High Resolution Nearshore Substrate Mapping and Persistence Analysis with Multi-spectral Aerial Imagery.

FINAL REPORT

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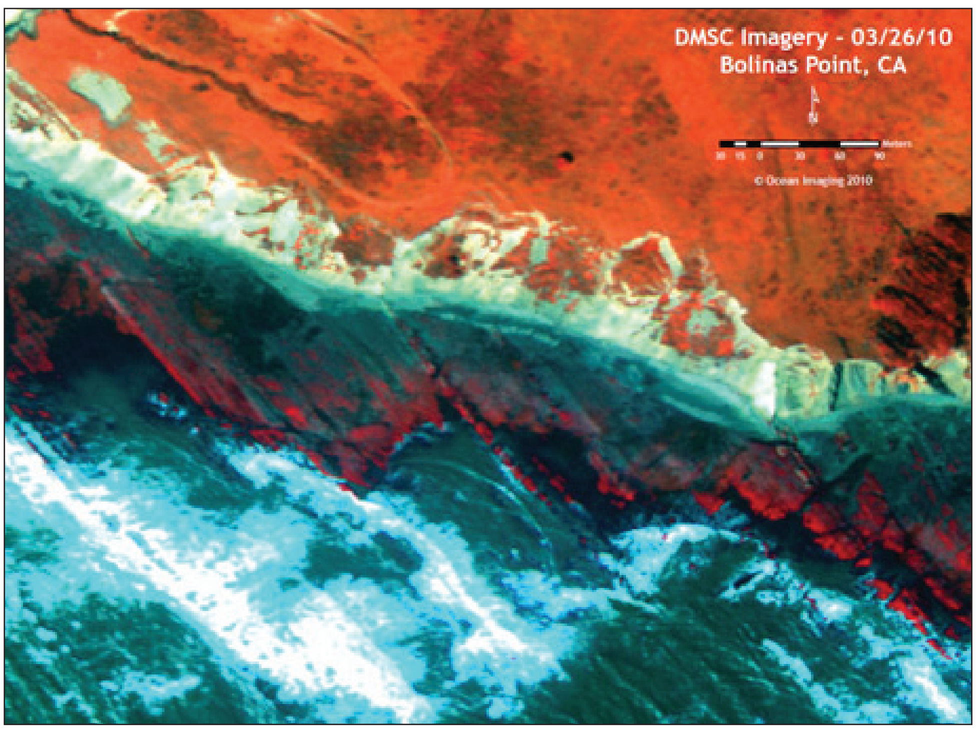

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Executive Summary

Marine Protected Areas (MPAs) in the North-Central California (NCC) region encompass numerous ecosystem types, including Estuarine, Beach, Rocky and Soft-bottom Intertidal, and Kelp ecosystems that have been identified as prime focuses for the region's MPA monitoring. These resources cover very large areas and the utilization of field sampling and measurements to establish a baseline characterization data base 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 data base 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. Additionally, such a baseline data base 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 and estuarine substrate distribution map data base covering all of the newly-created MPAs in the California North Central Coast region, and significant areas outside of the MPAs. This was accomplished using multispectral aerial imagery which was classified for substrate type using algorithms trained, in part, with field sample data collected specifically for this project. The region of coverage included the entire coastline between Pigeon Point and Pt. Arena (290 km) plus inland areas covering the estuarine, bay and river MPAs. Three remote sensing data sets were utilized to create the final substrate map products: 1) 4-band imagery collected in March, 2010 by Ocean Imaging Corp. with its DMSC-MKII sensor; 2) 4-band imagery collected in September, 2010 by Fugro EarthData with a Leica ADS-40 sensor; 3) Light Detection and Ranging (LIDAR) topographic data collected by Fugro in March, 2010. The LIDAR data set (providing high resolution topographical data of the intertidal zone) proved to be extremely useful when applied to the processing for two specific purposes: 1) to first isolate the intertidal zone from the many multispectral signature terrestrial targets further inland, which served to maximize the substrate type separation efficiency of the classification algorithms, and 2) to subdivide the intertidal zone into several subzones that were classified separately – which further increased the accuracy of the final classification product. Field data and photographs collected for this project in summer 2011were 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 USGS orthoquad regions for delivery. The habitat classes this process was able confidently identify and map using the DMSC and ADS40 imagery for the intertidal zones were:

1. Whitewash/Undefined
2. Water
3. Sandy Beach
4. Mixed Red/Brown Algae
5. Tidepool/Shadow
6. Terrestrial Vegetation
7. Unvegetated Rock
8. Wrack
9. Kelp/Brown Algae
10. Blue-Green Algae
11. Cobