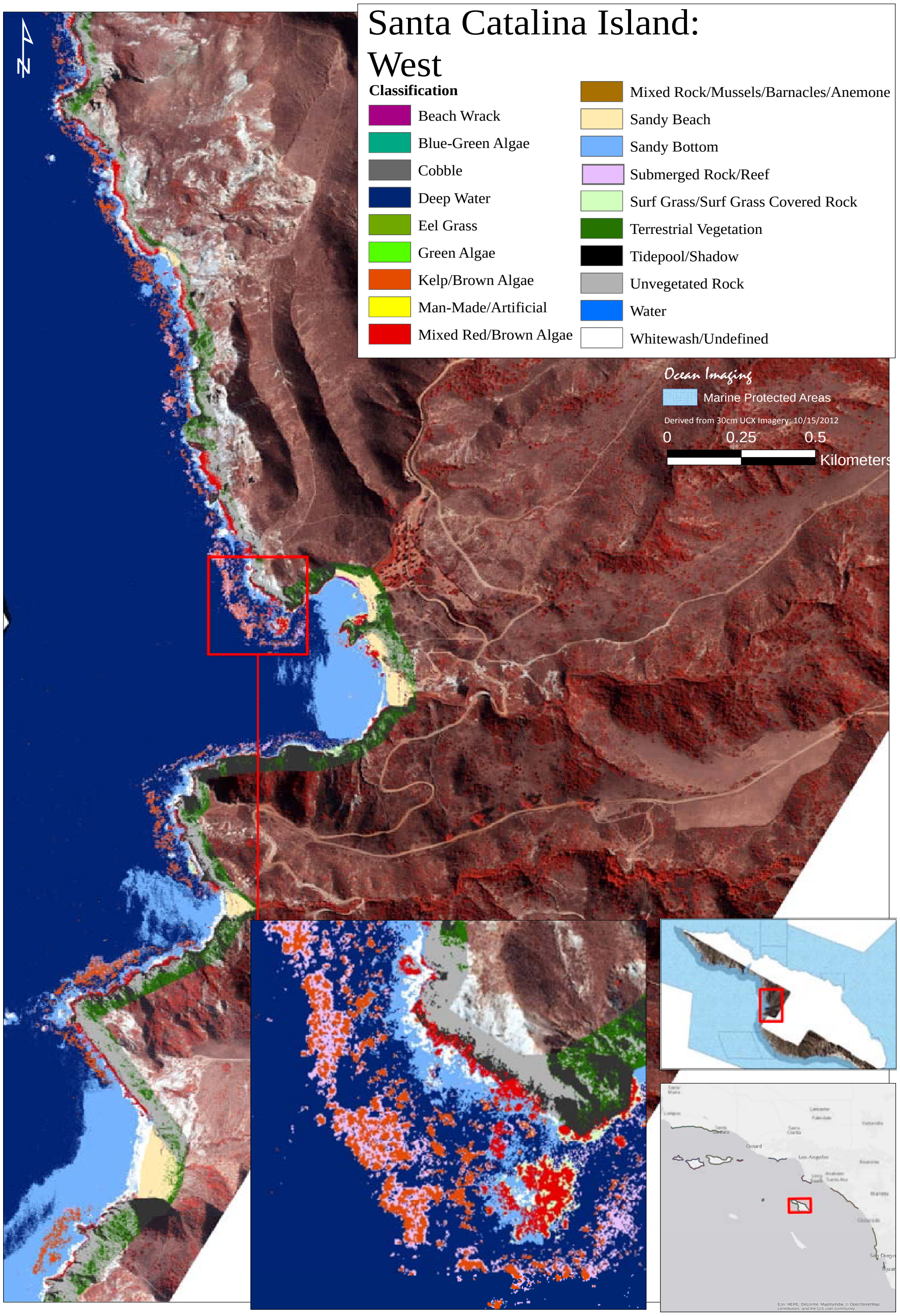


Figure 7A.

A sample sub/intertidal habitat classification of the western side of Catalina Island. This section of the Catalina Island (West) SCR subregion is outside of any MPA region. Figure 7B is a sample classification product from the Farnsworth Onshore SMCA.

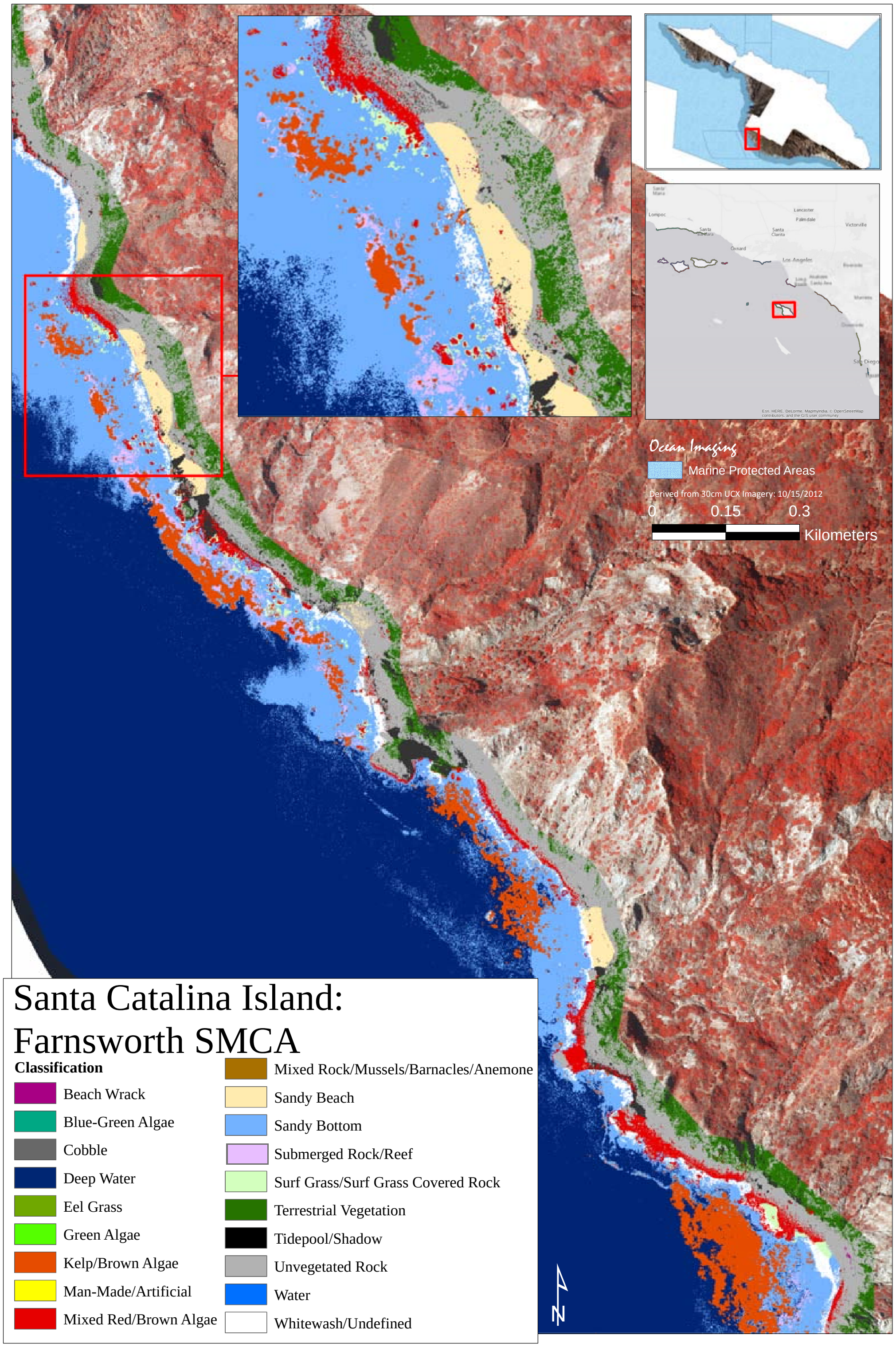


Figure 7B.

A sample classification product from the Farnsworth Onshore SMCA.

GSD, it is near impossible to distinguish between the kelp types of macro, brown alga and rocks covered with smaller species of red and/or brown algae. Hence the lower accuracy levels for these classes. Other sources of error include the high spatial resolution of the field point samples (i.e. many sample points per 1 meter pixel) leading to a variety of field reference classes for each pixel location. This acted to lower the overall accuracy results. It also should be mentioned that given the nature of the field data used, while very useful for this assessment, they were most often collected in areas of high biodiversity with a variety of substrates existing within a relatively small area. If field sample areas included more homogeneous regions such as long stretches of beach, cobble and areas of unvegetated rock higher up in the intertidal zone, we estimate that the overall accuracy of the classifications would be in the 80%-85% range which is considered quite acceptable when assessing thematic maps created from remotely sensed imagery.

3.2 Database Overview and Baseline Characterization Discussion

As expected, and as was the case with the Northern California Coast (NCC) dataset, the MPA substrate classifications revealed major trends linked to the types of MPAs. For example, red/brown algae and rocks covered in the mixed class of red/brown algae, barnacles, mussels and anemones dominated the mid to lower intertidal zones of rocky coastal MPAs while green algae was most prevalent in the mid to upper intertidal zone. Also, significantly more surf grass is prevalent in the SCR when compared to the NCC region.

The database also reveals, however, major differences in substrate composition between MPAs of the same type. **Tables 3.1-3.8** list the class compositions of regions classified within each SCR OI-Aerial subregion and each MPA respectively - both as total area for each class that was classifiable from the imagery, and as a percentage of total classifiable area within each subregion/MPA. It is important to note that the values refer only to intertidal and subtidal areas that had sufficient multispectral signal to be classified. Areas covered by whitewater and water too deep or turbid to yield a sufficient multispectral reflectance profile were not "sampled" and are thus not included or were classified as "Deep Water". This fact is important when consulting the database for information on substrate types that tend to be found near the deeper portion of the intertidal zone and beyond. For example, despite all efforts to collect the imagery during peak low tides, in some areas, surf grass might not be fully represented in the classifications of rocky coastline areas. It tended to be distributed in the lower intertidal zone and was thus often obscured by whitewater and/or turbidity in the overlying water column. This difference could partially account for the dramatic differences in surf grass coverage between 2002 and 2012 as seen in the change detection analysis discussed below.

Fortunately, however, the clear waters in the SCR did allow for classification well into the subtidal zone imaged for most of the SCR OI-Aerial subregions. This resulted in the offshore classes such as "Submerged Sandy Bottom" and "Submerged Rock/ Reef" showing the overall highest percentage of area covered. The more ecologically significant classes therefore covered a relatively small percentage of our SCR study areas and the MPAs. Since the MPAs were created to purposefully encompass areas holding rich and varied ecological resources, the remote sensing-derived database was expected to reflect the greater abundance of such habitats within as opposed to outside the MPAs. The percentage cover of ecologically important classes, however, was very similar within the MPAs when compared to the area outside of the MPAs. For example, the important class "Mixed Red/ Brown Algae" covered 0.72% of the classified area within the MPAs and 0.67% outside of the protected zones. "Kelp/Brown Algae" covered 2.21% of the classified area within the MPAs and 2.60% outside of the protected zones and "Surf Grass" covered 0.55% of the total area in the MPAs ad 0.58% outside of them. Conversely, the "Sandy Beach" and "Unvegetated Rock" substrates are almost twice as abundant outside the MPAs. These baseline similarities and differences must be considered in future studies comparing closely located MPAs.

Table 3.1

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

SCR OI-Aerial Subregion	Anacapa Island		Coal Oil Point		Dana Point/Laguna Beach		Encinitas/La Jolla	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	183,698	4.700	658,165	1.737	658,165	1.392	972,273	3.274
Sandy Beach	36,761	0.940	2,005,490	5.293	5,124,440	10.838	3,244,730	10.926
Mixed Red/Brown Algae	133,064	3.404	41,725	0.110	583,693	1.235	216,606	0.729
Shadow	657,361	16.818	701,954	1.853	64,930	0.137	14,003	0.047
Terrestrial Vegetation	133,536	3.416	832,971	2.198	886,370	1.875	428,988	1.444
Unvegetated Rock	182,571	4.671	177,057	0.467	267,430	0.566	452,746	1.524
Beach Wrack	434	0.011	16,536	0.044	10,806	0.023	55,386	0.186
Kelp/Brown Algae	51,746	1.324	2,752,990	7.265	996,933	2.109	907,276	3.055
Blue-Green Algae	41,460	1.061	60	0.000	0	0.000	192	0.001
Mixed Rock/Mussels/Barnacles/Anemone	29,387	0.752	17,742	0.047	235	0.000	194	0.001
Cobble	11,202	0.287	28,528	0.075	53,606	0.113	23,524	0.079
Man-Made/Artificial	263	0.007	53,451	0.141	364,854	0.772	210,751	0.710
Surf Grass	1,716	0.044	316,206	0.835	389,221	0.823	273,200	0.920
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	2,599	0.066	7,941	0.021	2,289	0.005	828	0.003
Submerged Sandy Bottom	1,515,590	38.775	30,280,700	79.914	4,871,210	10.303	16,858,500	56.766
Submerged Rock/Reef	241,438	6.177	0	0.000	565,706	1.196	5,377,220	18.106
Deep Water	685,862	17.547	0	0.000	32,441,000	68.613	661,807	2.228
Total	3,908,688		37,891,516		47,280,888		29,698,224	

SCR OI-Aerial Subregion	Imperial Beach		La Jolla/Point Loma		Point Conception		Point Dume	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	425,902	4.589	261,259	1.749	448,294	1.384	59,324	0.333
Sandy Beach	690,166	7.436	858,424	5.747	1,461,750	4.512	1,845,460	10.371
Mixed Red/Brown Algae	376	0.004	195,673	1.310	206,260	0.637	147,858	0.831
Shadow	12,961	0.140	40,715	0.273	193,164	0.596	258,780	1.454
Terrestrial Vegetation	312,316	3.365	217,072	1.453	823,842	2.543	594,034	3.338
Unvegetated Rock		0.000	220,314	1.475	261,703	0.808	91,911	0.517
Beach Wrack	17,530	0.189	13,054	0.087	32,962	0.102	557	0.003
Kelp/Brown Algae	815	0.009	373,981	2.504	1,531,680	4.728	1,161,970	6.530
Blue-Green Algae	0	0.000	2,662	0.018	121	0.000	496	0.003
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	4	0.000	22,828	0.070	247	0.001
Cobble	3,863	0.042	38,419	0.257	60,482	0.187	811	0.005
Man-Made/Artificial	117,827	1.270	80,018	0.536	11,464	0.035	434,368	2.441
Surf Grass	0	0.000	322,865	2.162	504,426	1.557	159,676	0.897
Eel Grass	3052	0.033	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	7,360	0.049	7,496	0.023	1,629	0.009
Submerged Sandy Bottom	7,696,500	82.925	10,655,700	71.341	26,831,100	82.818	1,474,800	8.288
Submerged Rock/Reef	0	0.000	1,648,720	11.038	0	0.000	119680	0.673
Deep Water	0	0.000	0	0.000	0	0.000	11442300	64.305
Total	9,281,308		14,936,240		32,397,572		17,793,901	

Table 3.2

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

SCR OI-Aerial Subregion	Point Vicente		San Miguel Island		Santa Barbara Island		Santa Catalina Island (East)	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	574,641	3.253	670,935	1.642	53,030	0.504	11,701	0.099
Sandy Beach	206,019	1.166	1,521,310	3.723	5,175	0.049	39,196	0.333
Mixed Red/Brown Algae	306,732	1.737	629,557	1.541	86,830	0.825	29,554	0.251
Shadow	215,559	1.220	501,486	1.227	58,733	0.558	579,564	4.921
Terrestrial Vegetation	669,145	3.788	3,478,820	8.513	319,711	3.038	483,495	4.105
Unvegetated Rock	338,865	1.918	1,132,520	2.771	451,627	4.291	338,771	2.877
Beach Wrack	265	0.002	10,148	0.025	0	0.000	0	0.000
Kelp/Brown Algae	2,994,870	16.955	1,533,820	3.753	190,962	1.814	7,032	0.060
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	79	0.000	0	0.000	0	0.000	55	0.000
Cobble	493,930	2.796	0	0.000	4,183	0.040	2,298	0.020
Man-Made/Artificial	50,869	0.288	0	0.000	0	0.000	31,302	0.266
Surf Grass	41,241	0.233	70,171	0.172	3,546	0.034	3,051	0.026
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	950	0.005	36,557	0.089	0	0.000	27	0.000
Submerged Sandy Bottom	6,219,680	35.212	2,722,900	6.663	803,845	7.638	510,188	4.332
Submerged Rock/Reef	374,377	2.119	1,083,800	2.652	157609	1.498	43,406	0.369
Deep Water	5,176,430	29.306	27,472,600	67.228	8389210	79.712	9,697,180	82.341
Total	17,663,652		40,864,624		10,524,461		11,776,820	

SCR OI-Aerial Subregion	Santa Catalina Island (North)		Santa Catalina Island (West)		Santa Rosa Island (North)		Santa Rosa Island (South)	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	7,009	0.026	161,874	0.432	1,098,870	4.131	669,420	2.803
Sandy Beach	190,462	0.695	243,577	0.651	1,090,330	4.099	1,191,250	4.987
Mixed Red/Brown Algae	117,139	0.427	371,618	0.993	259,675	0.976	184,561	0.773
Shadow	1,613,310	5.883	553,555	1.478	685,771	2.578	256,748	1.075
Terrestrial Vegetation	958,966	3.497	781,906	2.088	957,845	3.601	749,644	3.138
Unvegetated Rock	413,750	1.509	1,609,910	4.300	845,732	3.179	662,880	2.775
Beach Wrack	1,080	0.004	1,849	0.005	2,271	0.009	7,444	0.031
Kelp/Brown Algae	14,035	0.051	531,589	1.420	1,361,550	5.118	1,394,460	5.838
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	92	0.000	0	0.000	0	0.000	0	0.000
Cobble	29,882	0.109	1,512	0.004	0	0.000	22,805	0.095
Man-Made/Artificial	7,157	0.026	1,475	0.004	1,076	0.004	0	0.000
Surf Grass	1,752	0.006	92,266	0.246	528,035	1.985	325,838	1.364
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	236	0.001	3,710	0.014	6,343	0.027
Submerged Sandy Bottom	1,443,980	5.265	4,140,220	11.058	7,999,140	30.069	6,925,680	28.995
Submerged Rock/Reef	906,656	3.306	368931	0.985	2,675,888	10.059	3,233,489	13.537
Deep Water	21,718,900	79.196	28580600	76.335	9,093,000	34.180	8,255,210	34.561
Total	27,424,170		37,441,118		26,602,893		23,885,772	

Table 3.3

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

SCR OI-Aerial Subregion	Santa Cruz Island (North)		Santa Cruz Island (Northeast)		Santa Cruz Island (South)	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	2,518,001	7.958	95,665	0.367	551,383	1.274
Sandy Beach	86,526	0.273	156,884	0.602	813,347	1.879
Mixed Red/Brown Algae	106,432	0.336	114,866	0.441	163,959	0.379
Shadow	442,547	1.399	1,155,782	4.435	852,934	1.970
Terrestrial Vegetation	1,104,433	3.490	913,356	3.505	2,156,790	4.983
Unvegetated Rock	971,556	3.071	791,689	3.038	1,629,630	3.765
Beach Wrack	220	0.001	1	0.000	5,302	0.012
Kelp/Brown Algae	203,344	0.643	37,052	0.142	348,443	0.805
Blue-Green Algae	0	0.000	1	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	150	0.000	0	0.000	2	0.000
Cobble	1,800	0.006	80,863	0.310	3,491	0.008
Man-Made/Artificial	0	0.000	1,088	0.004	0	0.000
Surf Grass	65,442	0.207	12,583	0.048	249,524	0.576
Eel Grass	0	0.000	38	0.000	0	0.000
Green Algae	0	0.000	494	0.002	59,005	0.136
Submerged Sandy Bottom	2,398,591	7.581	1,315,658	5.048	6,600,920	15.250
Submerged Rock/Reef	44343	0.140	274,952	1.055	1,584,420	3.660
Deep Water	23698002	74.896	21,109,459	81.002	28,266,400	65.302
Total	31,641,387		26,060,431		43,285,550	

Table 3.4

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

MPA	Abalone Cove SMCA		Anacapa Island SMCA		Anacapa Island SMR		Arrow Point to Lion Head Point (Catalina Island) SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	31,419	3.432	8,744	2.056	27,721	2.382	409	0.025
Sandy Beach	16,862	1.842	356	0.084	4,035	0.347	12,283	0.751
Mixed Red/Brown Algae	15,010	1.639	1,634	0.384	24,183	2.078	13,511	0.826
Shadow	835	0.091	213,582	50.213	97,513	8.381	26,645	1.628
Terrestrial Vegetation	197	0.022	425	0.100	1,073	0.092	4,099	0.250
Unvegetated Rock	2,446	0.267	565	0.133	6,359	0.547	3,233	0.198
Beach Wrack	0	0.000	0	0.000	193	0.017	0	0.000
Kelp/Brown Algae	70,834	7.736	91	0.021	29,412	2.528	1,018	0.062
Blue-Green Algae	0	0.000	522	0.123	5,366	0.461	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	31	0.003	314	0.074	1,862	0.160	0	0.000
Cobble	8,681	0.948	0	0.000	74	0.006	64	0.004
Man-Made/Artificial	0	0.000	0	0.000	175	0.015	450	0.027
Surf Grass	4,267	0.466	0	0.000	45	0.004	1,517	0.093
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	80	0.009	0	0.000	14	0.001	0	0.000
Submerged Sandy Bottom	430,499	47.018	78,690	18.500	568,980	48.900	223,673	13.669
Submerged Rock/Reef	6,370	0.696	1,997	0.469	158,279	13.603	104,459	6.384
Deep Water	328,080	35.832	118,429	27.843	238,280	20.478	1,245,012	76.084
Total	915,612		425,350		1,163,564		1,636,373	

MPA	Blue Cavern (Catalina Island) SMCA		Cabrillo SMR		Campus Point SMCA		Carrington Point SMR	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	65	0.002	8,587	0.864	145,882	3.408	172,021	5.703
Sandy Beach	4,368	0.123	4,818	0.485	262,720	6.137	22,816	0.756
Mixed Red/Brown Algae	18,571	0.522	42,434	4.271	160	0.004	21,460	0.711
Shadow	107,865	3.034	431	0.043	15,222	0.356	25,894	0.858
Terrestrial Vegetation	13,238	0.372	212	0.021	901	0.021	2,252	0.075
Unvegetated Rock	12,223	0.344	4,929	0.496	211	0.005	25,145	0.834
Beach Wrack	0	0.000	901	0.091	105	0.002	0	0.000
Kelp/Brown Algae	55	0.002	49,356	4.968	567,567	13.258	64,674	2.144
Blue-Green Algae	0	0.000	586	0.059	23	0.001	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	25	0.001	0	0.000	2,253	0.053	0	0.000
Cobble	1,503	0.042	5,720	0.576	0	0.000	0	0.000
Man-Made/Artificial	1,411	0.040	1	0.000	104	0.002	433	0.014
Surf Grass	0	0.000	60,333	6.073	71,405	1.668	0	0.000
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	1,038	0.104	936	0.022	0	0.000
Submerged Sandy Bottom	15,998	0.450	803,563	80.885	3,213,294	75.063	1,390,507	46.101
Submerged Rock/Reef	83,141	2.339	10,555	1.062	0	0.000	134,375	4.455
Deep Water	3,296,527	92.730	0	0.000	0	0.000	1,156,633	38.347
Total	3,554,989		993,464		4,280,783		3,016,209	

Table 3.5

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

MPA	Casino Point (Catalina Island) SMCA		Crystal Cove SMCA		Dana Point SMCA		Farnsworth Onshore (Catalina Island) SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	28	0.132	11,036	0.195	21,052	0.407	19,929	0.648
Sandy Beach	0	0.000	186,700	3.297	297,175	5.751	1,972	0.064
Mixed Red/Brown Algae	479	2.228	101,773	1.797	116,158	2.248	22,689	0.738
Shadow	3,130	14.557	317	0.006	1,618	0.031	4,780	0.155
Terrestrial Vegetation	1,298	6.036	70	0.001	1,703	0.033	926	0.030
Unvegetated Rock	150	0.699	18,259	0.322	28,424	0.550	12,325	0.401
Beach Wrack	0	0.000	101	0.002	201	0.004	9	0.000
Kelp/Brown Algae	188	0.873	117,195	2.070	574,507	11.117	84,302	2.741
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	86	0.002	0	0.000	0	0.000
Cobble	0	0.000	0	0.000	0	0.000	184	0.006
Man-Made/Artificial	1,027	4.774	0	0.000	153	0.003	0	0.000
Surf Grass	0	0.000	117,720	2.079	29,217	0.565	8,440	0.274
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	271	0.005	47	0.001	0	0.000
Submerged Sandy Bottom	1,474	6.855	237,541	4.195	206,305	3.992	309,886	10.077
Submerged Rock/Reef	9	0.041	126,125	2.227	163,081	3.156	12,057	0.392
Deep Water	13,720	63.804	4,745,434	83.803	3,727,973	72.141	2,597,731	84.473
Total	21,504		5,662,628		5,167,612		3,075,230	

MPA	Goleta Slough SMCA		Harris Point SMR		Judith Rock SMR		Kashtayit SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	0	0.000	320,763	3.503	21,021	1.162	36,491	1.428
Sandy Beach	2,215	48.034	109,473	1.196	7,593	0.420	45,638	1.785
Mixed Red/Brown Algae	0	0.000	31,432	0.343	42,339	2.340	2,810	0.110
Shadow	1,379	29.919	14,726	0.161	3,536	0.195	311	0.012
Terrestrial Vegetation	269	5.824	623	0.007	585	0.032	26	0.001
Unvegetated Rock	7	0.152	10,061	0.110	2,361	0.130	1,261	0.049
Beach Wrack	3	0.059	9	0.000	0	0.000	94	0.004
Kelp/Brown Algae	0	0.000	78,887	0.862	241,237	13.331	13,849	0.542
Blue-Green Algae	0	0.000	0	0.000	0	0.000	62	0.002
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	0	0.000	0	0.000	493	0.019
Cobble	0	0.000	0	0.000	0	0.000	656	0.026
Man-Made/Artificial	0	0.000	0	0.000	0	0.000	1,054	0.041
Surf Grass	0	0.000	523	0.006	3,395	0.188	8,580	0.336
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	201	0.002	36	0.002	124	0.005
Submerged Sandy Bottom	738	16.011	660,348	7.212	140,665	7.773	2,444,667	95.640
Submerged Rock/Reef	0	0.000	79,710	0.871	111,832	6.180	0	0.000
Deep Water	0	0.000	7,849,641	85.728	1,235,002	68.247	0	0.000
Total	4,611		9,156,397		1,809,601		2,556,117	

Table 3.6

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

MPA	Laguna Beach SMCA		Laguna Beach SMR		Long Point (Catalina Island) SMR		Lover's Cove (Catalina Island) SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	1,525	0.102	7,709	0.135	284	0.009	41	0.028
Sandy Beach	39,720	2.647	137,704	2.409	5,609	0.182	1,596	1.085
Mixed Red/Brown Algae	24,939	1.662	93,432	1.635	2,427	0.079	2,177	1.479
Shadow	80	0.005	365	0.006	96,341	3.127	24,943	16.951
Terrestrial Vegetation	58	0.004	5,738	0.100	4,586	0.149	2,341	1.591
Unvegetated Rock	4,988	0.332	32,026	0.560	2,730	0.089	1,278	0.868
Beach Wrack	0	0.000	1,699	0.030	0	0.000	0	0.000
Kelp/Brown Algae	2,203	0.147	159,871	2.797	47	0.002	610	0.415
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	96	0.002	67	0.002	0	0.000
Cobble	0	0.000	220	0.004	93	0.003	0	0.000
Man-Made/Artificial	0	0.000	198	0.003	0	0.000	1,234	0.839
Surf Grass	2,728	0.182	71,217	1.246	0	0.000	1,507	1.024
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	123	0.002	0	0.000	0	0.000
Submerged Sandy Bottom	59,023	3.934	150,689	2.637	55,498	1.801	8,070	5.484
Submerged Rock/Reef	20,830	1.388	233,958	4.093	92,986	3.018	5,652	3.841
Deep Water	1,344,364	89.597	4,820,390	84.340	2,820,291	91.539	97,702	66.396
Total	1,500,459		5,715,435		3,080,961		147,151	

MPA	Lover's Cove SMCA		Matlahuayl SMR		Naples SMCA		Point Conception SMR	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	19	0.037	34,079	1.843	31,112	1.161	84,807	1.511
Sandy Beach	1,223	2.322	202,041	10.929	117,731	4.395	158,584	2.826
Mixed Red/Brown Algae	569	1.080	37,314	2.018	17,956	0.670	50,975	0.908
Shadow	10,015	19.018	6,258	0.339	19,505	0.728	3,706	0.066
Terrestrial Vegetation	31	0.059	8,776	0.475	5	0.000	2,904	0.052
Unvegetated Rock	414	0.786	5,826	0.315	81	0.003	13,121	0.234
Beach Wrack	0	0.000	21,402	1.158	3,784	0.141	3,398	0.061
Kelp/Brown Algae	197	0.375	28,431	1.538	467,538	17.452	166,652	2.970
Blue-Green Algae	0	0.000	0	0.000		0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	0	0.000	10,805	0.403	0	0.000
Cobble	0	0.000	0	0.000	703	0.026	0	0.000
Man-Made/Artificial	0	0.000	10,262	0.555	0	0.000	0	0.000
Surf Grass	1,508	2.864	11,957	0.647	66,145	2.469	96,800	1.725
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	0	0.000	213	0.008	1,029	0.018
Submerged Sandy Bottom	7,549	14.335	671,673	36.334	1,943,405	72.543	5,029,107	89.628
Submerged Rock/Reef	5,618	10.668	280,101	15.152	0	0.000	0	0.000
Deep Water	25,518	48.456	530,505	28.697	0	0.000	0	0.000
Total	52,662		1,848,626		2,678,982		5,611,084	

Table 3.7

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

MPA	Point Dume SMCA		Point Dume SMR		Point Vicente SMCA		San Diego-Scripps Coastal SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	24,186	0.741	10,173	0.457	28,241	2.447	20,839	1.472
Sandy Beach	335,988	10.292	134,274	6.026	47	0.004	179,054	9.686
Mixed Red/Brown Algae	9,382	0.287	45,091	2.023	18,444	1.598	6,142	0.332
Shadow	115	0.004	475	0.021	1,218	0.106	193	0.010
Terrestrial Vegetation	6	0.000	0	0.000	30	0.003	8,215	0.444
Unvegetated Rock	0	0.000	369	0.017	0	0.000	7,167	0.388
Beach Wrack	9	0.000	0	0.000	0	0.000	103	0.006
Kelp/Brown Algae	136,377	4.178	190,815	8.563	320,234	27.744	0	0.000
Blue-Green Algae	178	0.005	6	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	107	0.005	37	0.003	0	0.000
Cobble	0	0.000	164	0.007	11,342	0.983	3,329	0.180
Man-Made/Artificial	0	0.000	0	0.000	0	0.000	2,948	0.159
Surf Grass	914	0.028	58,036	2.604	515	0.045	1,904	0.103
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	595	0.018	272	0.012	11	0.001	0	0.000
Submerged Sandy Bottom	354,084	10.847	124,246	5.576	112,729	9.766	0	0.000
Submerged Rock/Reef	2,181	0.067	56,299	2.526	17,857	1.547	1,185,016	64.103
Deep Water	2,400,388	73.532	1,608,057	72.162	643,544	55.754	466	0.025
Total	3,264,405		2,228,383		1,154,248		1,415,376	

MPA	San Elijo Lagoon SMCA		Santa Barbara Island SMR		South La Jolla SMR		South Point SMR	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	0	0.000	4,789	0.249	25,777	1.551	39,699	1.346
Sandy Beach	174	0.006	5	0.000	23,647	1.423	121,781	4.130
Mixed Red/Brown Algae	0	0.000	23,799	1.238	5,777	0.348	97,201	3.296
Shadow	0	0.000	590	0.031	519	0.031	62	0.002
Terrestrial Vegetation	0	0.000	2,873	0.149	3	0.000	4,982	0.169
Unvegetated Rock	0	0.000	15,899	0.827	1,241	0.075	40,179	1.363
Beach Wrack	7	0.000	0	0.000	26	0.002	3,380	0.115
Kelp/Brown Algae	0	0.000	128,462	6.682	9,652	0.581	64,435	2.185
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	0	0.000	0	0.000	0	0.000	0	0.000
Cobble	0	0.000	0	0.000	342	0.021	3,715	0.126
Man-Made/Artificial	3	0.000	0	0.000	0	0.000	3,279	0.111
Surf Grass	0	0.000	0	0.000	33,429	2.011	81,212	2.754
Eel Grass	0	0.000	0	0.000	0	0.000	0	0.000
Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Submerged Sandy Bottom	579	0.022	314,403	16.354	718,019	43.203	0	0.000
Submerged Rock/Reef	0	0.000	74,127	3.856	306,111	18.419	660,101	22.386
Deep Water	0	0.000	1,357,522	70.613	537,412	32.336	1,828,637	62.016
Total	763		1,922,468		1,661,955		2,948,663	

Table 3.8

Coverage by area and percent of vegetation/substrate classes derived from the 2012 multispectral imagery listed by MPA and SCR OI-Aerial subregions.

MPA	Swami's SMCA		Tijuana River Mouth SMCA		Painted Cave SMCA		Scorpion SMR	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	133,965	3.084	136,680	4.634	2,518,001	8.008	95,665	0.367
Sandy Beach	420,371	9.678	47,160	1.599	0	0.000	156,884	0.602
Mixed Red/Brown Algae	5,779	0.133	3	0.000	106,432	0.338	114,866	0.441
Shadow	0	0.000	0	0.000	442,547	1.407	1,155,782	4.437
Terrestrial Vegetation	18	0.000	0	0.000	1,104,433	3.513	913,356	3.507
Unvegetated Rock	30	0.001	0	0.000	971,556	3.090	791,689	3.039
Beach Wrack	3,412	0.079	12,927	0.438	0	0.000	0	0.000
Kelp/Brown Algae	456,018	10.499	815	0.028	203,344	0.647	37,052	0.142
Blue-Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	6	0.000	0	0.000	0	0.000	0	0.000
Cobble	89	0.002	50	0.002	0	0.000	80,863	0.310
Man-Made/Artificial	678	0.016	2	0.000	0	0.000	1,088	0.004
Surf Grass	76,635	1.764	0	0.000	0	0.000	0	0.000
Eel Grass	0	0.000	471	0.016	0	0.000	0	0.000
Green Algae	0	0.000	0	0.000	0	0.000	0	0.000
Submerged Sandy Bottom	2,669,487	61.457	2,751,520	93.284	2,398,591	7.628	1,315,658	5.051
Submerged Rock/Reef	577,151	13.287	0	0.000	0	0.000	274,952	1.056
Deep Water		0.000	0	0.000	23,698,002	75.368	21,109,459	81.043
Total	4,343,640		2,949,628		31,442,906		26,047,314	

MPA	Gull Island SMR		Cat Harbor (Catalina Island) SMCA	
Classification	**Area(m^2)**	**Area %**	**Area(m^2)**	**Area %**
Whitewash/Undefined	551,383	1.274	1,057	0.282
Sandy Beach	813,347	1.879	20,674	5.513
Mixed Red/Brown Algae	163,959	0.379	693	0.185
Shadow	852,934	1.971	6,342	1.691
Terrestrial Vegetation	2,156,790	4.983	4,294	1.145
Unvegetated Rock	1,629,630	3.765	9,363	2.497
Beach Wrack	5,302	0.012	685	0.183
Kelp/Brown Algae	348,443	0.805	2,257	0.602
Blue-Green Algae	0	0.000	0	0.000
Mixed Rock/Mussels/Barnacles/Anemone	2	0.000	0	0.000
Cobble	0	0.000	265	0.071
Man-Made/Artificial	0	0.000	2,392	0.638
Surf Grass	249,524	0.577	3,835	1.023
Eel Grass	0	0.000	0	0.000
Green Algae	59,005	0.136	0	0.000
Submerged Sandy Bottom	6,600,920	15.251	314,565	83.887
Submerged Rock/Reef	1,584,420	3.661	8,564	2.284
Deep Water	28,266,400	65.307	1	0.000
Total	43,282,059		374,987	

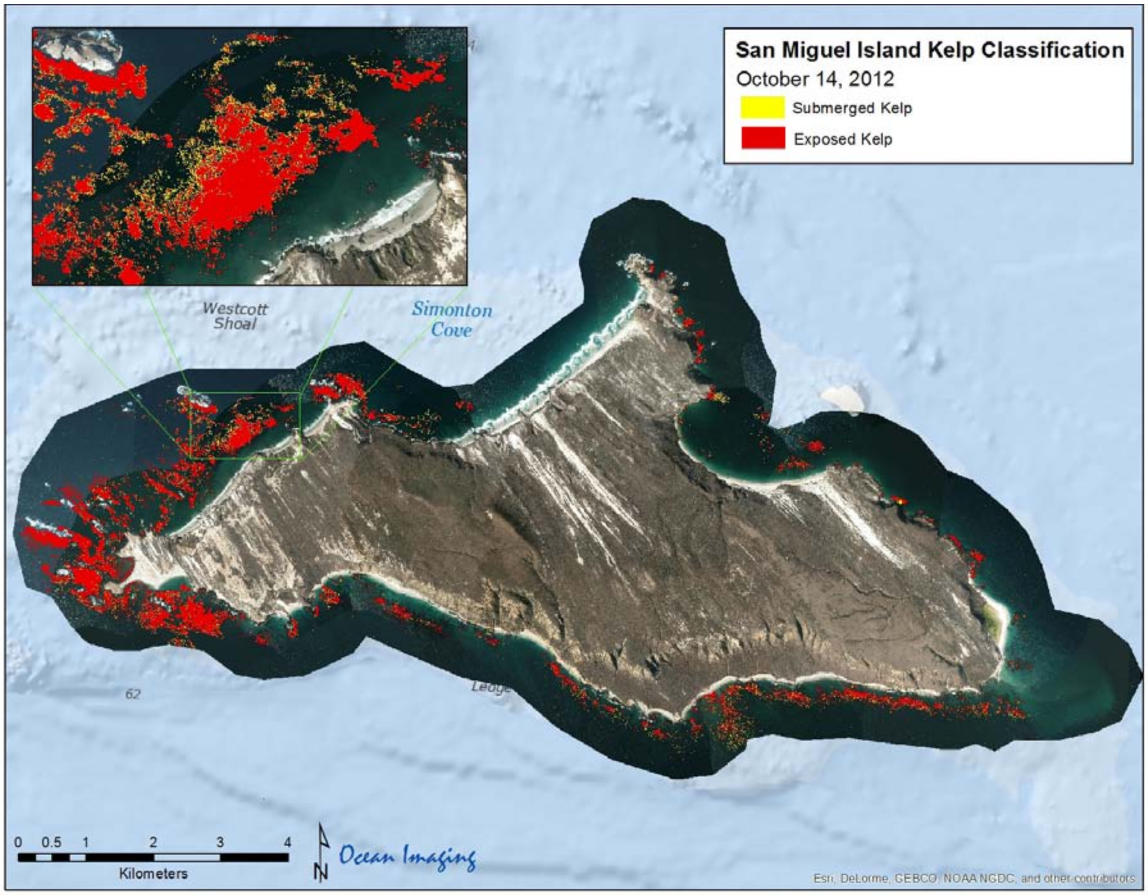


Figure 8.

Two-class classification of Giant Kelp off of San Miguel Island.
Data were acquired using the Microsoft UltraCam-X on October 14, 2012.

Despite the above considerations, the database represents the most spatially comprehensive and highest resolution, synoptic survey of the SCR MPAs to-date. Since many parts of the coastline in the region are extremely difficult to access, a field sampling-based region-wide survey of the same scope is, for all practical purposes, impossible. The remote sensing derived data can serve three major purposes: 1) to obtain data on vegetation/substrate composition and spatial distribution in areas that have not been sampled by any other means; 2) to help identify areas of interest for future additional field sampling or study sites; 3) to serve as a comparison baseline for similar surveys in the future.

As was also the case with the NCC Aerial database, the substrate classes of the database are relatively broad compared to those utilized for most field sampling surveys. This is so for two reasons: 1) Limits of the multispectral technology in ability to consistently separate specific algae types or species. This was, in turn, affected by either the reflectance spectra of certain species being too similar for the available 4-channel instrument, and/or the species being too intermixed spatially for the 30cm-1m data resolution to allow adequate spatial separation; 2) A high emphasis was placed on achieving consistent, high classification accuracy. Although a greater number of more species-specific classes could have potentially been derived over certain areas, they

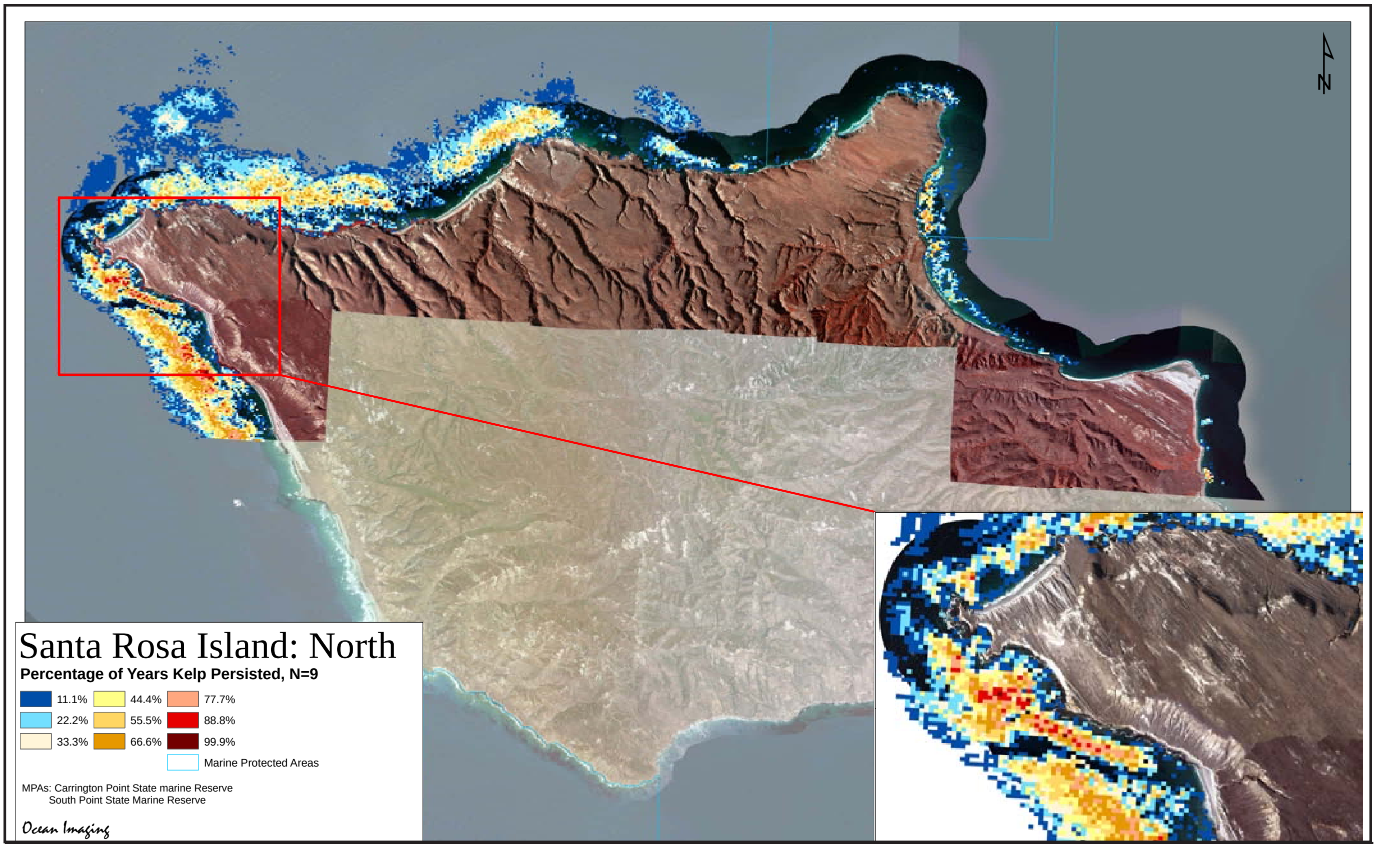


Figure 9.

Sample Giant Kelp persistence map for the Santa Rosa Island North SCR subregion. Kelp persistence is represented as the percentage of the number of years used for the analysis that a pixel was classified as showing kelp.

could not be reliably extended through most of the rest of the region. As was anticipated from the beginning of this project, the remote sensing-derived database thus represents a coarser classification scheme (but much more spatially complete) than site-specific field surveys. This is illustrated when we used the high definition Biodiversity Contact Point Survey data as the reference data in our accuracy assessment.

In order for any cross-correlation comparison to take place, the field sampling-based data had to be significantly “degraded” to the remote sensing-based classes for the analysis. This, along with multiple and varied field sample points within each 1-meter pixel no doubt played a role in reducing the overall accuracy of the habitat classifications as derived via the Congalton matrix.

While the future use of even higher resolution multi-spectral imagery (10cm - 20cm), might improve the ability to map the spatial heterogeneity of the target areas and thus perhaps increase the fidelity of the derived products, it is doubtful it would significantly increase the identification accuracy and/or species specificity. This, as explained above, is due to the fact that many of the species intermix on a rock or substrate with spatial variability of scales even less than 10-20 cm. It also could be proposed that the use of hyperspectral imagery would better resolve the spectral signatures of the different species and substrates and result in more detailed and accurate habitat maps. While this may be true to a certain extent, the cost to acquire, calibrate, process, classify and analyze this type of remotely sensed data at a resolution of 10 cm to 30 cm would be significantly higher than what was expended for this

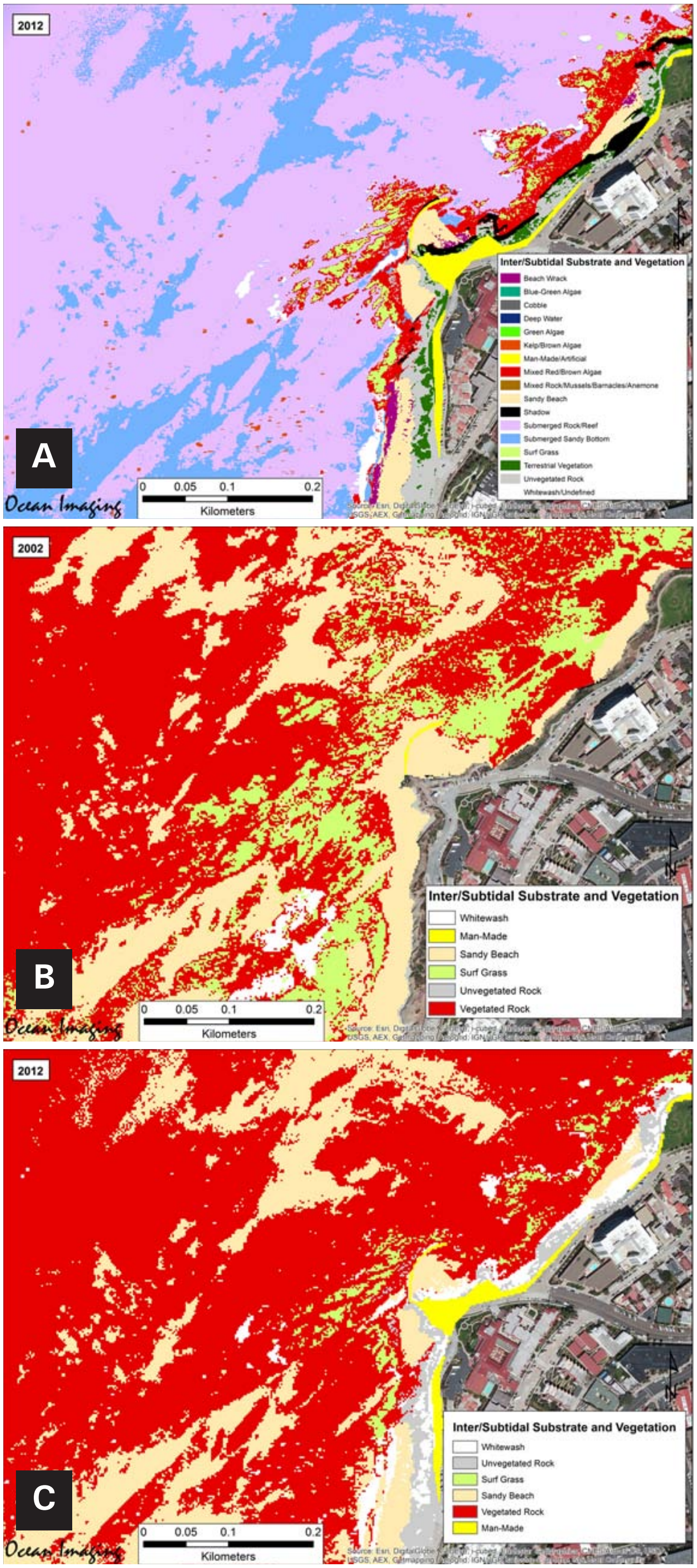


Figure 10.

In 2002, Ocean Imaging generated a substrate/vegetation classification (B) from a data set acquired by their DMSC MkII multi-spectral imager, for the San Diego Association of Governments (SANDAG).

The 2012 data set (A) was acquired with the high resolution Microsoft UltraCam-X multispectral imager.

In order to generate a 2012 substrate/vegetation classification that could be statistically compared to the 2002 data set, the intertidal habitat classification derived from the 2012 high resolution, UltraCam-X multispectral imagery (A) must first be reduced to match the spatial resolution of the 2002 data (B).

Specific classes in the 2012 map (A) are then pared down to match the same classes identified in the 2002 classification product (C).

Finally, the two thematic maps with the same general classes (2012 [C] and 2002 [B]) are compared by the substrate/vegetation types noted above to generate the change detection analyses.

project - perhaps on the order of five to ten times the cost for data acquisition and processing labor, not to mention the time necessary to generate the classification maps.

3.3 Change Detection Results and Analysis

In addition to the important database applications noted above, the 2012 database should also be useful for the detection of major changes or trends when compared on its general level to future field surveys. Such changes can occur rapidly – e.g. due to major storms, landslides and erosion, or may reflect long-term climatic changes – e.g. changes in upper intertidal zone substrate patterns due to sea level rise and related sea water and salt deposition onto higher rock and soil surfaces. As an example of this, as described above, change detection analysis using multispectral-derived intertidal classification from 2002 and the 2012 intertidal habitat classification was performed. The results of this analysis are shown in **Table 4** and **Figure 11**. The dramatic change between sand covered bottom and

Table 4.

Coverage area of vegetation/substrate classes by MPA and SCR OI-Aerial subregion for 2002 and 2012 and the percent change in area from 2002 to 2012.

SCR OI-Aerial Subregion of Interest

	Dana Point Laguna Beach			Encinitas La Jolla			Imperial Beach		
Substrate Class:	2002	2012	Change	2002	2012	Change	2002	2012	Change
Surf Grass (m²)	29,223	167,400	473%	910,132	273,492	-70%	0	0	0%
Eel Grass (m²)	0	0	0%	2,696	0	-100%	0	3,064	NA
Vegetated Rock (m²)	2,893,678	208,632	-93%	6,637,583	5,572,444	-16%	311,303	392	-100%
Unvegetated Rock (m²)	3,368	76,092	2159%	4,165	475,688	11320%	0	21,124	NA
Sand (m²)	12,062,778	12,441,136	3%	19,731,482	20,398,380	3%	7,920,773	8,352,572	5%

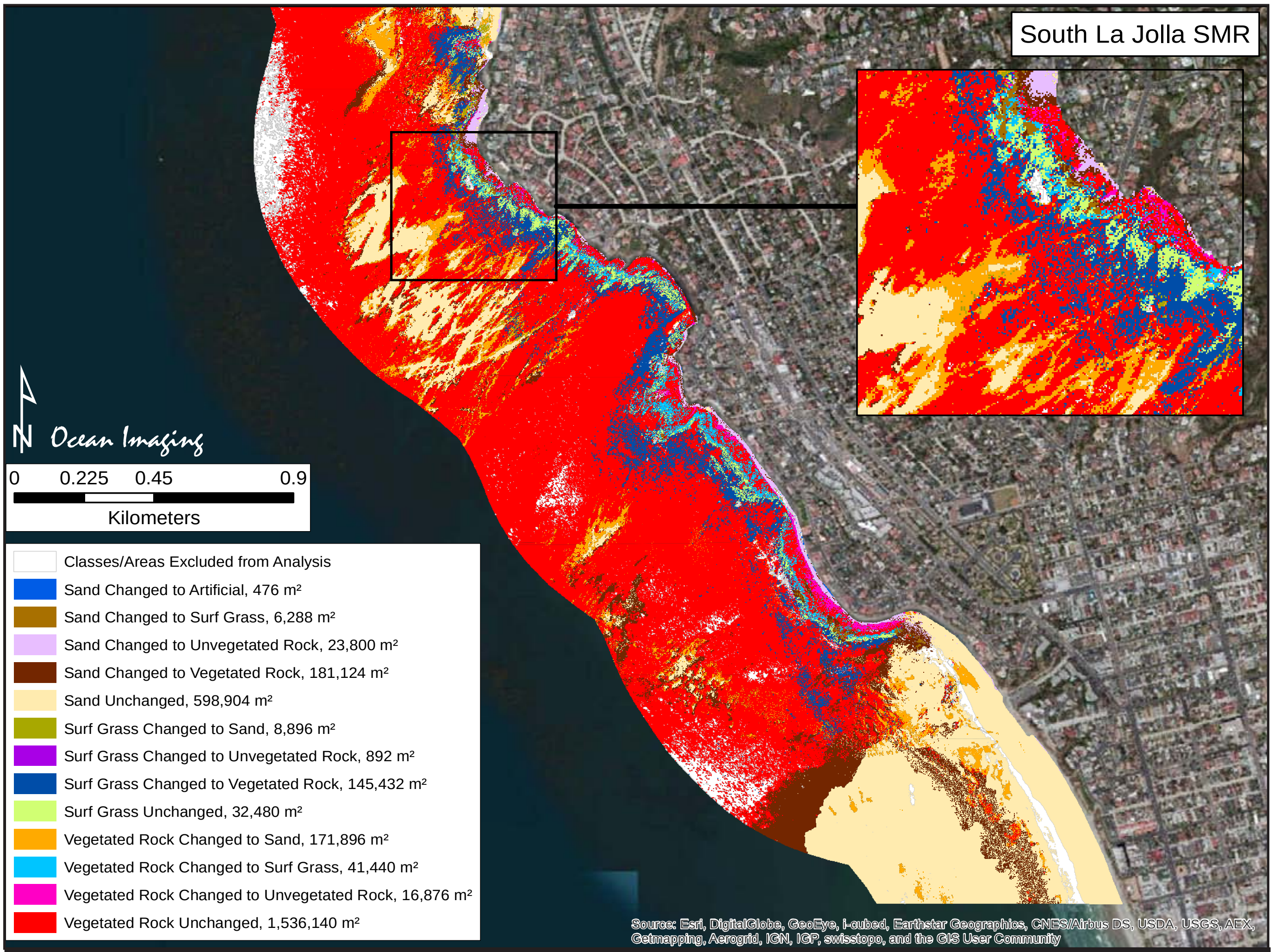
	La Jolla Point Loma		
Substrate Class:	2002	2012	Change
Surf Grass (m²)	377,613	323,020	-14%
Eel Grass (m²)	0	0	0%
Vegetated Rock (m²)	6,073,574	1,855,176	-69%
Unvegetated Rock (m²)	0	259,200	NA
Sand (m²)	6,237,307	11,512,652	85%

MPA of Interest

	Cabrillo SMR			Matlahuayl SMR			South La Jolla SMR		
Substrate Class:	2002	2012	Change	2002	2012	Change	2002	2012	Change
Surf Grass (m²)	9,206	60,477	557%	61,677	12,006	-81%	191,495	80,755	-58%
Eel Grass (m²)	0	0	0%	2,688	0	-100%	0	0	0%
Vegetated Rock (m²)	709,663	55,008	-92%	252,300	317,182	26%	1,812,629	1,925,659	6%
Unvegetated Rock (m²)	0	11,075	NA	1,617	5,821	260%	0	43,692	NA
Sand (m²)	76,587	807,320	954%	1,359,224	1,404,485	3%	847,032	782,271	-8%

	San Diego Scripps SMCA			Swamis SMCA			Tijuana SMCA		
Substrate Class:	2002	2012	Change	2002	2012	Change	2002	2012	Change
Surf Grass (m²)	368	1,876	410%	179,617	76,448	-57%	0	0	0%
Eel Grass (m²)	0	0	0%	0	0	0%	0	448	NA
Vegetated Rock (m²)	3,848	5,604	46%	857,058	582,395	-32%	214,554	0	-100%
Unvegetated Rock (m²)	0	6,496	NA	0	0	0%	0	12,836	NA
Sand (m²)	1,399,581	1,362,354	-3%	2,869,525	3,080,795	7%	2,703,310	2,984,492	10%

vegetated rock over the 10 year period in areas such as the Cabrillo SMR is most likely not due to a transformation of the bottom cover, but rather the over classification of submerged, vegetation rock on the 2002 data set. We found that the differences in the multispectral imagery used, 2002 vs. 2012 data classification methods and technology, along with environmental conditions at the time of data collection provided the best explanation for extreme changes in substrate cover seen in **Table 4**, rather than large scale changes to the environment during the 10-year time period. Lack of a consistent gain or loss pattern between different regions, in the case of surf grass for example, indicates however, that the differences are not entirely due to non-environmental factors and there is merit in using synoptic, thematic maps derived from remotely sensed data to compare intertidal baseline data over many years. As is further discussed below, however, it is critical that the type of imagery used, classification methodology and conditions at the time of data collection are as close to the same as possible between the datasets being used in the analysis. In the case of this study this was not possible since the 2002 data



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 11.

Sample change detection analysis. Colors of the vegetation or substrate which remained the same over the 10-year period are the same as those represented in the 2012 sub/intertidal habitat classifications. The other colors represent areas in which the classes changed from 2002 to 2012.

and derived products were acquired and generated with no foreknowledge that they would be used to compare to the 2012 dataset.

3.4 Kelp Persistence Analysis Discussion

The project also utilized historical archived aerial imagery and newly acquired imagery to produce kelp canopy classifications for the designated SCR sub¬regions from 2011 and 2012 as well as to compute its persistence over the period 1999 to 2012. A sample of this analysis from the San Miguel Island subregion is shown in **Figure 12.** The persistence analyses show a high degree of inter-annual variability which must be considered in future assessments of the state of this important resource. For most subregions, kelp beds closer to shore showed a higher level of persistence over the time period and off-shore beds tended to exhibit a higher degree of inter-annual variability. In general, the persistence of kelp beds inside of MPAs paralleled neighboring beds outside of the MPA. A few exceptions are the Campus Point State Marine Conservation Area and Naples State Marine Conservation area. These two MPAs both include larger kelp beds relative to beds along the Santa Barbara Coast between Santa Barbara and Point Conception, but also the beds inside of these MPAs show a higher degree of persistence when compared to the kelp beds outside of these MPAs along this stretch of coastline (**Figure 13**). The kelp bed within the South La Jolla State Marine Reserve is another bed which exhibited a higher degree of kelp bed persistence inside of the MPA compared to neighboring non-MPA beds (**Figure 14**). Finally, the Imperial Beach, CA subregion is an interesting case study. During the 1999-2009 time period (no data were available for this area 2010-2012), major bed locations shifts and coverage area variability give the appearance in the persistence analysis that this kelp bed rarely persists longer than one year. In actuality the same bed appears to change in location slightly from year to year with some years (1999 and 2003) showing very sparse coverage and others (2008 and 2009) exhibiting much larger canopy area. **Figure 15** illustrates this change in bed size and location through the years. No other kelp beds in the SCR show this kind of susceptibility to envi¬ronmental influence and variability.

Tables 5.1-5.8 show the kelp coverage areas in m^2 by SCR OI-Aerial subregion, individual MPAs as well as the non-MPA areas surrounding the MPAs in that particular subregion. Plots of the kelp area over time for each OI-Aerial subregion, the MPAs within the subregion and the non-MPA areas within the subregion are included in Appendix 2 at the end of this document. Note significant inter-annual changes in bed size over the time period in areas such as Catalina Island, Santa Rosa Island and Anacapa Island. Overall, the change in bed coverage area within the MPAs followed the same trends through the years as kelp beds falling outside of the MPAs. Notable exceptions are a marked proportional increase in the area of kelp in the non-MPA zones surrounding the Campus Point and Naples SMCAs compared to the beds within the MPAs between 2008-2012; a drop off of the kelp area in the non-MPA areas vs. a slight increase within the Point Vicente and Abalone Cove SMCAs in the Point Vicente subregion; an increase of the kelp area within the Gull Island SMR compared to a decrease in kelp area outside of this MPA (Santa Cruz Island South subregion); and a relative increase of kelp area within the Santa Barbara Island SMR compared to outside of the MPA between 2009-2012 (**Figure 16**).

3.5 Long-Term Monitoring Recommendations

As was touched upon in the above discussion, any future remotely-sensed derived databases to be used for comparison to the 2012 sub/intertidal and kelp databases generated as part of this study should be as close as possible to the 2012 data in regards to:

1) the multispectral camera system used
2) the time of year the data are acquired
3) the tidal and environmental conditions at the time of data collection
4) the processing techniques used to create the image mosaics
5) the classification techniques utilized to create the thematic maps

As was illustrated in the change detection analysis performed as part of this project, even small differences in the above factors can lead to diminished confidence in the analysis of the environmental/habitat change over the time period being studied.

Table 5.1

Kelp Coverage by Year (m^2).

Anacapa Island - Kelp Area (m^2)

	Anacapa Island					
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMR	(Difference) Non MPA - SMR
1999	16,720	16,559	161	16,398	0	16,559
2003	116,812	91,477	3,275	88,202	22,060	69,417
2004	199,980	162,190	1,256	160,934	36,534	125,656
2005	260,492	161,023	10,300	150,723	89,169	71,854
2006	101,252	77,787	2,485	75,302	20,980	56,807
2008	95,564	57,264	65	57,199	38,235	19,029
2010	329,384	197,570	42	197,528	131,772	65,798
2012	345,692	150,407	12,076	138,331	183,209	-32,802

Coal Oil Point - Kelp Area (m^2)

	Coal Oil Point		Naples		Campus Point	
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
1999	501,180	183,191	28,564	154,627	289,425	-106,234
2002	2,506,568	1,743,822	183,314	1,560,508	579,432	1,164,390
2003	2,621,240	1,606,737	347,862	1,258,875	666,641	940,096
2004	2,329,044	1,095,937	682,736	413,201	550,371	545,566
2005	2,650,672	1,330,724	655,552	675,172	664,396	666,328
2008	2,722,820	1,307,817	632,556	675,261	782,447	525,370
2011	3,842,168	2,587,994	607,185	1,980,809	646,989	1,941,005
2012	3,859,768	2,490,425	651,140	1,839,285	718,203	1,772,222

Table 5.2

Kelp Coverage by Year (m^2).

Encinitas / La Jolla - Kelp Area (m^2)

Year	Encinitas / La Jolla		Swami's		San Diego Scripps	
	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
1999	1,321,428	271,700	89,176	182,524	0	271,700
2003	3,156,024	1,800,381	488,097	1,312,284	0	1,800,381
2005	860,456	210,175	1,201	208,974	0	210,175
2006	155,072	45,665	6,416	39,249	10,364	35,301
2008	5,623,012	3,024,449	743,385	2,281,064	0	3,024,449
2009	3,977,360	1,991,901	798,847	1,193,054	0	1,991,901
2011	3,907,128	1,718,924	884,841	834,083	270	1,718,654
2012	2,601,076	1,612,994	816,005	796,989	16	1,612,978

Year	Matlahuayl		Swami's	
	SMR	(Difference) Non MPA - SMR	SMCA	(Difference) Non MPA - SMCA
1999	0	271,700	89,176	182,524
2003	148,490	1,651,891	488,097	1,312,284
2005	16,665	193,510	1,201	208,974
2006	8,615	37,050	6,416	39,249
2008	31,268	2,993,181	743,385	2,281,064
2009	27,019	1,964,882	798,847	1,193,054
2011	48,603	1,670,321	884,841	834,083
2012	39,153	1,573,841	816,005	796,989

Imperial Beach - Kelp Area (m^2)

Year	Imperial Beach		Tijuana River Mouth	
	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA
1999	10,017	0	10,017	-10,017
2003	45,319	0	45,319	-45,319
2004	99,065	0	99,065	-99,065
2005	345,012	0	345,012	-345,012
2006	501,594	0	501,594	-501,594
2008	2,389,519	0	2,389,519	-2,389,519
2009	856,200	0	856,200	-856,200

Table 5.3

Kelp Coverage by Year (m^2).

Laguna Beach / Dana Point - Kelp Area (m^2)

	Laguna Beach / Dana Point		Laguna Beach			
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR	SMCA	(Difference) Non MPA - SMCA
2003	1,263,820	1,022,973	2,840	1,020,133	124	1,022,849
2005	574,920	460,266	0	460,266	0	460,266
2008	1,744,540	968,342	6,464	961,878	28	968,314
2009	3,219,684	2,228,312	36,847	2,191,465	584	2,227,728
2011	3,212,392	1,519,543	503,121	1,016,422	24,111	1,495,432
2012	3,212,276	1,519,983	503,133	1,016,850	24,097	1,495,886

	Dana Point		Crystal Cove	
Year	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
2003	236,687	786,286	1,196	1,021,777
2005	113,906	346,360	748	459,518
2008	699,658	268,684	70,048	898,294
2009	861,796	1,366,516	92,145	2,136,167
2011	795,418	724,125	370,199	1,149,344
2012	795,015	724,968	370,048	1,149,935

La Jolla / Point Loma - Kelp Area (m^2)

	La Jolla / Point Loma		Cabrillo	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR
1999	4,602,988	4,535,328	67,660	4,467,668
2003	3,564,780	3,500,461	64,319	3,436,142
2004	3,910,312	3,906,693	3,619	3,903,074
2005	3,470,372	3,469,584	788	3,468,796
2008	6,854,140	6,849,908	4,232	6,845,676
2009	4,902,940	4,887,356	15,584	4,871,772
2011	6,034,196	5,877,884	156,312	5,721,572
2012	3,278,444	3,270,650	7,794	3,262,856

Table 5.4

Kelp Coverage by Year (m²).

Point Conception - Kelp Area (m²)

	Point Conception				Kashtayit	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR	SMCA	(Difference) Non MPA - SMCA
1999	645,732	583,413	62,319	521,094	0	583,413
2002	1,448,176	1,086,492	361,364	725,128	320	1,086,172
2003	5,541,652	4,889,873	651,779	4,238,094	0	4,889,873
2004	2,317,492	1,826,370	478,470	1,347,900	12,652	1,813,718
2005	3,165,844	2,856,930	308,162	2,548,768	752	2,856,178
2008	3,071,248	2,618,606	438,393	2,180,213	14,249	2,604,357
2011	489,320	415,839	0	415,839	73,481	342,358
2012	3,931,776	3,386,417	474,576	2,911,841	70,783	3,315,634

Point Dume - Kelp Area (m²)

	Point Dume					
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMR	(Difference) Non MPA - SMR
1999	545,144	485,216	54,788	430,428	5,140	480,076
2003	98,712	98,712	0	98,712	0	98,712
2004	1,755,900	1,312,896	223,062	1,089,834	219,942	1,092,954
2005	1,486,504	1,269,911	142,436	1,127,475	74,157	1,195,754
2006	981,780	803,274	91,879	711,395	86,627	716,647
2008	443,592	320,931	38,788	282,143	83,873	237,058
2009	1,787,784	1,455,791	155,706	1,300,085	176,287	1,279,504
2011	2,156,180	1,765,221	155,773	1,609,448	235,186	1,530,035
2012	3,142,064	2,383,146	287,454	2,095,692	471,464	1,911,682

Point Vicente - Kelp Area (m²)

	Point Vicente				Abalone Cove	
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
1999	1,224,816	1,209,828	7,044	1,202,784	7,944	1,201,884
2003	838,548	756,145	33,608	722,537	48,795	707,350
2004	948,040	936,441	7,150	929,291	4,449	931,992
2005	1,538,104	1,471,540	45,777	1,425,763	20,787	1,450,753
2006	2,290,376	2,205,520	30,325	2,175,195	54,531	2,150,989
2008	4,295,088	3,843,402	293,465	3,549,937	158,221	3,685,181
2009	3,996,876	3,759,770	183,188	3,576,582	53,918	3,705,852
2011	2,498,288	2,094,767	297,078	1,797,689	106,443	1,988,324
2012	4,297,640	3,853,320	353,577	3,499,743	90,743	3,762,577

Table 5.5

Kelp Coverage by Year (m^2).

San Miguel - Kelp Area (m^2)

	San Miguel		Harris Point		Judith Rock	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR	SMR	(Difference) Non MPA - SMR
1999	1,974,852	1,845,836	11,240	1,834,596	117,776	1,728,060
2003	5,997,208	5,573,243	44,466	5,528,777	379,499	5,193,744
2004	10,562,660	9,659,245	438,699	9,220,546	464,716	9,194,529
2005	11,637,848	10,370,616	632,300	9,738,316	634,932	9,735,684
2006	5,105,664	4,368,121	454,053	3,914,068	283,490	4,084,631
2008	5,147,240	4,517,531	144,451	4,373,080	485,258	4,032,273
2010	6,172,680	5,629,771	99,999	5,529,772	442,910	5,186,861
2011	3,918,924	3,755,373	82,403	3,672,970	81,148	3,674,225
2012	2,955,776	2,448,322	132,839	2,315,483	374,615	2,073,707

Santa Barbara Island - Kelp Area (m^2)

	Santa Barbara Island			
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR
1999	450,432	439,198	11,234	427,964
2003	216,512	212,626	3,886	208,740
2004	642,636	564,926	77,710	487,216
2005	762,004	673,684	88,320	585,364
2006	91,820	73,800	18,020	55,780
2008	118,656	106,145	12,511	93,634
2009	125,836	97,604	28,232	69,372
2010	496,372	184,138	312,234	-128,096
2011	455,624	142,772	312,852	-170,080
2012	465,288	167,321	297,967	-130,646

Santa Catalina Island (East) - Kelp Area (m^2)

	Santa Catalina Island (East)		Casino Point		Lover's Cove	
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
1999	13,080	13,080	0	13,080	0	13,080
2003	80,224	75,816	0	75,816	4,408	71,408
2004	147,696	134,034	2,766	131,268	10,896	123,138
2005	89,132	73,465	2,890	70,575	12,777	60,688
2006	26,676	19,830	0	19,830	6,846	12,984
2008	18,044	16,742	906	15,836	396	16,346
2011	46,628	36,094	8,782	27,312	1,752	34,342
2012	26,136	26,136	0	26,136	0	26,136

Table 5.6

Kelp Coverage by Year (m^2).

Santa Catalina Island (North) - Kelp Area (m^2)

Year	Santa Catalina Island (North)		Arrow Point to Lion Head Point		Blue Cavern	
	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA	SMCA	(Difference) Non MPA - SMCA
1999	337,024	331,219	4,717	326,502	0	331,219
2003	769,108	518,489	54,401	464,088	148,750	369,739
2004	1,153,236	799,191	113,090	686,101	121,069	678,122
2005	590,708	499,669	37,906	461,763	49,712	449,957
2006	193,740	172,870	13,397	159,473	6,429	166,441
2008	447,040	403,130	35,986	367,144	4,774	398,356
2011	1,216,548	947,206	154,970	792,236	83,069	864,137
2012	355,008	314,221	12,533	301,688	10,252	303,969

Year	Long Point		Cat Harbor	
	SMR	(Difference) Non MPA - SMR	SMCA	(Difference) Non MPA - SMCA
1999	0	331,219	1,088	330,131
2003	46,905	471,584	563	517,926
2004	116,685	682,506	3,201	795,990
2005	1,478	498,191	1,943	497,726
2006	844	172,026	200	172,670
2008	862	402,268	2,288	400,842
2011	4,092	943,114	27,211	919,995
2012	0	314,221	18,002	296,219

Santa Catalina Island (West) - Kelp Area (m^2)

Year	Santa Catalina Island (West)		Farnsworth Onshore	
	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA
1999	640,488	549,677	90,811	458,866
2003	390,964	362,986	27,978	335,008
2004	1,044,196	894,744	149,452	745,292
2005	384,680	321,916	62,764	259,152
2006	552,036	469,472	82,564	386,908
2008	446,088	421,132	24,956	396,176
2011	1,630,108	1,432,358	197,750	1,234,608
2012	1,200,296	1,066,657	133,639	933,018

Table 5.7

Kelp Coverage by Year (m^2).

Santa Cruz Island (North) - Kelp Area (m^2)

	Santa Cruz Island (North)		Painted Cave	
Year	SCR OI-Aerial Subregion	Non-MPA	SMCA	(Difference) Non MPA - SMCA
1999	87,584	87,584	0	87,584
2003	36,360	36,352	8	36,344
2004	1,066,232	1,064,444	1,788	1,062,656
2005	1,137,136	1,113,854	23,282	1,090,572
2006	199,664	197,499	2,165	195,334
2008	271,660	270,104	1,556	268,548
2010	523,244	521,936	1,308	520,628
2011	409,672	408,664	1,008	407,656
2012	392,568	392,524	44	392,480

Santa Cruz Island (Northeast) - Kelp Area (m^2)

	Santa Cruz Island (Northeast)		Scorpion	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR
1999	87,584	87,584	0	87,584
2003	36,360	36,352	8	36,344
2004	1,066,232	1,064,444	1,788	1,062,656
2005	1,137,136	1,113,854	23,282	1,090,572
2006	199,664	197,499	2,165	195,334
2008	271,660	270,104	1,556	268,548
2010	523,244	521,936	1,308	520,628
2011	409,672	408,664	1,008	407,656
2012	392,568	392,524	44	392,480

Santa Cruz Island (South) - Kelp Area (m^2)

	Santa Cruz Island (South)		Gull Island	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR
1999	833,024	710,920	122,104	588,816
2003	1,800,872	1,682,052	118,820	1,563,232
2004	2,617,312	1,395,622	1,221,690	173,932
2005	2,378,260	1,609,019	769,241	839,778
2006	1,873,860	1,797,371	76,489	1,720,882
2008	844,852	766,566	78,286	688,280
2010	2,602,268	1,978,381	623,887	1,354,494
2011	1,842,184	1,533,909	308,275	1,225,634
2012	1,248,116	1,088,387	159,729	928,658

Table 5.8

Kelp Coverage by Year (m^2).

Santa Rosa Island North - Kelp Area (m^2)

	Santa Rosa Island (North)		Carrington Point		Skunk Point (North)	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR	SMR	(Difference) Non MPA - SMR
1999	2,124,708	1,932,024	190,344	1,741,680	2,340	1,929,684
2003	9,112,420	8,744,358	307,386	8,436,972	60,676	8,683,682
2004	12,112,504	11,669,791	415,333	11,254,458	27,380	11,642,411
2005	13,842,728	13,239,539	580,229	12,659,310	22,960	13,216,579
2006	5,403,552	5,070,309	296,551	4,773,758	36,692	5,033,617
2008	6,195,868	6,055,993	119,739	5,936,254	20,136	6,035,857
2010	6,886,088	6,648,977	187,339	6,461,638	49,772	6,599,205
2011	6,027,072	5,792,982	192,502	5,600,480	41,588	5,751,394
2012	4,955,592	4,570,028	314,988	4,255,040	70,576	4,499,452

Santa Rosa Island (South) - Kelp Area (m^2)

	Santa Rosa Island (South)		South Point		Skunk Point (South)	
Year	SCR OI-Aerial Subregion	Non-MPA	SMR	(Difference) Non MPA - SMR	SMR	(Difference) Non MPA - SMR
1999	2,425,036	1,887,739	515,514	1,372,225	21,783	1,865,956
2003	5,692,784	4,514,069	1,111,085	3,402,984	67,630	4,446,439
2004	6,699,200	5,566,348	1,086,312	4,480,036	46,540	5,519,808
2005	8,032,804	6,729,385	1,274,525	5,454,860	28,894	6,700,491
2006	1,931,036	1,593,651	258,463	1,335,188	78,922	1,514,729
2008	5,238,592	4,355,920	857,234	3,498,686	25,438	4,330,482
2010	5,269,036	4,191,342	1,013,750	3,177,592	63,944	4,127,398
2011	3,137,784	2,431,243	650,946	1,780,297	55,595	2,375,648
2012	3,205,524	2,536,037	611,699	1,924,338	57,788	2,478,249

Any long term monitoring plan which aims to take advantage of the synoptic, comprehensive habitat map products generated from remote sensing data should take this into serious consideration.

3.6 End-product Delivery, File Structure and Public Access Considerations

Due to the large size of the files, all of the mosaicked imagery, habitat classification and kelp persistence products were delivered directly to Mr. Aaron McGregor of the California Ocean Science Trust (OST) on a portable hard drive with the intent to make as much of the data available via the OceanSpaces.org server as is possible given the capabilities of the site. The intertidal and kelp raster image files were delivered in GeoTIFF (.tif) format. The habitat classifications for both the intertidal zones and kelp beds were delivered as both GeoTIFF (.tif) raster images and ESRI Shapefiles. The kelp persistence and intertidal change detection maps were delivered as GeoTIFF (.tif) and ESRI Shapefiles files. Adobe acrobat (.PDF) files showing the multispectral imagery, habitat classifications, kelp persistence and change detection analyses were also generated for each OI-Aerial subregion, and in some cases, even smaller subsections, with the intent to provide higher detail representations of the data products suitable for the capabilities of the OceanSpaces server. At the time of this report no mechanism was in place for the direct upload of these files to OceanSpaces.org, so the PDF files

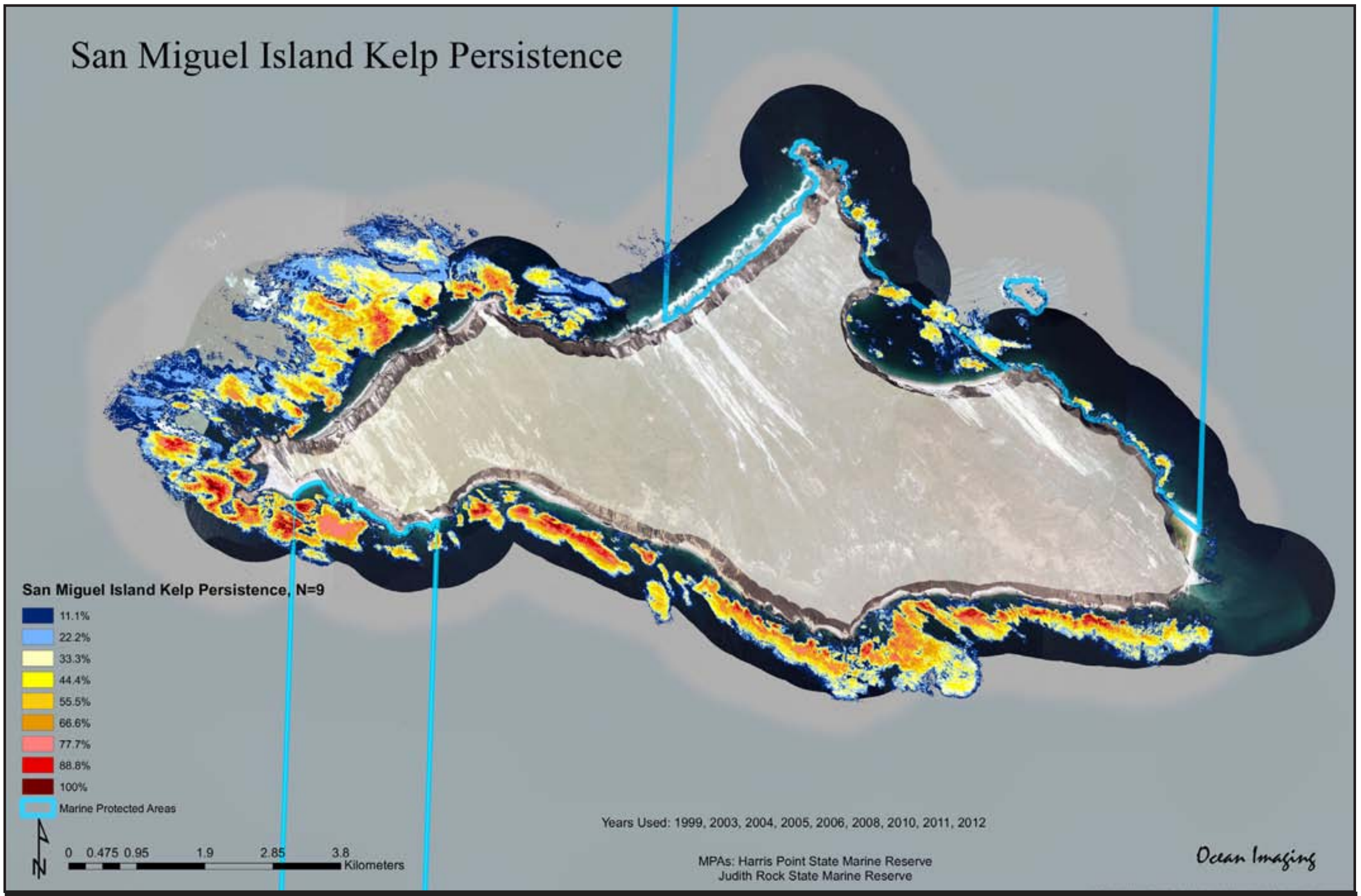


Figure 12.

Sample kelp persistence analysis of the San Miguel OI-Aerial subregion. Note the lower persistence levels in the offshore kelp beds as opposed to the beds closer to shore.

were included on the delivered hard drive. Due to the extremely large size of the image data files the 30 cm multispectral imagery was not included on the delivered media. OI will, however, maintain these data and deliver to the OST or any other authorized requesting party, if requested, in the future. OI will also work closely with Mr. McGregor and the OST to ensure the availability of all the OI deliverables to any authorized requesting party.

All of the imagery and data products were delivered with associated metadata files in Federal Geographic Data Committee (FDGC) formatted .xml files. PDF versions of the metadata files were also included so as to offer metadata in a format conducive to the OceanSpaces environment. **Appendix 2** provides a sample metadata file.

4. Partnerships

Two data sharing partnerships were formed between OI and other SCR investigators. First, following the initial processing of the UCX multispectral imagery, priority was placed on sub-sectioning mosaics of areas requested by a few of the SCR Principal Investigators (PIs) in order to deliver the imagery covering locations in selected MPAs to them as soon after data collection as was possible. Specifically, Dr. Kevin Hovel of SDSU and Rani Gaddam of UCSC requested smaller image mosaics of several areas relevant to their research and SCR projects. In order to keep the data files to a manageable size, imagery were generated covering roughly a 2 kilometer radius surrounding each of the locations requested by the PIs. Areas of interest

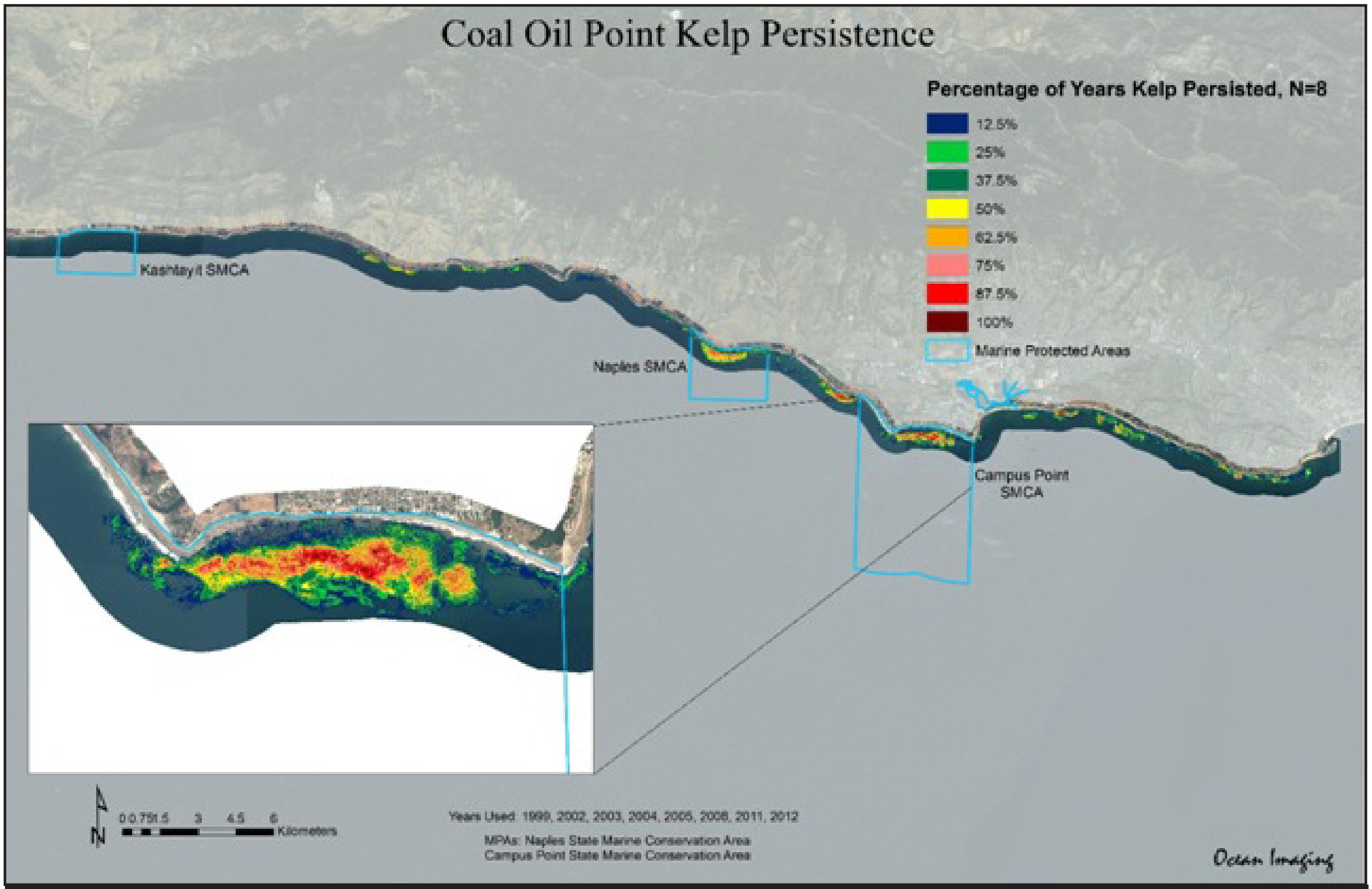


Figure 13.

Kelp persistence analysis of the Coal Oil Point OI-Aerial subregion, showing higher persistence within the Campus Point SMCA and Naples SMCA compared to surrounding kelp beds.

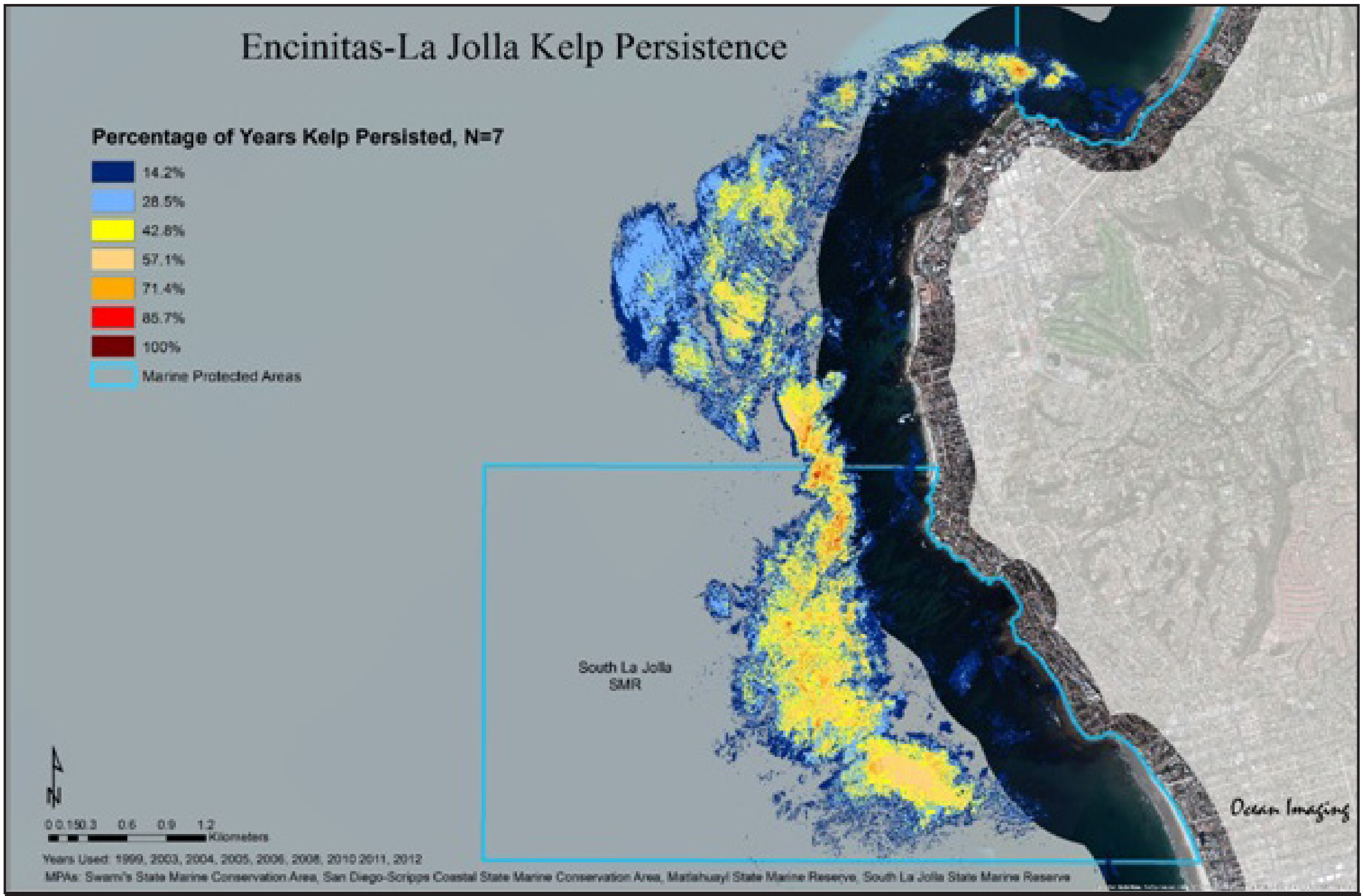


Figure 14.

Kelp persistence analysis of the southern end of the Encinitas-La Jolla OI-Aerial subregion, showing higher persistence within the South La Jolla SMR compared to beds north of the MPA.

(AOI) were prioritized by the requesting PI so as not to over task Ocean Imaging (OI), however OI was able to process and deliver custom imagery for all of the locations for which data were acquired (a few requested areas were even outside of the geographical scope included in this project). **Figure 17** shows the locations of areas for which custom image mosaics were created, colorized by priority level. **Figure 18** shows a sample of these smaller mosaic products. All of these data were shipped to the requesting PIs in early 2013.

Second, as explained above, the South Coast Baseline Project (SCBP) group was gracious enough to provide OI with an invaluable set of Biodiversity Point Contact Survey data from 31 sampling sites within the SCR. For this project we selected 17 of the South Coast Baseline Rocky Intertidal Biodiversity Survey sites to both aid in the creation of classification training sets and for the accuracy assessment described below. Each of the sites contained up to 1,100 biodiversity sampling points gridded inside survey bolts, which were located in the OI imagery and classifications using GPS locations. The field data were digitized as points in ArcGIS using the GPS locations of the survey site boundary bolts noted above and tied to geospatially accurate base maps matching the corresponding locations in the mosaicked, georectified imagery and classification rasters. The selection of the 17 sites was based on the field data sampling dates, the location as well as the grid/matrix set up of each site

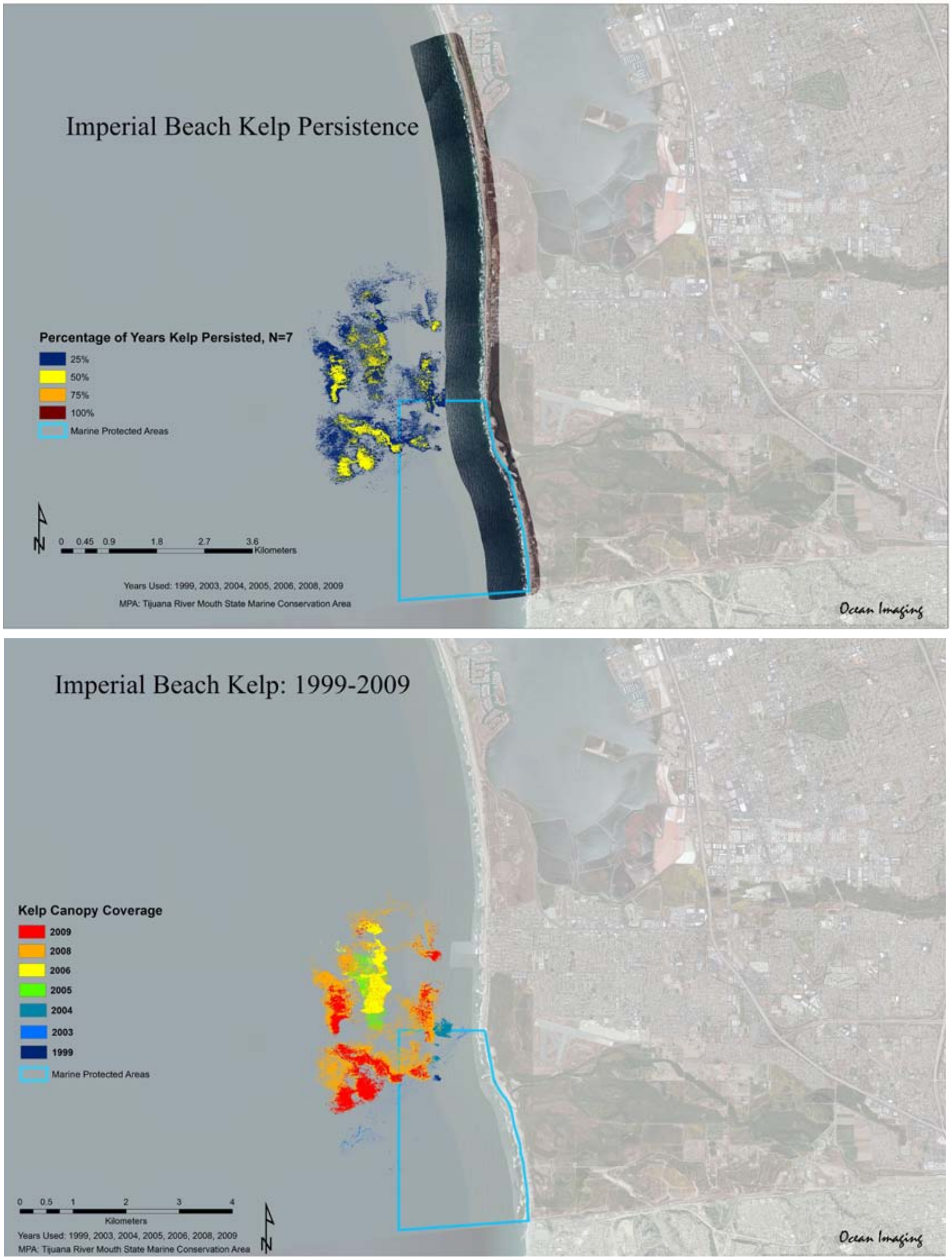


Figure 15.

Imperial Beach persistence analysis (top) shows only a small percentage of this kelp bed existing at a significant size for more than 50% years analyzed. Displaying the kelp coverage by individual year (bottom) reveals that the bed did exist for most of the years during the 10-year time span, but the core of the bed showed a high variability in location and size – with the majority of canopy coverage being outside of the Tijuana MPA.

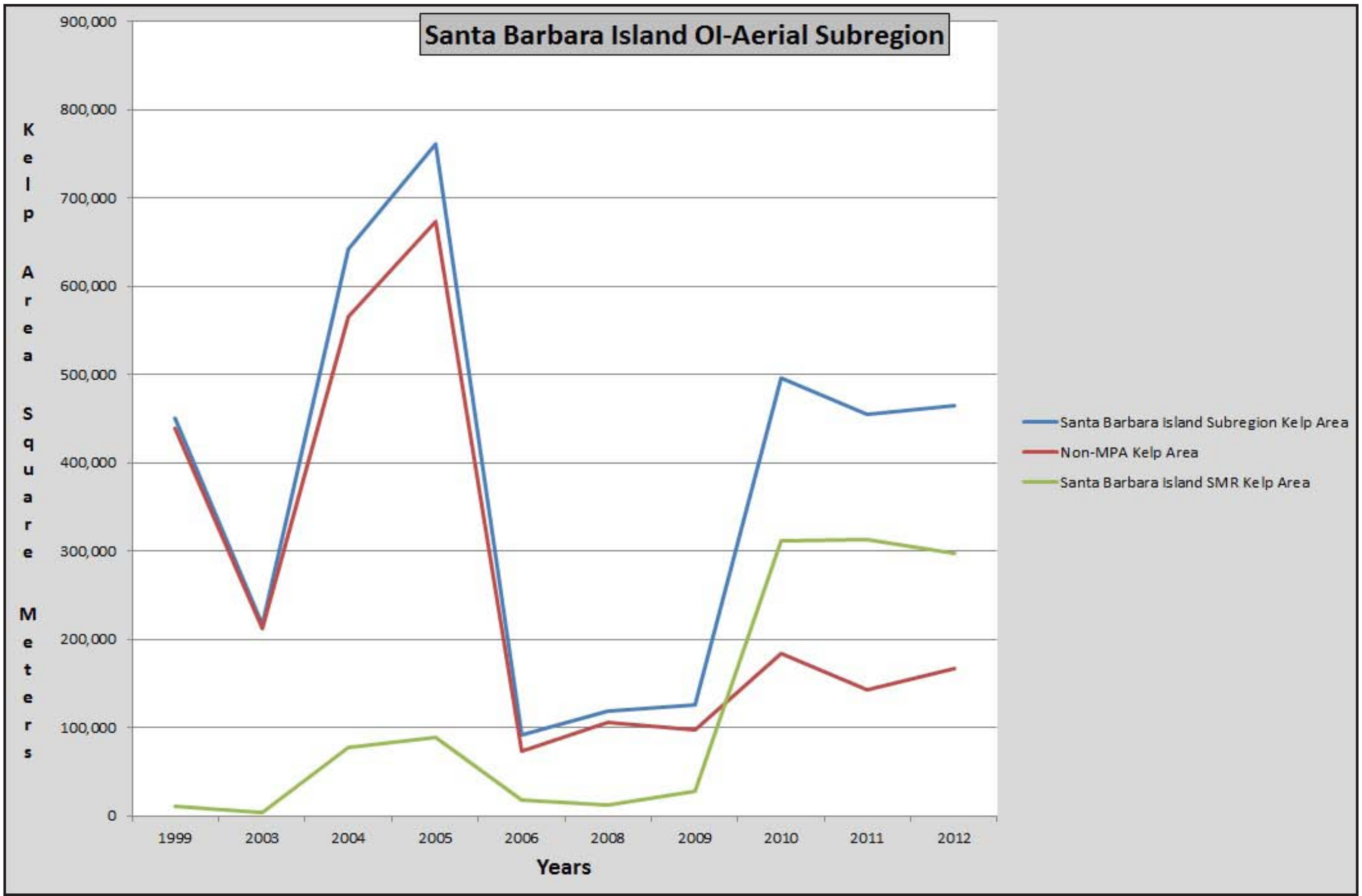


Figure 16.

Kelp area in square meters in the Santa Barbara Island OI-Aerial subregion. Note the significant increase in the area of kelp coverage within the Santa Barbara Island SMR after 2009. Plots of all of the other OI-Aerial subregions are in Appendix 1.

and how the transects overlaid on the classification data. This resulted in over 18,000 points available for use in training the classification algorithms and for the accuracy assessment. Roughly half of the survey data (approximately 8,450 points) were set aside for the accuracy assessment work. The other half were used to guide the classification training sets. The field data were spatially compared to the image-derived classes. The comparison results were then used to re-train the classifications to produce a more accurate product. Since the biodiversity survey points were much more specific in their identification of the substrate or vegetation type, the names/classes were grouped to match the equivalent class in the remote sensing-derived habitat classification. Next, over 8,450 of the biodiversity survey points selected were spatially joined in ArcGIS to the habitat classification raster for each survey site. This represented roughly half of the points for each site – the other half having been used in the classification process. Once the two databases were pared-down and joined via the methods discussed above, 4,671 data point pairs were entered into the Congalton matrix to show the accuracy of the reference data to the image-derived classifications. Having a limited number of OI-collected photographs and field samples compared to the 4,671 field sample points provided by the South Coast Rocky Intertidal Baseline Project offered both a unique and extremely valuable dataset to aid in the assessment of the OI-Aerial habitat classification products.

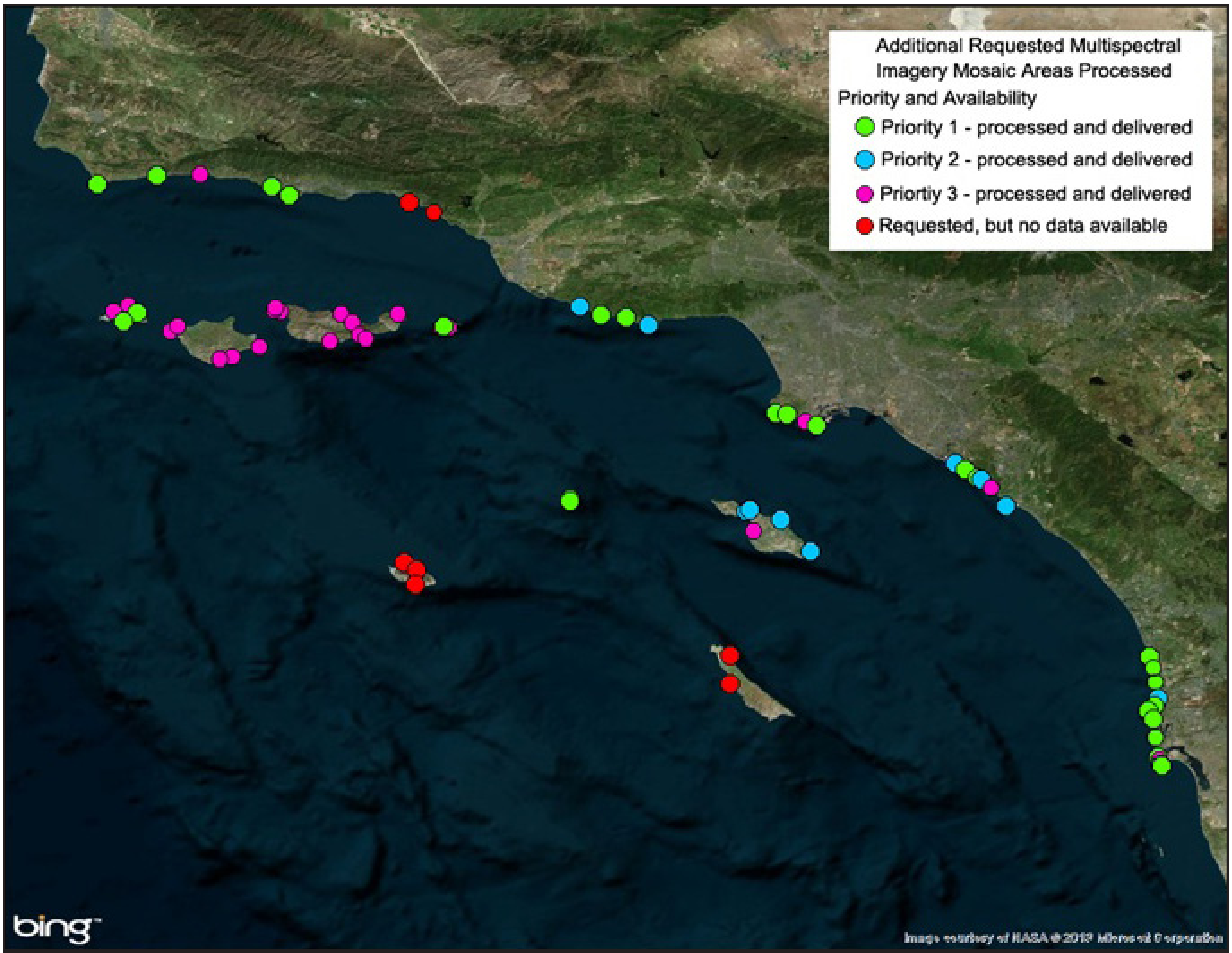


Figure 17.

Locations for which smaller, custom image mosaics were created for SCR partner PIs. The requested locations were prioritized by the requesting PI (shown as different colors above). OI was able to process and deliver imagery for nearly all of the requested locations.

5. Financial Discussion

The project was completed within the proposed budget. As stated above, the originally proposed work plan included the use of Ocean Imaging's (OI's) DMSC-MkII aerial system for these image data acquisitions. However, OI made the decision to utilize the Microsoft UltraCamX aerial sensor instead - albeit at a higher acquisition cost. OI took advantage of this opportunity and financed the increased cost (approximately $16,000). As is described above, the addition of the LiDAR and biodiversity field datasets required significant additional processing labor which was not planned for in the original proposal. While both of these datasets proved valuable towards delivering the most accurate classification products possible, an internal rebudget from the project's second into third year was done to shift the cost of an originally proposed (but cancelled) field data trip to the Channel Islands into labor categories commensurate with the additional processing and analysis load.

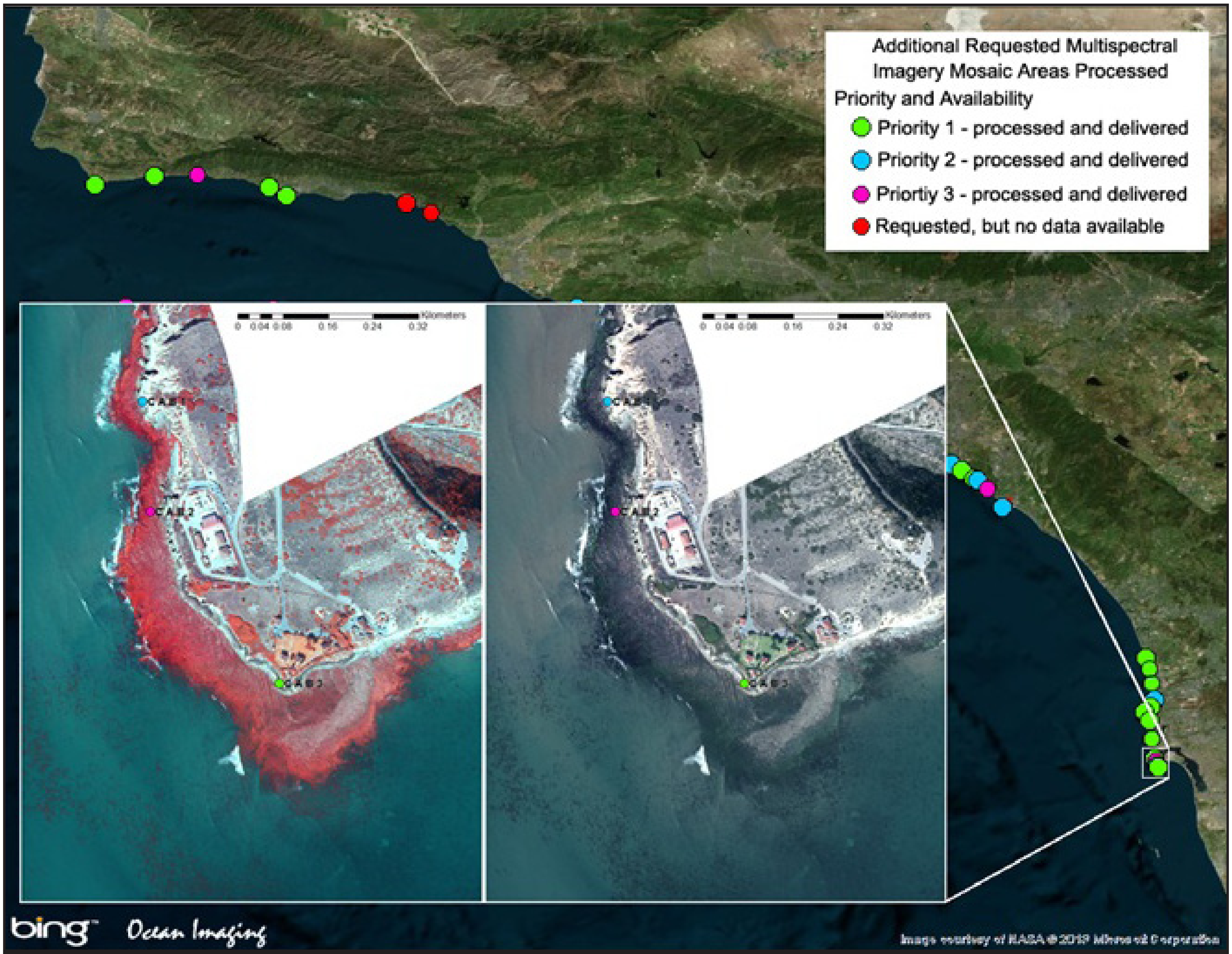


Figure 18.

RGB and NIR-RGB image sample of small image mosaic covering a requested location in the Point Loma, CA OI-Aerial subregion.

6. References

Abbott, I.A. & Hollenberg, G.J. (1976). Marine algae of California. pp. [i]-xii, 1-827, 701 figs. Stanford, California: Stanford University Press.

Congalton, R. 2001. Accuracy assessment and validation of remotely sensed and other spatial information. The International Journal of Wildland Fire. Vol 10. pp. 321-328.

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ESRI 2011, ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

http://abuzadan.staff.uns.ac.id/files/2012/05/Supervised-classification-Using-ArcGIS-10.pdf

http://resources.arcgis.com/en/help/main/10.1/index.html#/How_Maximum_Likelihood_Classification_works/009z000000q9000000/

http://resources.arcgis.com/en/help/main/10.1/index.html#/How_Iso_Cluster_works/009z000000q8000000/

http://oceanspaces.org/monitoring/regions/south-coast/collecting-data#baseline

http://www.eeb.ucsc.edu/pacificrockyintertidal/methods/index.html#bio-method

Appendix 1 - Kelp Persistence Analyses Yearly Kelp Canopy Coverage

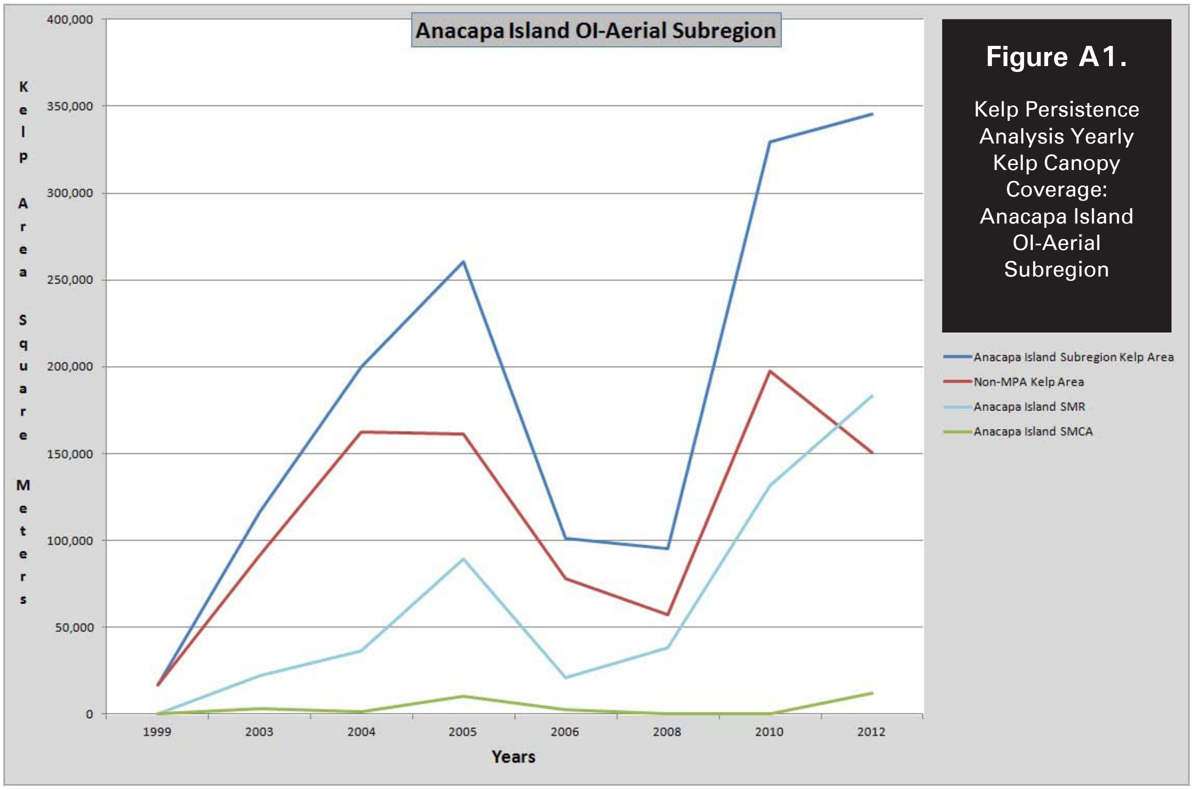

Figure A1.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Anacapa Island OI-Aerial Subregion

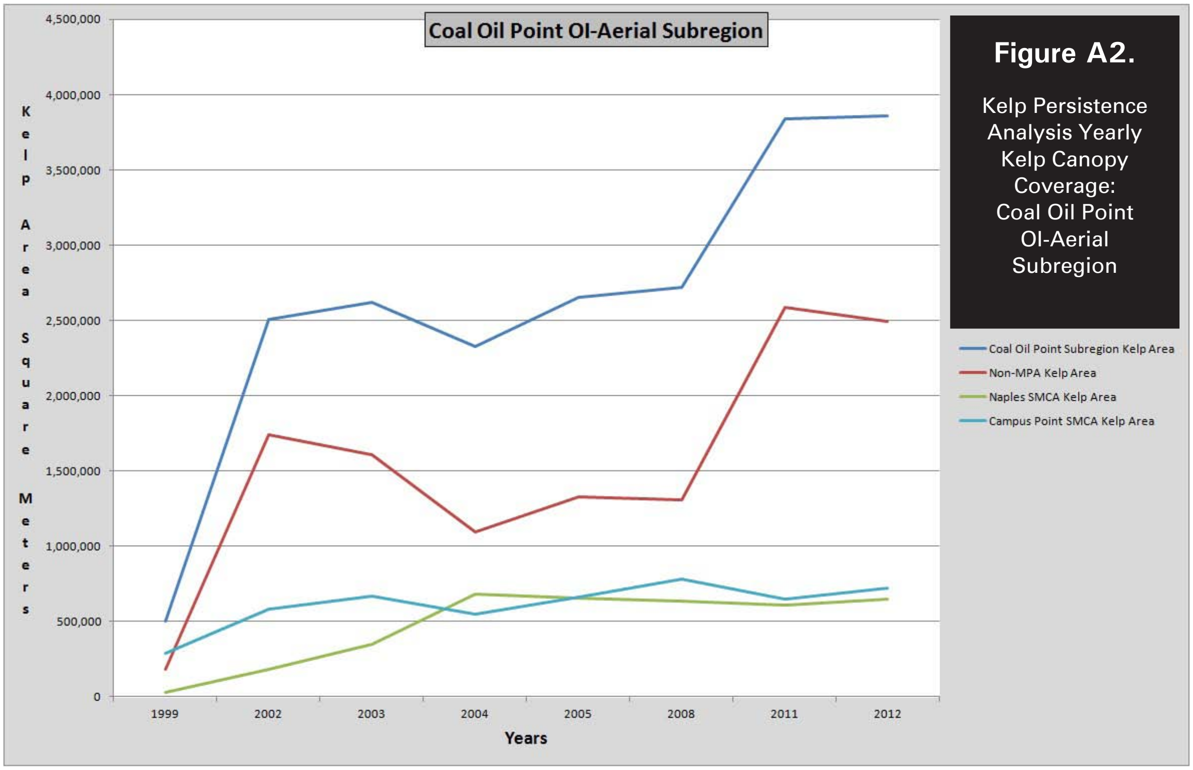

Figure A2.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Coal Oil Point OI-Aerial Subregion

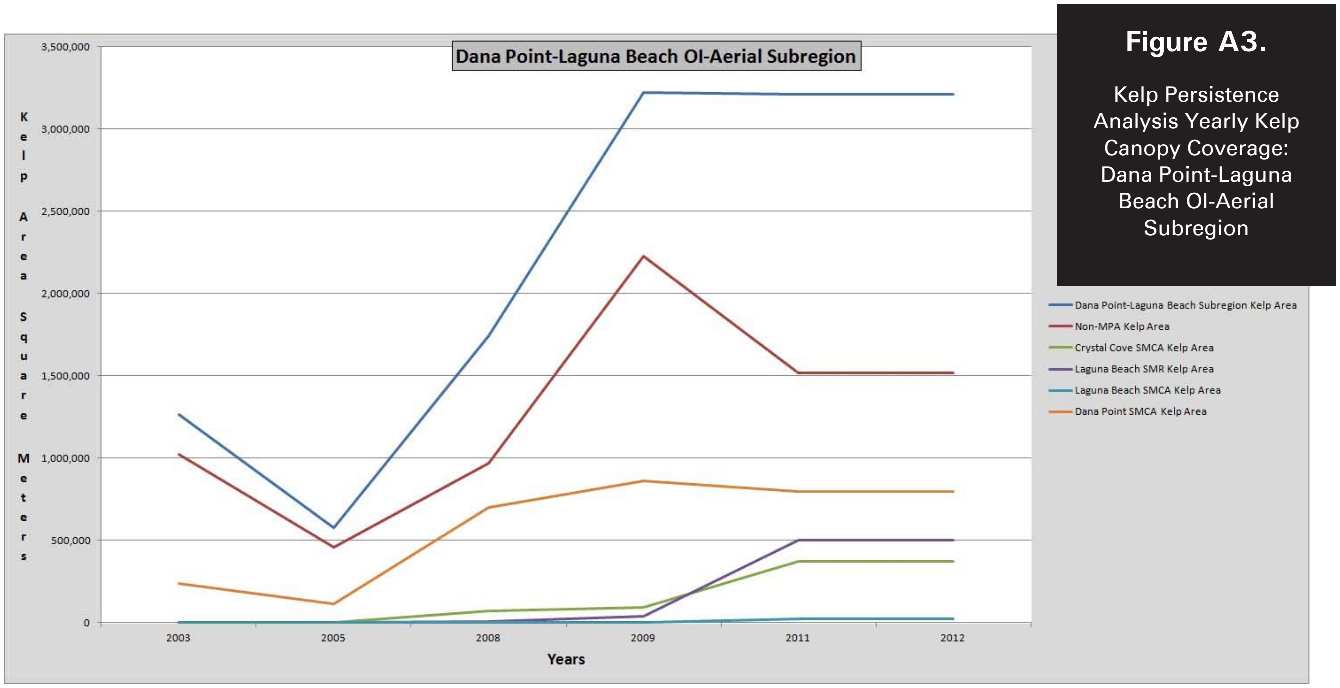

Figure A3.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Dana Point-Laguna Beach OI-Aerial Subregion

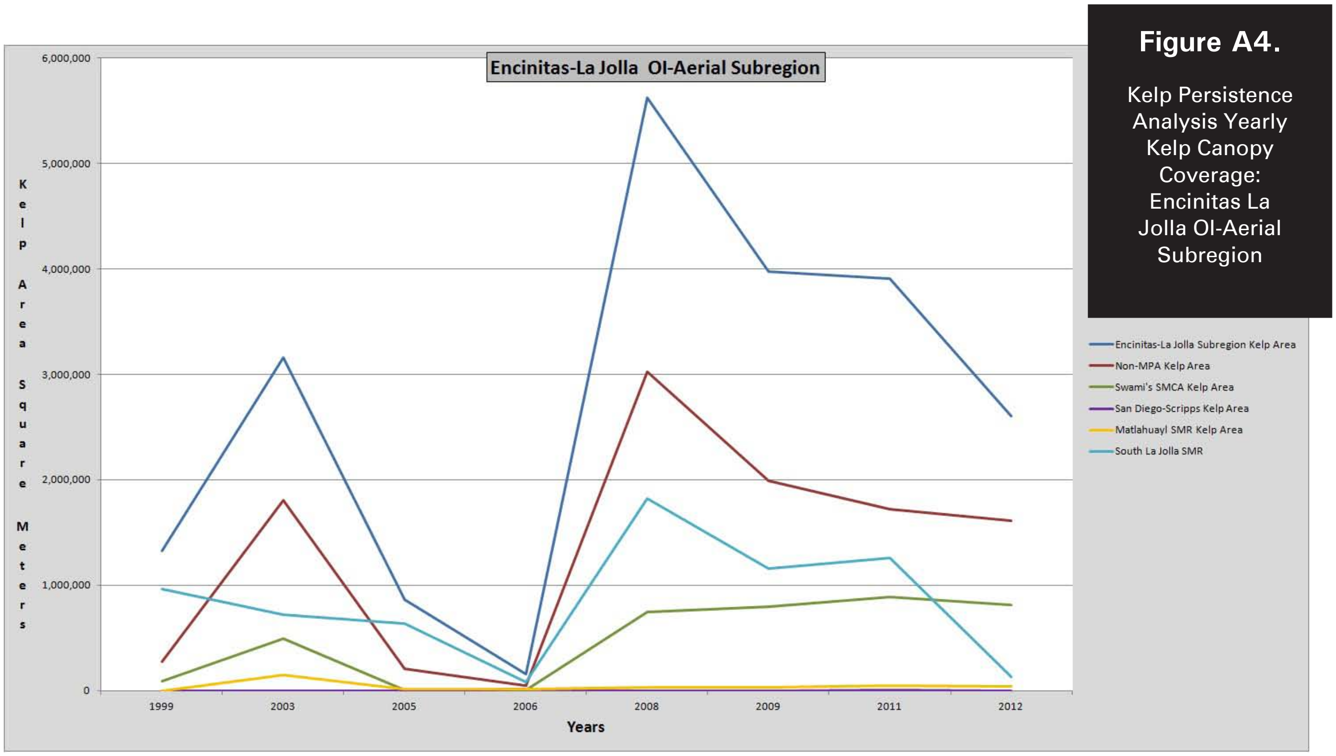

Figure A4.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Encinitas La Jolla OI-Aerial Subregion

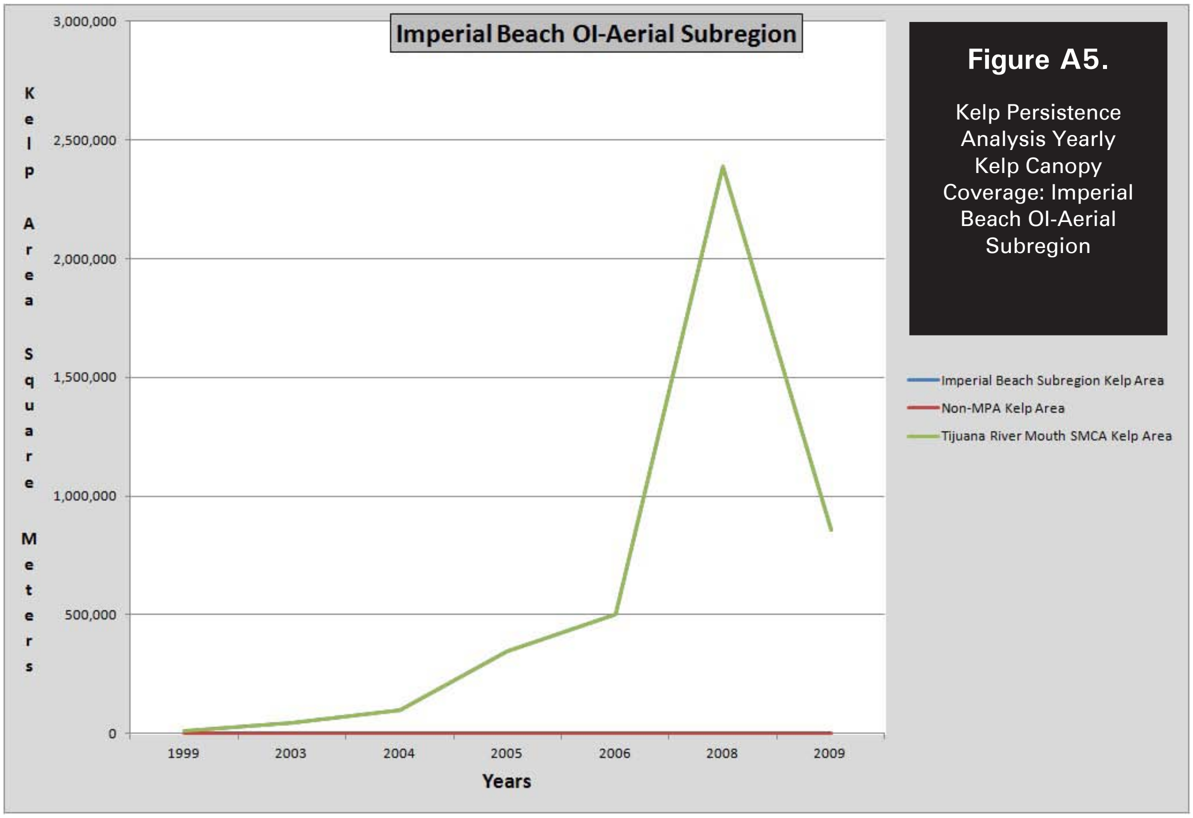

Figure A5.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Imperial Beach OI-Aerial Subregion

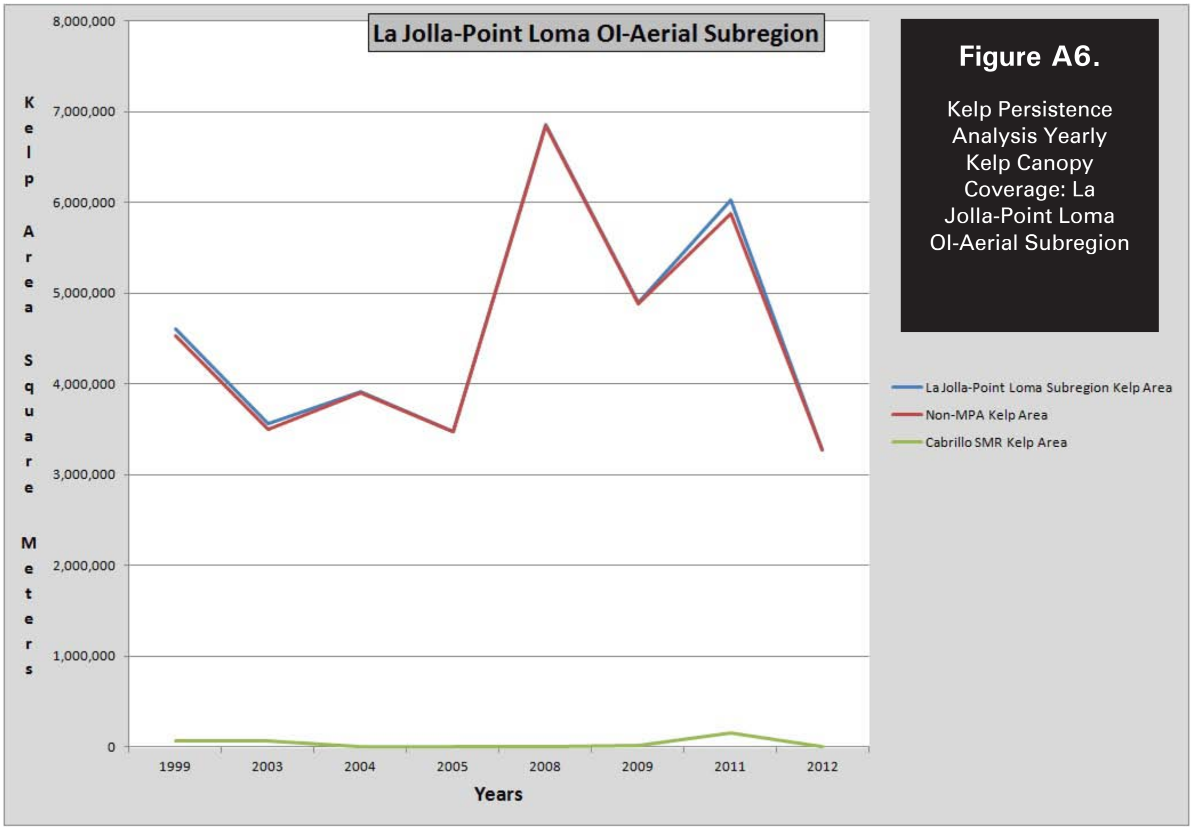

Figure A6.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: La Jolla-Point Loma OI-Aerial Subregion

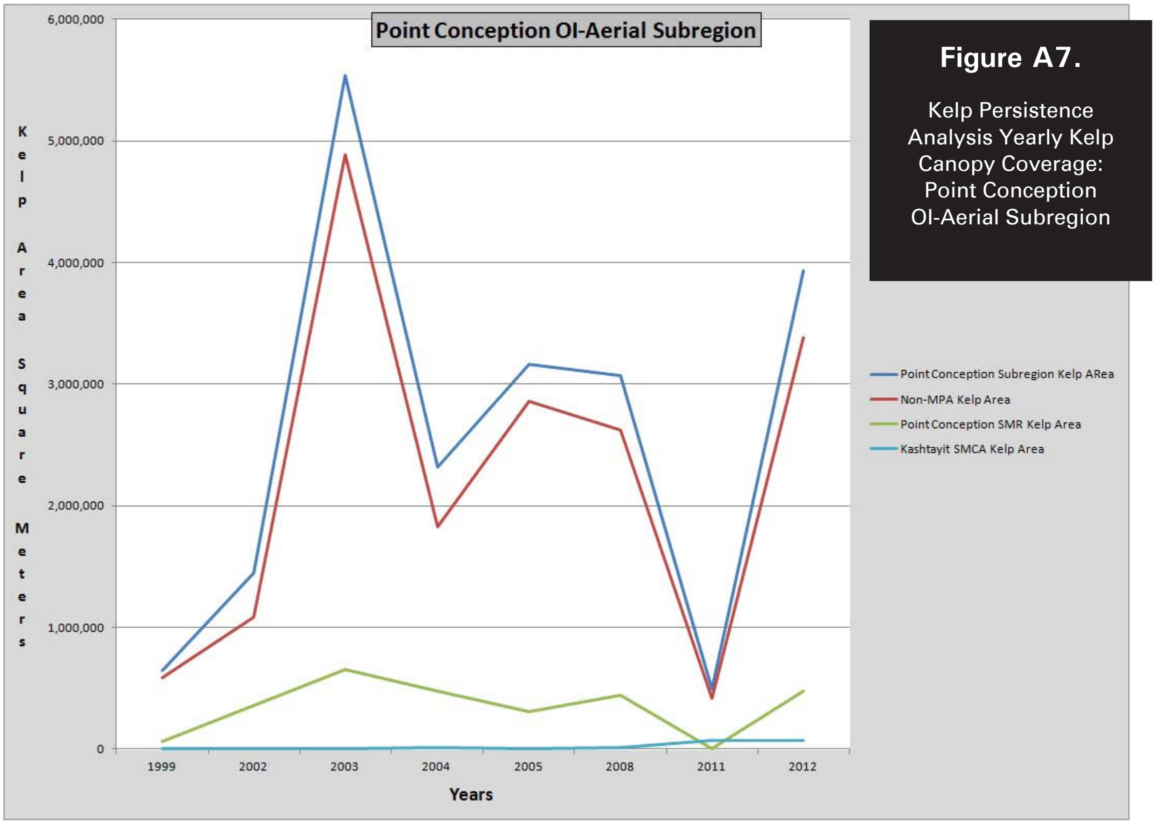

Figure A7.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Point Conception OI-Aerial Subregion

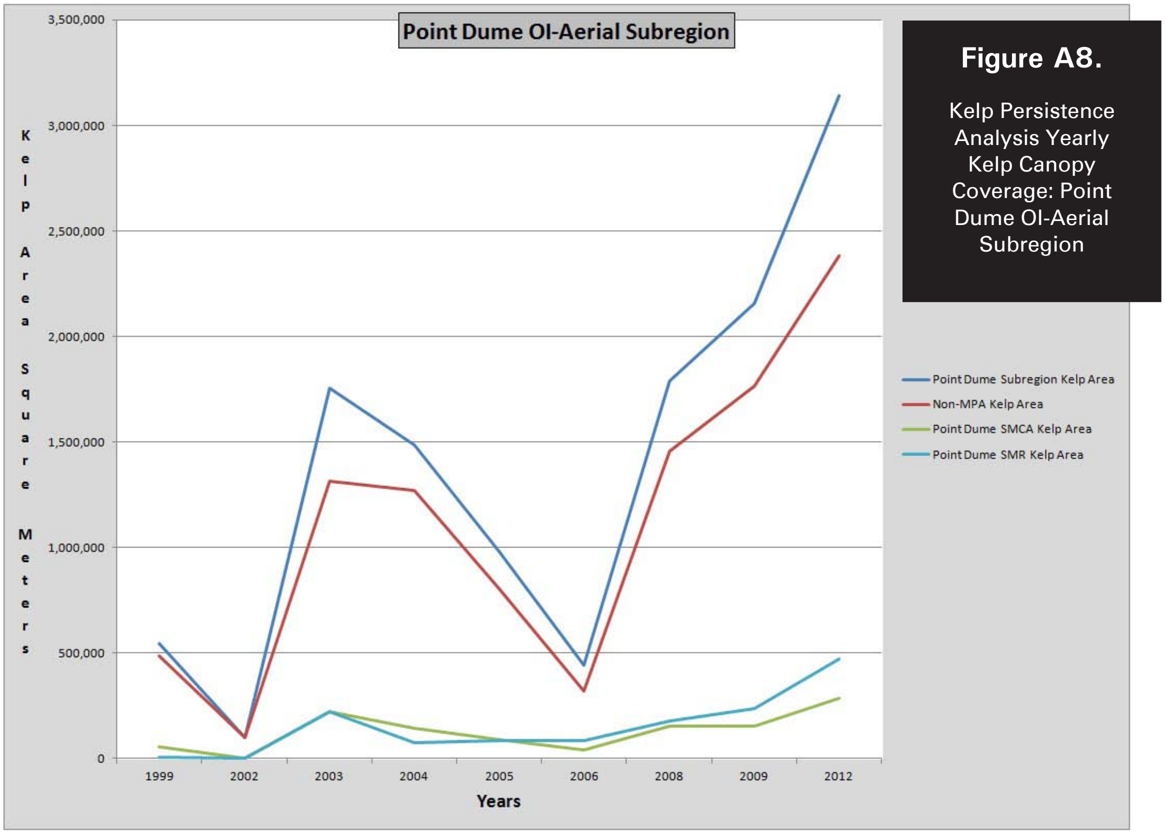

Figure A8.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Point Dume OI-Aerial Subregion

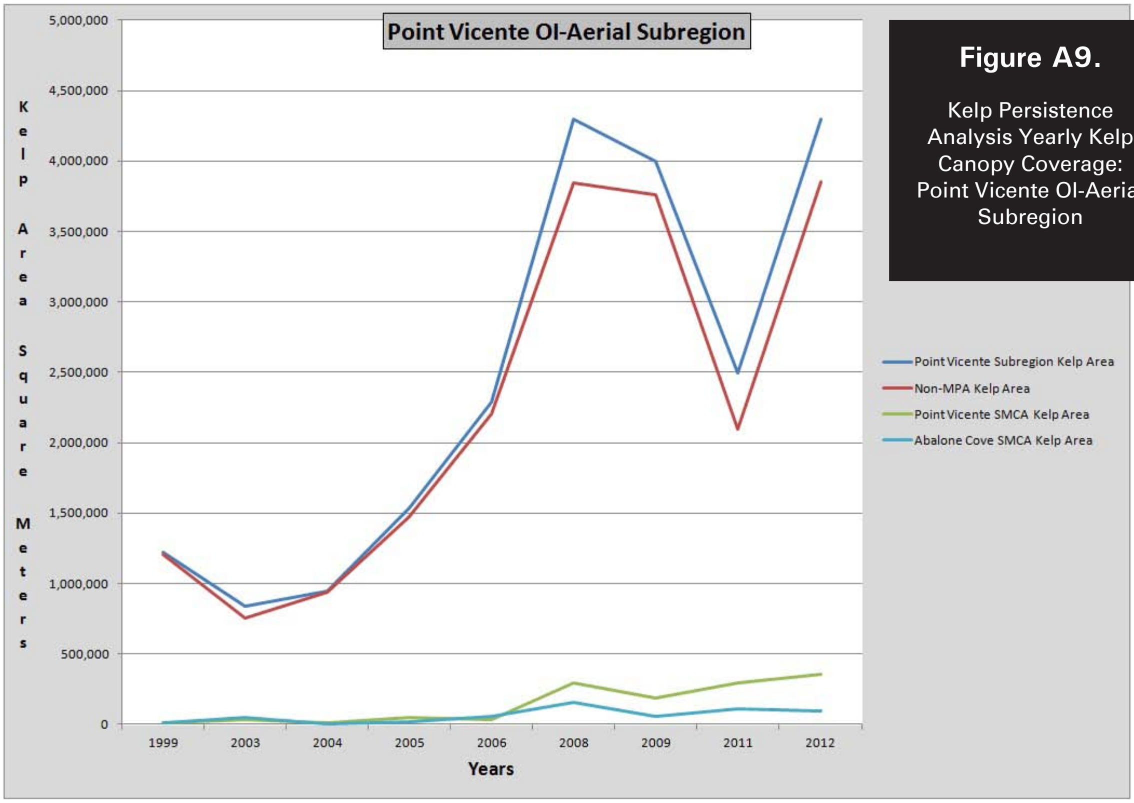

Figure A9.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Point Vicente OI-Aerial Subregion

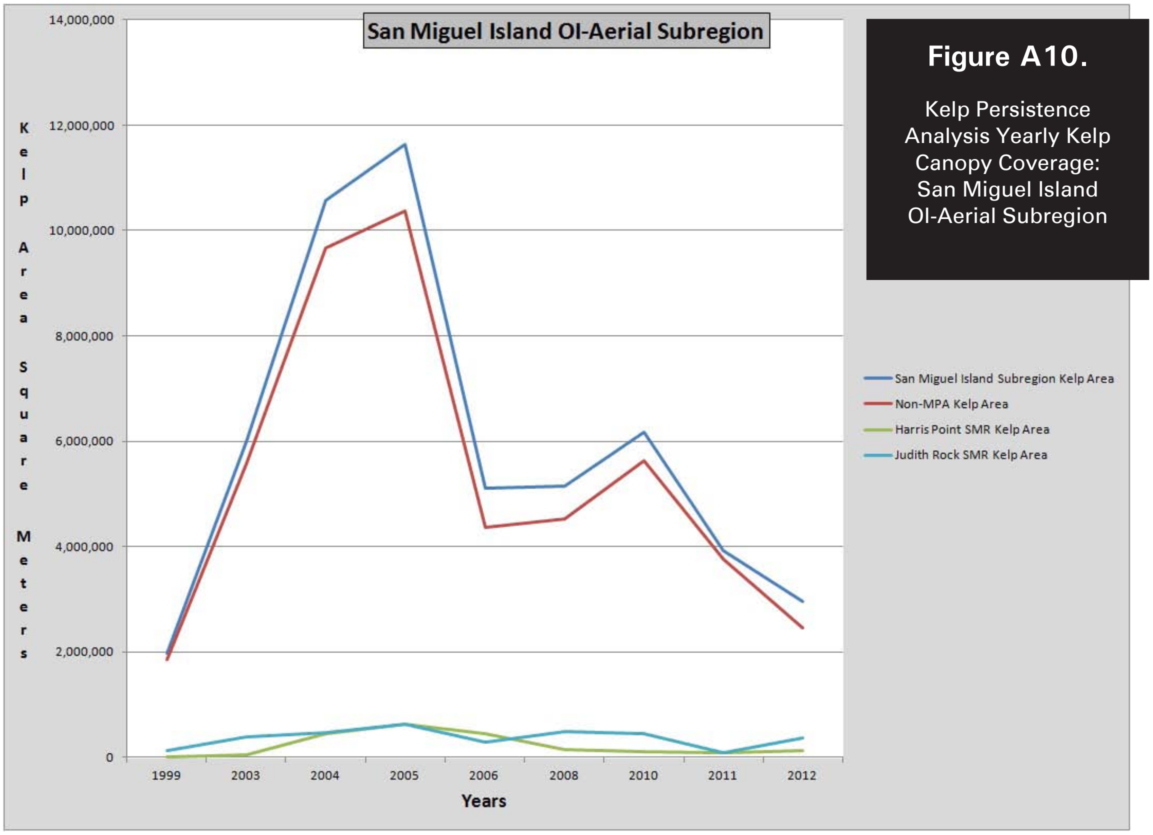

Figure A10.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: San Miguel Island OI-Aerial Subregion

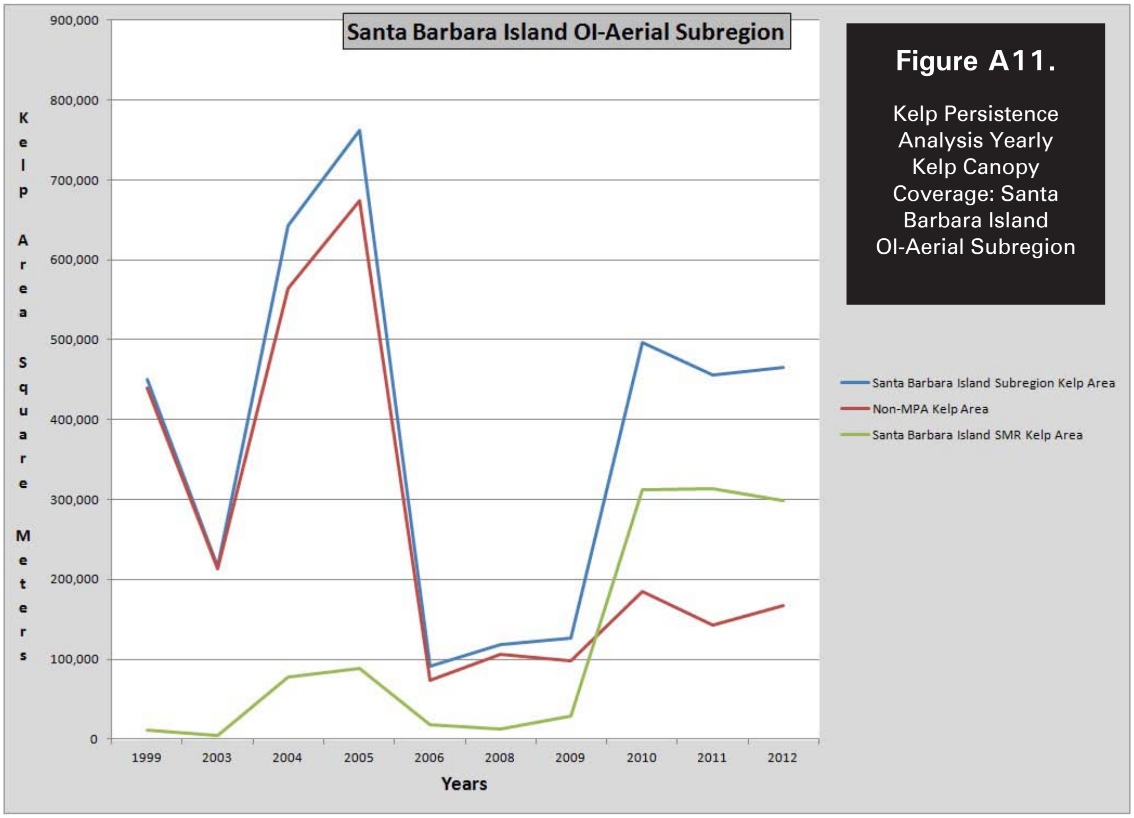

Figure A11.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Barbara Island OI-Aerial Subregion

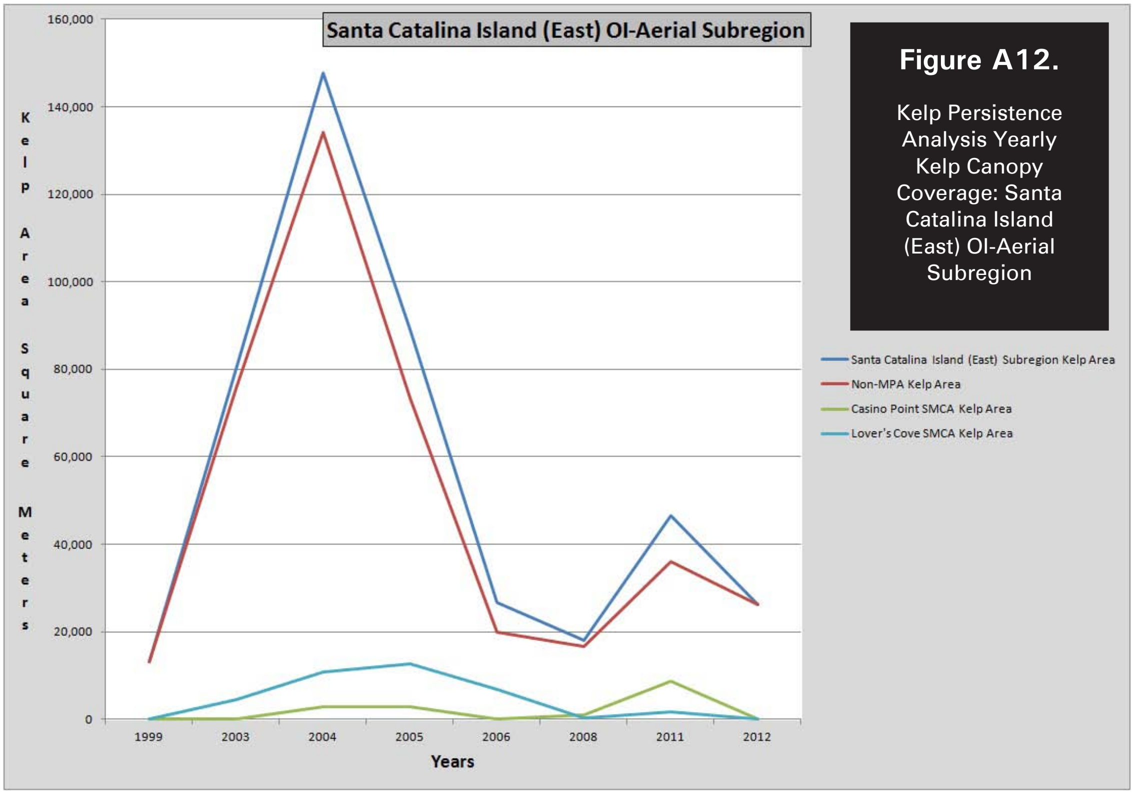

Figure A12.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Catalina Island (East) OI-Aerial Subregion

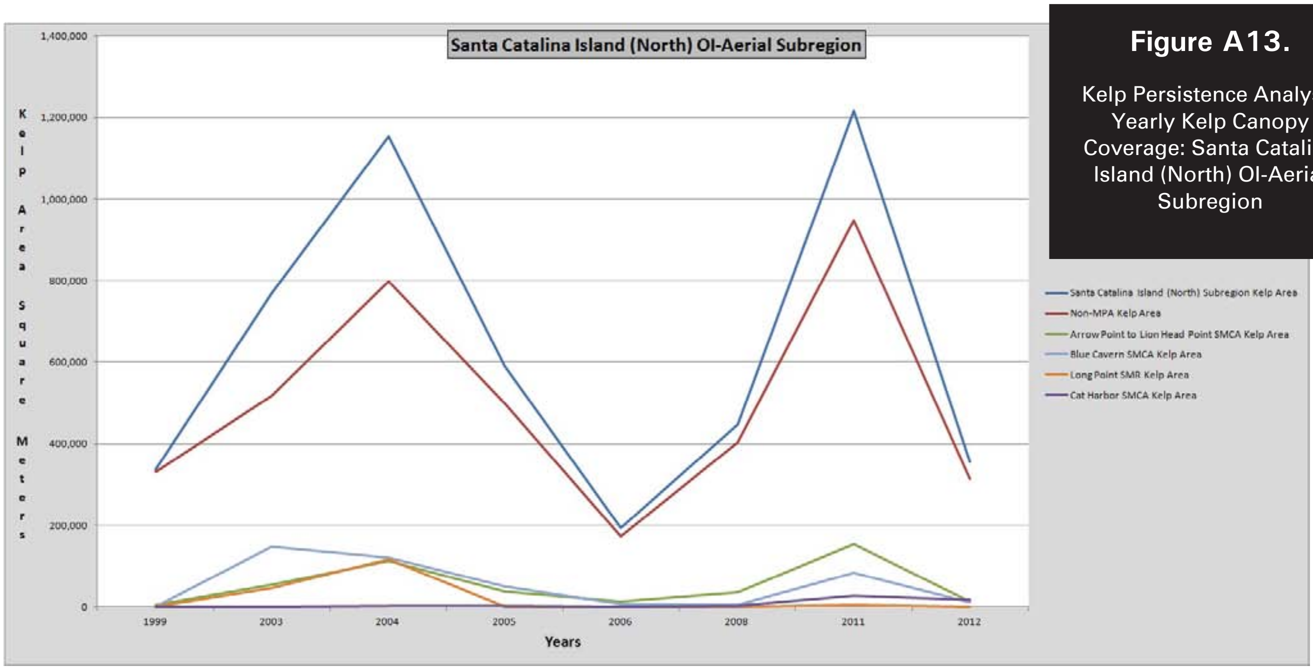

Figure A13.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Catalina Island (North) OI-Aerial Subregion

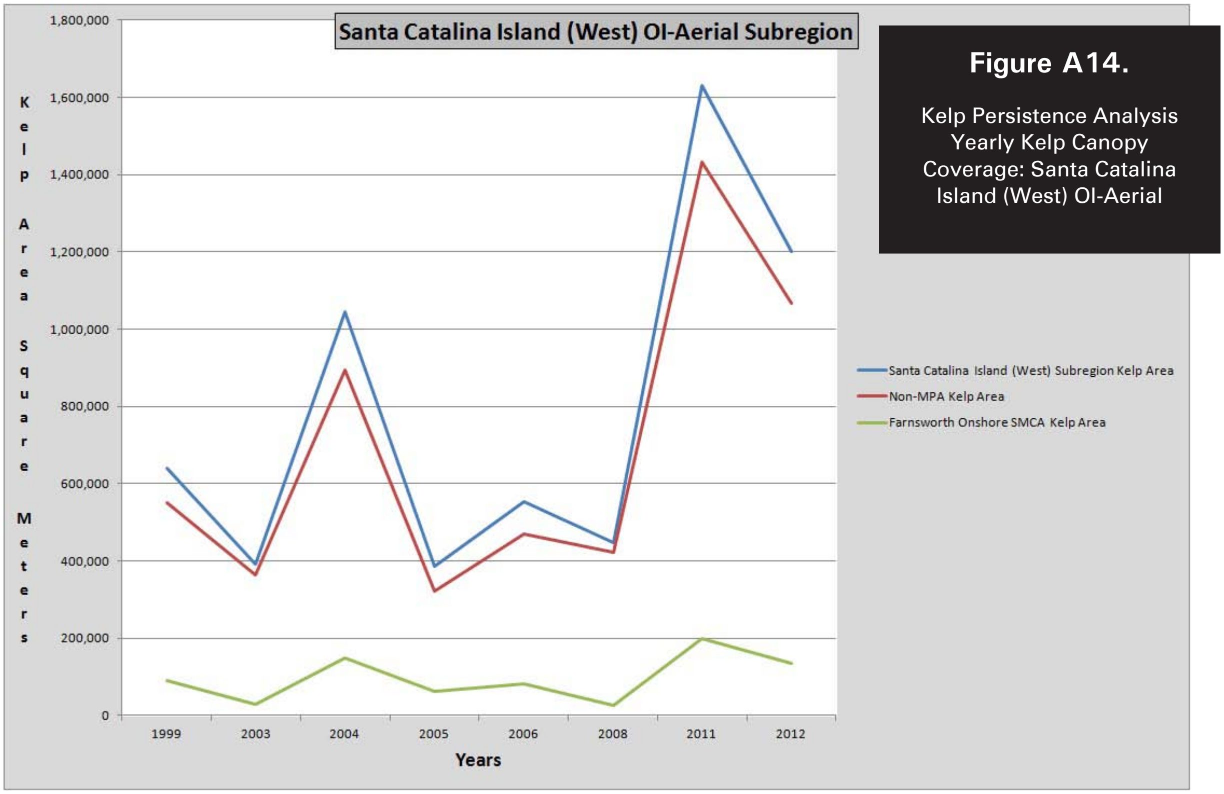

Figure A14.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Catalina Island (West) OI-Aerial

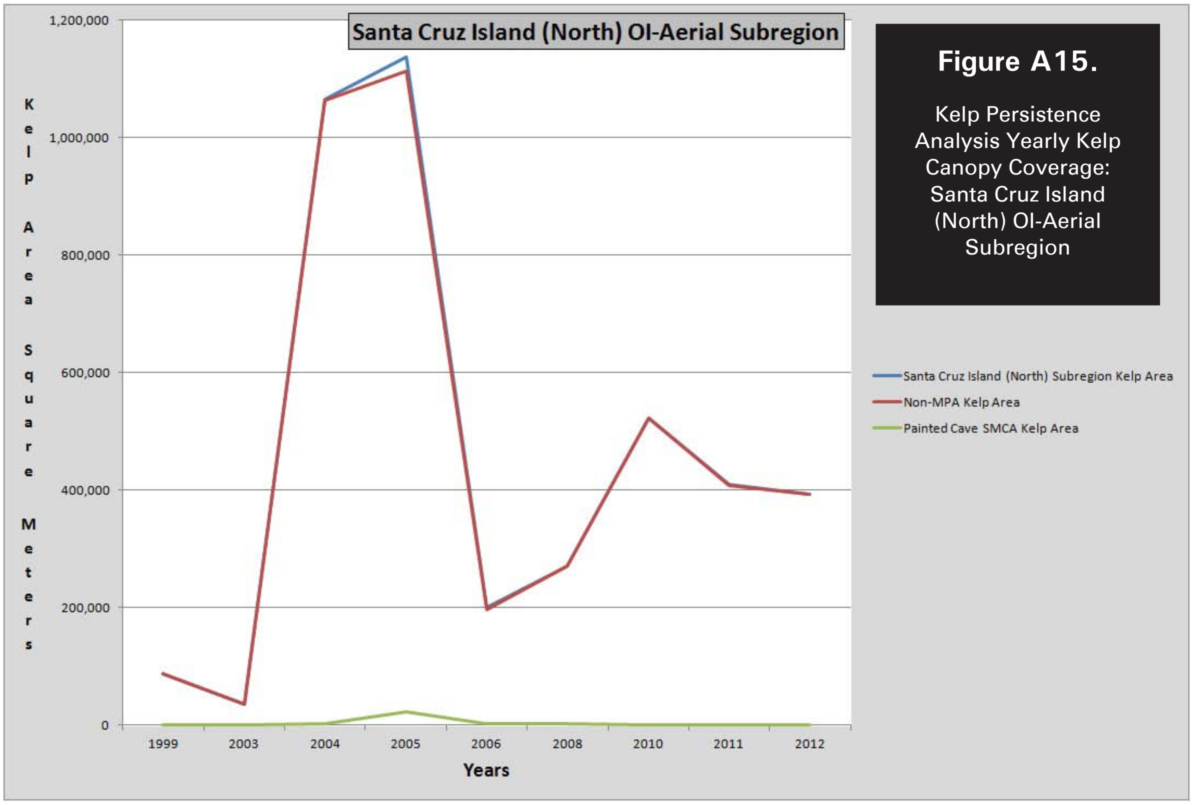

Figure A15.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Cruz Island (North) OI-Aerial Subregion

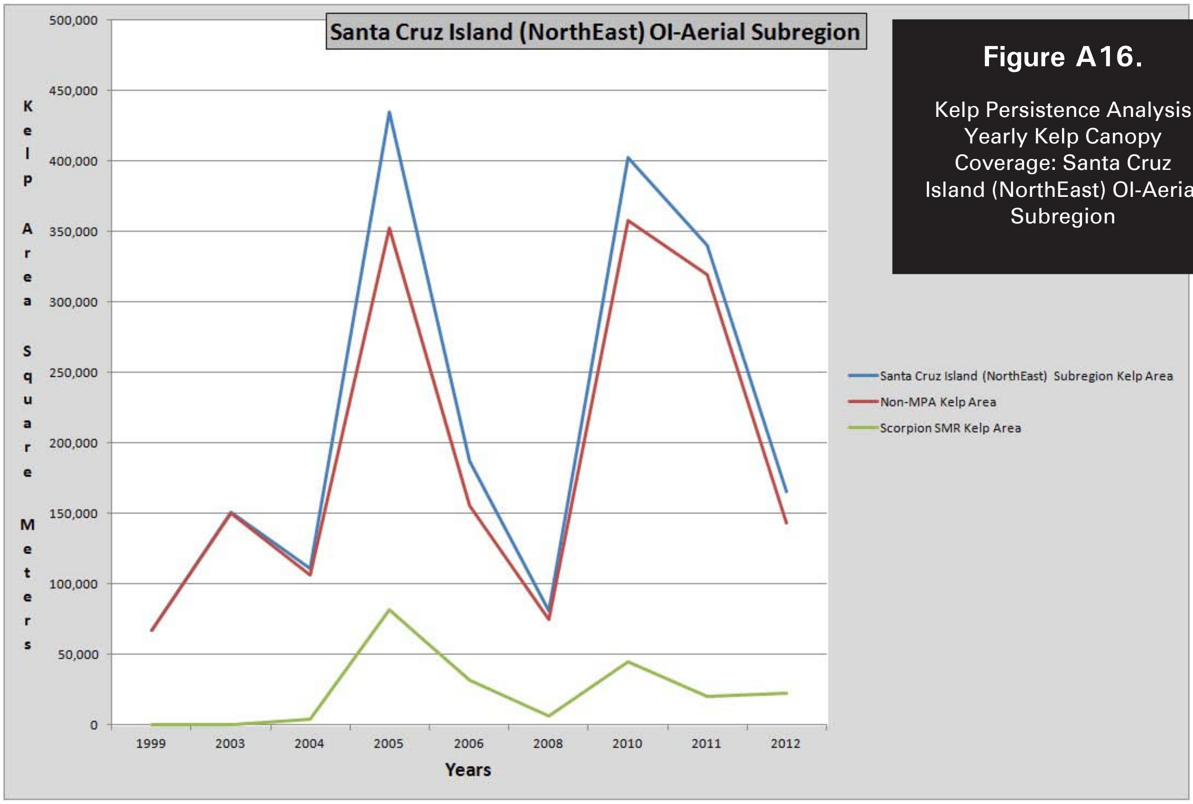

Figure A16.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Cruz Island (NorthEast) OI-Aerial Subregion

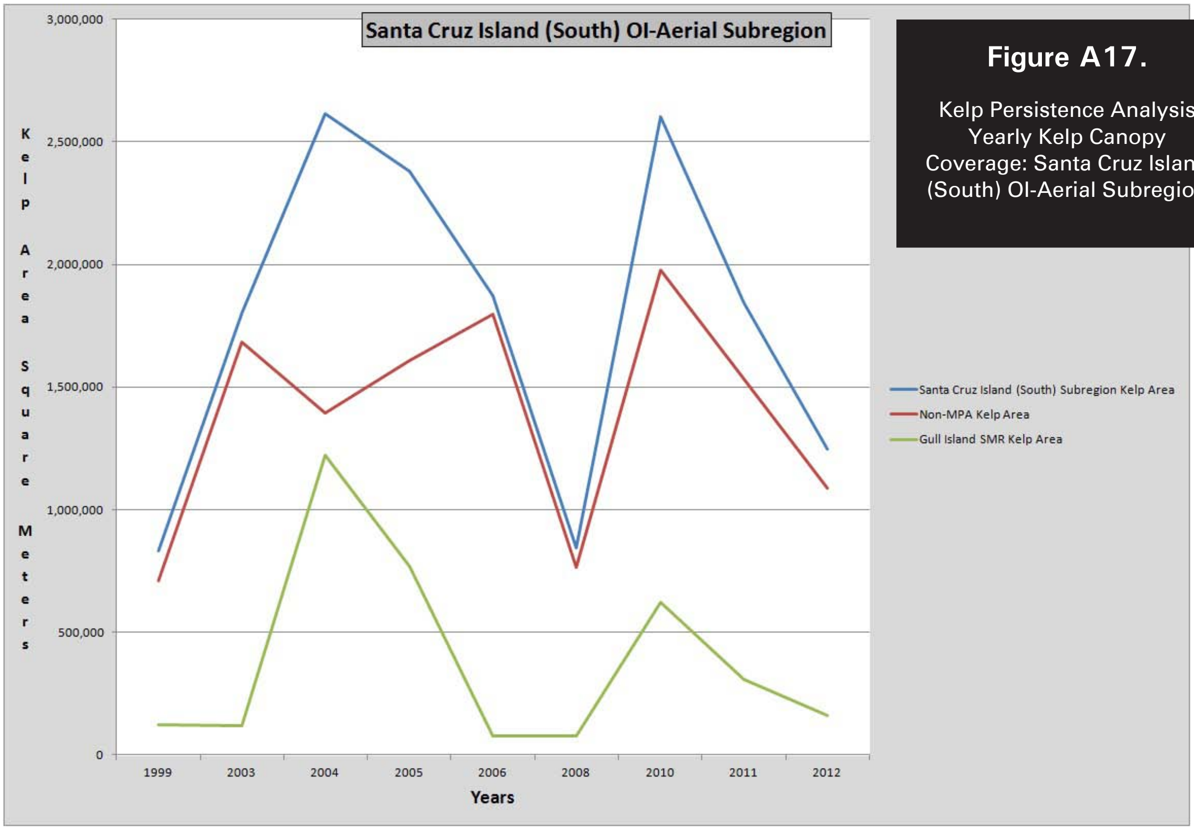

Figure A17.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Cruz Island (South) OI-Aerial Subregion

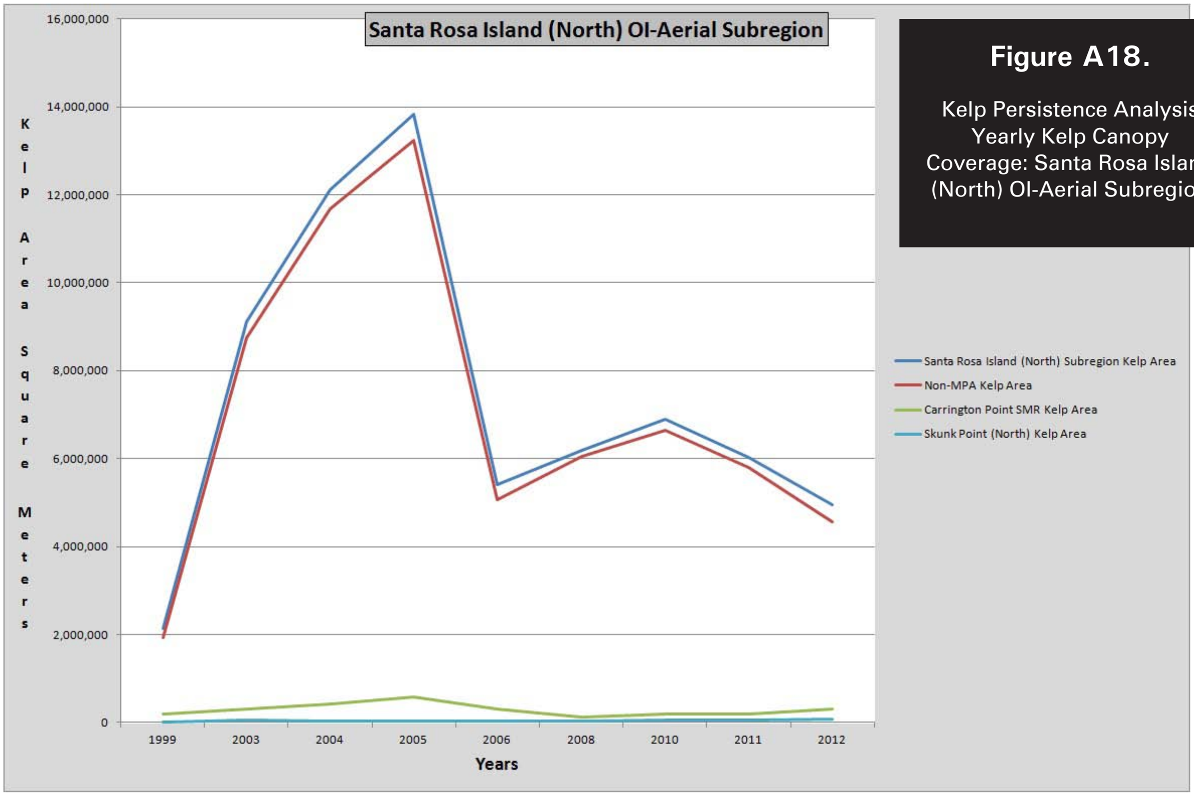

Figure A18.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Rosa Island (North) OI-Aerial Subregion

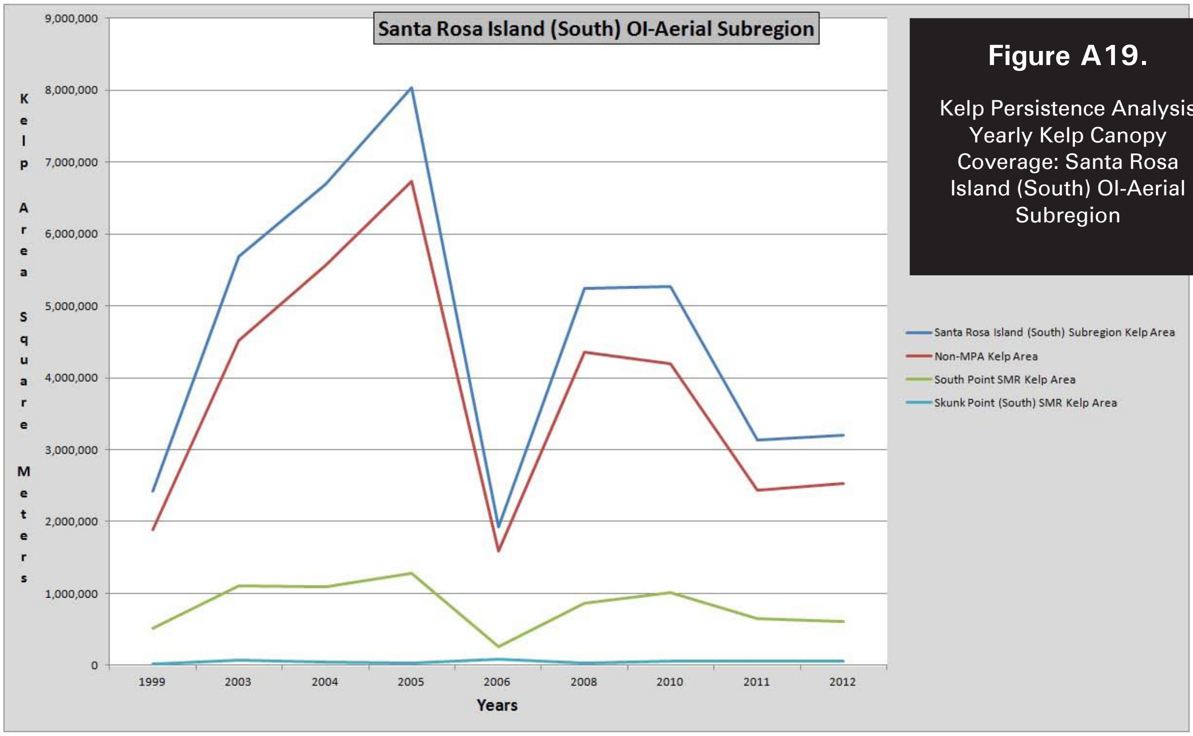

Figure A19.

Kelp Persistence Analysis Yearly Kelp Canopy Coverage: Santa Rosa Island (South) OI-Aerial Subregion

Appendix II - Deliverables' Metadata

SCR_Aerial_PointVicente_06252012_IntClass.tif

Raster Dataset

Thumbnail Not Available

Tags

California, MPA, SMCA, SMR, intertidal, Microsoft UltrCam-X, biota, Ocean Imaging, oceans, MPA Baseline Program, Sea Grant, South Coast, substrate, wetlands, multispectral imagery, imagery, base maps, Earth cover, kelp, habitat classification, environment

Summary

This raster dataset was developed for the Sea Grant South Coast MPA Baseline Program as part of the project "Nearshore Substrate Mapping and Change Analysis using Historical and Concurrent Multispectral Imagery" (#R/MPA 30 10-049). The study region is the South Coast Region (SCR). Imagery was acquired on June 25, 2012 at a spatial resolution of 0.3 meters using a Microsoft UltraCam-X digital camera acquiring in the red, green, blue and near-infrared bands. Information on the UltraCam-X camera system and wavelengths for each ban can be found in the file "The Microsoft Vexcel UltraCam X.pdf" included in the Support folder on the image data delivery media and on the OceanSpaces.org server. This image mosaic product is a result of the resampling of the 0.3 meter data to 1 meter GSD. Details on this system and the data processing are below in the Lineage section of this document. Individual UCX image tiles were mosaicked into sections based on the islands covered and local coastal regions as well as the SCR MPA zones in order to generate this multispectral image product. These imagery were subsequently used to generate habitat classification thematic maps of the SCR's intertidal region and kelp beds from Point Conception to Imperial Beach, CA. The imagery files deliverd are in GeoTIFF format. More information on the classes resolved and processing methods are in the Lineage section of this document.

Description

This raster dataset contains a habitat classification of either offshore giant kelp beds and/or the intertidal zone along the California South Coast Region (SCR) from from Point Conception, CA down to Imperial beach, CA. This specific raster classification includes the Point Vicente SMCA and the Abalone Cove SMCA.

Credits

There are no credits for this item.

Use limitations

TBD by Sea Grant or MPA Baseline Program Managers

Extent

West	-118.436024	**East**	-118.248165
North	33.842513	**South**	33.691349

Scale Range

Maximum (zoomed in)	1:5,000
Minimum (zoomed out)	1:150,000,000

ArcGIS Metadata ▶

Topics and Keywords ▶

THEMES OR CATEGORIES OF THE RESOURCE imageryBaseMapsEarthCover, environment, biota, oceans

* CONTENT TYPE Downloadable Data
EXPORT TO FGDC CSDGM XML FORMAT AS RESOURCE DESCRIPTION No

THEME KEYWORDS biota, oceans, imageryBaseMapsEarthCover, environment

Thesaurus ▶
Title ISO 19115 Topic Categories

Hide Thesaurus ▲

Theme keywords California, MPA, Intertidal, ADS40, Ocean Imaging, MPA Baseline Program, DMSC, Sea Grant, Substrate, Wetlands, Multispectral Imagery, Kelp, Habitat Classification

Hide Topics and Keywords ▲

Citation ▶

* Title SCR_Aerial_PointVicente_06252012_IntClass.tif

Presentation formats digital map
FGDC geospatial presentation format raster digital data

Hide Citation ▲

Citation Contacts ▶

Responsible party
Individual's name Mark Hess
Organization's name Ocean Imaging
Contact's role point of contact

Contact information ▶
Phone
Voice 303-948-5272
Fax 303-948-2549

Address
Type both
Delivery point 13976 W. Bowles Ave. Ste 100
City Littleton
Administrative area Colorado
Postal code 80127
Country US
e-mail address mhess@oceani.com

Hours of service
9:00 AM - 5:00 PM MST

Hide Contact information ▲

Hide Citation Contacts ▲

Resource Details ▶

Dataset languages English (UNITED STATES)
Dataset character set utf8 - 8 bit UCS Transfer Format

Spatial representation type * grid

* PROCESSING ENVIRONMENT Version 6.2 (Build 9200) ; Esri ArcGIS 10.2.1.3497

ARCGIS ITEM PROPERTIES
* NAME SCR_Aerial_PointVicente_06252012_IntClass.tif
* LOCATION file://G:\Projects\SeaGrant_SC\Deliverables\2012 Intertidal\Classifications\Rasters\SCR_Aerial_PointVicente_06252012_IntClass.tif
* ACCESS PROTOCOL Local Area Network

Hide Resource Details ▲

Extents ▶

EXTENT
DESCRIPTION
Anacap Island incuding the Anacapa Island SMCA and Anacapa Island SMR.

GEOGRAPHIC EXTENT
BOUNDING RECTANGLE
WEST LONGITUDE -123.229248
EAST LONGITUDE -123.124961
SOUTH LATITUDE 38.436021
NORTH LATITUDE 38.500191

EXTENT
GEOGRAPHIC EXTENT
BOUNDING RECTANGLE
EXTENT TYPE Extent used for searching
* WEST LONGITUDE -118.436024
* EAST LONGITUDE -118.248165
* NORTH LATITUDE 33.842513
* SOUTH LATITUDE 33.691349
* EXTENT CONTAINS THE RESOURCE Yes

EXTENT IN THE ITEM'S COORDINATE SYSTEM
* WEST LONGITUDE 367133.631040
* EAST LONGITUDE 384318.631040
* SOUTH LATITUDE 3728856.325000
* NORTH LATITUDE 3745397.325000
* EXTENT CONTAINS THE RESOURCE Yes

Hide Extents ▲

Resource Points of Contact ▶

POINT OF CONTACT
INDIVIDUAL'S NAME Mark Hess
ORGANIZATION'S NAME Ocean Imaging
CONTACT'S ROLE point of contact

CONTACT INFORMATION ▶
PHONE
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FAX 303-948-2549

ADDRESS
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City Littleton
Administrative area Colorado
Postal code 80127
Country US
e-mail address mhess@oceani.com

Hours of service
M-F 9:00 AM - 5:00 PM MST

Hide Contact information ▲

Point of contact
Individual's name Mark Hess
Organization's name Ocean Imaging
Contact's role point of contact

Contact information ▶
Phone
Voice 303-948-5272
Fax 303-948-2549

Address
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e-mail address mhess@oceani.com

Hours of service
M-F 9:00 AM - 5:00 PM MST

Hide Contact information ▲

Hide Resource Points of Contact ▲

Resource Maintenance ▶

Resource maintenance
Update frequency not planned

Maintenance contact
Individual's name Mark Hess
Organization's name Ocean Imaging
Contact's role point of contact

Contact information ▶
Phone
Voice 303-948-5272
Fax 303-948-2549

ADDRESS
TYPE both
DELIVERY POINT 13976 W. Bowles Ave. Ste 100
CITY Littleton
ADMINISTRATIVE AREA Colorado
POSTAL CODE 80127
COUNTRY US
E-MAIL ADDRESS mhess@oceani.com

HOURS OF SERVICE
9:00 AM - 5:00 PM MST

Hide Contact information ▲

Hide Resource Maintenance ▲

Resource Constraints ►

CONSTRAINTS
LIMITATIONS OF USE

TBD by Sea Grant or MPA Baseline Program Managers

Hide Resource Constraints ▲

Spatial Reference ►

ARCGIS COORDINATE SYSTEM
* TYPE Projected
* GEOGRAPHIC COORDINATE REFERENCE GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_11N
* COORDINATE REFERENCE DETAILS

PROJECTED COORDINATE SYSTEM
WELL-KNOWN IDENTIFIER 32611
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
HIGH PRECISION true
LATEST WELL-KNOWN IDENTIFIER 32611
WELL-KNOWN TEXT PROJCS[“WGS_1984_UTM_Zone_11N”,GEOGCS[“GCS_WGS_1984”,DATUM[“D_WGS_1984”,SPHEROID[“WGS_1984”,6378137.0,298.257223563]],PRIMEM[“Greenwich”,0.0],UNIT[“Degree”,0.0174532925199433]],PROJECTION[“Transverse_Mercator”],PARAMETER[“false_easting”,500000.0],PARAMETER[“false_northing”,0.0],PARAMETER[“central_meridian”,-117.0],PARAMETER[“scale_factor”,0.9996],PARAMETER[“latitude_of_origin”,0.0],UNIT[“Meter”,1.0],AUTHORITY[“EPSG”,32611]]

REFERENCE SYSTEM IDENTIFIER
* VALUE 32611
* CODESPACE EPSG
* VERSION 8.2.6

Hide Spatial Reference ▲

Spatial Data Properties ►

Georectified Grid ►

* Number of dimensions 2

Axis dimensions properties

Dimension type row (y-axis)
* Dimension size 16541
* Resolution 1.000000 Meter

Axis dimensions properties

Dimension type column (x-axis)
* Dimension size 17185
* Resolution 1.000000 Meter

* Cell geometry area
* Point in pixel center

* Transformation parameters are available Yes

* Check points are available No

Corner points
* Point 367133.631040 3728856.325000
* Point 367133.631040 3745397.325000
* Point 384318.631040 3745397.325000
* Point 384318.631040 3728856.325000

* Center point 375726.131040 3737126.825000

Hide Georectified Grid ▲

Vector ►

Geometric objects

Object type composite
Object count 14

Hide Vector ▲

Georectified Grid ►

* Point in pixel center

* Transformation parameters are available Yes

* Check points are available No

Corner points
* Point 367133.631040 3728856.325000
* Point 367133.631040 3745397.325000

- * POINT 384318.631040 3745397.325000
- * POINT 384318.631040 3728856.325000

* CENTER POINT 375726.131040 3737126.825000

Hide Georectified Grid ▲

ARCGIS RASTER PROPERTIES ▶

GENERAL INFORMATION

- * PIXEL DEPTH 16
- * COMPRESSION TYPE None
- * NUMBER OF BANDS 1
- * RASTER FORMAT TIFF
- * SOURCE TYPE continuous
- * PIXEL TYPE signed integer
- * NO DATA VALUE 32767
- * HAS COLORMAP No
- * HAS PYRAMIDS Yes

Hide ArcGIS Raster Properties ▲

Hide Spatial Data Properties ▲

Spatial Data Content ▶

IMAGE DESCRIPTION

- * TYPE OF INFORMATION image

BAND INFORMATION

- * DESCRIPTION Band_1
- * MAXIMUM VALUE 24.000000
- * MINIMUM VALUE 1.000000
- UNITS
  - * SYMBOL Meter
- * NUMBER OF BITS PER VALUE 16

Hide Spatial Data Content ▲

Data Quality ▶

SCOPE OF QUALITY INFORMATION ▶

RESOURCE LEVEL dataset

Hide Scope of quality information ▲

Hide Data Quality ▲

Lineage ▶

LINEAGE STATEMENT

Inter/subtidal image data processing: This habitat classification product was created using the ESRI ArcGIS 10.0 and 10.1 Geoprocessing tools. Depending on the target region and habitat types, both supervised Maximum Likelihood and unsupervised Iso Cluster classification techniques were used. The 30cm UCX imagery was resampled to 1 meter to create the final thematic map product. As stated in the Data Source section, all of the image data were georeferenced, orthorectified and mosaicked into geographical segments based on the flight lines and then into local, coastal and island regions encompassing the SCR MPAs for more efficient classification and data management using ERDAS Imagine and ESRI ArcGIS software applications. The imagery was of very high quality and shows excellent spectral and spatial definition. Water penetration in areas of calm seas appears to be more than sufficient to classify submerged substrate including subsurface, offshore kelp. To maximize the efficiency and substrate class resolving power of the multispectral classification algorithms, it is best (and sometimes necessary) to first isolate the intertidal zone (i.e. the area of interest) from the many multispectral signature terrestrial targets further inland. So, as was done for the Northern California classification work also funded by Sea Grant, the intertidal region is first segregated into elevation sections within and above the intertidal zone in order to eliminate cross correlation of reflectance values for marine and terrestrial vegetation with similar radiometric signatures. The different elevation segments are then classified and ultimately merged together into a final product. Field data and photographs were further utilized to create training sets used in the supervised classification procedure for each subzone. Each subzone classification was then manually edited in order to ensure the highest accuracy product possible and then mosaicked together into the local regions (listed in one of the Data Source sections) for delivery. Given the high quality and resolution of the UCX data, we were able to confidently distinguish and map the following classes:

1 - Whitewash/Undefined
2 - Water
3 - Sandy Beach
4 - Mixed Red/Brown Algae
5 - Shadow
6 - Terrestrial Vegetation
7 - Unvegetated Rock
8 - Beach Wrack
9 - Kelp/Brown Algae
10 - Blue-Green Algae
11 - Mixed Rock/Mussels/Barnacles/Anemone
12 - Cobble
13 - Man-Made/Artificial
14 - Driftwood
15 - Surf Grass
17 - Eel Grass
21 - Green Algae
22 - Submerged Sandy Bottom
23 - Submerged Rock/Reef
24 - Deep Water

Final classification product files have been delivered to Sea Grant and OceanSpaces in both GeoTIFF (.tif) and ESRI shapefile formats. ESRI Layer (.lyr) files are available with the shapefiles which provide information on classes.

Additional information about the imagery used to create this classification is in the Data Source and Process Step sections below.

Process step ►

Description

Ocean Imaging (OI) acquired 4-banded, multispectral Orthoimagery from Keystone Aerial Mapping.

The digital multispectral data are from the Microsoft UltraCamX Digital Sensor (UCX). This sensor is a 16-bit, 4000x4000 pixel, 4-channel instrument imaging in the red (580-700nm), green (480-640nm), blue (380-540nm) and near-infrared (680-960nm) wavelengths flown in tandem with a high accuracy airborne geographical positioning system (ABGPS) and inertial measurement unit (IMU) to achieve high geolocation accuracy and precision. The data were acquired at a ground sampling distance (GSD – i.e. horizontal spatial resolution) of 30 cm. during specific tide, sun angle and weather conditions. This reduces the possibility of sun glint contamination and ensures an acceptable level of solar illumination during times when as much of the substrate/vegetation in the intertidal zone is exposed as is possible. Requirements dictated that the data be collected during periods of seasonally low tides within a 3 hour time window, +/- 1.5 hours from the mean low water level (MLW). In most cases, the data were acquired +/- 1.5 hours of the mean lower low water lever (MLLW) which is lower than the required level. OI mosaicked the individual UCX image tiles into local coastal and island regions encompassing the SCR MPAs for more efficient classification and data management using ERDAS Imagine and ESRI ArcGIS software applications. Mosaicked imagery were then used to generate the habitat classification products. Final image mosaic files have been delivered to Sea Grant and Ocean Spaces in GeoTIFF (.tif) format.

Hide Process step ▲

SOURCE DATA ▶

DESCRIPTION

MPAs Contained in this OI Aerial coverage area include:

Anacapa Island: Anacapa Island SMCA, Anacapa Island SMR
Coal Oil Point: Naples SMCA, Campus Point SMCA
Dana Point-Laguna Beach: Crystal Cove SMCA, Laguna Beach SMR, Laguna SMCA, Dana Point SMCA
Encinitas-La Jolla: Swami's SMCA, San Diego-Scripps Coastal SMCA, Matlahuayl SMR
Imperial Beach: Tijuana River Mouth SMCA
La Jolla-Point Loma: South La Jolla SMR
Point Conception: Point Conception SMR, Kashtayit SMCA
Point Dume: Point Dume SMCA, Point Dume SMR
Point Vicente: Point Vicente SMCA, Abalone Cove SMCA
Santa Catalina Island West: Farnsworth Onshore (Catalina Island) SMCA, Cat Harbor SMCA
Santa Catalina Island East: Lover's Cove SMCA, Casino Point SMCA
Santa Catalina Island North: Long Point SMR, Blue Cavern SMCA, Arrow Point to Lion Head Point SMCA
San Miguel Island: Judith Rock SMR, Harris Point SMR
Santa Barbara Island: Santa Barbara Island SMR
Santa Cruz Island North: Painted Cove SMCA
Santa Cruz Island Northeast: Scorpion SMR
Santa Cruz Island South: Gull Island SMR
Santa Rosa Island North: Carrington Point SMR, Skunk Point SMR
Santa Rosa Island South: South Point SMR, Skunk Point SMR

Hide Source data ▲

Hide Lineage ▲

Geoprocessing history ▶

Process

Process name

Date 2012-02-08 15:08:12

Tool location C:\Program Files (x86)\ArcGIS\Desktop10.0\ArcToolbox\Toolboxes\Data Management Tools.tbx\MosaicToNewRaster

Command issued

```
MosaicToNewRaster bluegreen_now_sand2.img;Arched_classification_02081431.img C:\
KMJ\classifications\SG_NCC\Arched\editing Arched_classification_02081507.img
PROJCS[‘WGS_1984_UTM_Zone_10N’,GEOGCS[‘GCS_WGS_1984’,DATUM[‘D_WGS_1984’,SPHEROID[‘WGS_
1984’,6378137.0,298.257223563]],PRIMEM[‘Greenwich’,0.0],UNIT[‘Degree’,0.01745329251994
33]],PROJECTION[‘Transverse_Mercator’],PARAMETER[‘False_Easting’,500000.0],PARAMETER[‘
False_Northing’,0.0],PARAMETER[‘Central_Meridian’,-123.0],PARAMETER[‘Scale_Factor’,0.
9996],PARAMETER[‘Latitude_Of_Origin’,0.0],UNIT[‘Meter’,1.0]] 8_BIT_UNSIGNED # 1 FIRST
FIRST
```

Include in lineage when exporting metadata No

Hide Geoprocessing history ▲

Distribution ▶

Distribution format

* Name Raster Dataset

Hide Distribution ▲

Fields ▶

Details for object SCR_Aerial_PointVicente_06252012_IntClass.tif.vat ▶

* Type Table

* Row count 16

Field Count ▶

* Alias Count

* Data type Double

* Width 19

* Precision 0

* Scale 0

Hide Field Count ▲

Field OID ▶

* Alias OID

* Data type OID

* Width 4

* Precision 0

* Scale 0

Field description

Internal feature number.

Description source

ESRI

DESCRIPTION OF VALUES
Sequential unique whole numbers that are automatically generated.

Hide Field OID ▲

FIELD OID_1 ▶
- * ALIAS OID_1
- * DATA TYPE Integer
- * WIDTH 9
- * PRECISION 9
- * SCALE 0

Hide Field OID_1 ▲

FIELD OID_12 ▶
- * ALIAS OID_12
- * DATA TYPE Integer
- * WIDTH 9
- * PRECISION 9
- * SCALE 0

Hide Field OID_12 ▲

FIELD Value ▶
- * ALIAS Value
- * DATA TYPE Integer
- * WIDTH 9
- * PRECISION 9
- * SCALE 0

Hide Field Value ▲

FIELD Class_Name ▶
- * ALIAS Class_Name
- * DATA TYPE String
- * WIDTH 254
- * PRECISION 0
- * SCALE 0

Hide Field Class_Name ▲

Hide Details for object SCR_Aerial_PointVicente_06252012_IntClass.tif.vat ▲

Hide Fields ▲

Metadata Details ▶

METADATA LANGUAGE English (UNITED STATES)
METADATA CHARACTER SET utf8 - 8 bit UCS Transfer Format

SCOPE OF THE DATA DESCRIBED BY THE METADATA dataset
SCOPE NAME * dataset

* LAST UPDATE 2014-09-18

ARCGIS METADATA PROPERTIES
METADATA FORMAT ArcGIS 1.0
STANDARD OR PROFILE USED TO EDIT METADATA FGDC

CREATED IN ARCGIS FOR THE ITEM 2013-03-14 13:16:55
LAST MODIFIED IN ARCGIS FOR THE ITEM 2014-09-18 14:32:37

AUTOMATIC UPDATES
HAVE BEEN PERFORMED Yes
LAST UPDATE 2014-09-18 14:32:37

ITEM LOCATION HISTORY
ITEM COPIED OR MOVED 2013-03-14 13:16:55
FROM N:\SG_NCC\Data\Rasters\Classifications\ArchedRock\Arched_classification_02081507.img
TO \\192.168.0.6\Projects\SG_NCC\Data\Deliverables\Classification\Rasters\Arched_classification_02081507.img

Hide Metadata Details ▲

Metadata Contacts ▶

METADATA CONTACT
INDIVIDUAL'S NAME Mark Hess
ORGANIZATION'S NAME Ocean Imaging
CONTACT'S ROLE point of contact

CONTACT INFORMATION ▶
PHONE
VOICE 303-948-5272
FAX 303-948-2549

ADDRESS
TYPE both
DELIVERY POINT 13976 W. Bowles Ave. Ste 100
CITY Littleton
ADMINISTRATIVE AREA Colorado
POSTAL CODE 80127
COUNTRY US
E-MAIL ADDRESS mhess@oceani.com

HOURS OF SERVICE

9:00 AM - 5:00 PM MST

Hide Contact information ▲

Hide Metadata Contacts ▲

Metadata Maintenance ►

MAINTENANCE

UPDATE FREQUENCY not planned

MAINTENANCE CONTACT

INDIVIDUAL'S NAME Mark Hess ORGANIZATION'S NAME Ocean Imaging
CONTACT'S ROLE point of contact

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Hide Contact information ▲

Hide Metadata Maintenance ▲

Metadata Constraints ►

CONSTRAINTS

LIMITATIONS OF USE
TBD by Sea Grant or MPA Baseline Program Managers

Hide Metadata Constraints ▲

FGDC Metadata (read-only) ▼

☐ ☐DETAILED DESCRIPTION
ENTITY TYPE
ENTITY TYPE LABEL SCR_Aerial_PointVicente_06252012_IntClass.tif.vat

ATTRIBUTE
ATTRIBUTE LABEL Count

ATTRIBUTE
ATTRIBUTE LABEL OID
ATTRIBUTE DEFINITION
Internal feature number.

Attribute Definition Source ESRI
Attribute Domain Values
Unrepresentable Domain
Sequential unique whole numbers that are automatically generated.

Attribute
Attribute Label OID_1

Attribute
Attribute Label OID_12

Attribute
Attribute Label Value

Attribute
Attribute Label Class_Name

Hide Entities and Attributes ▲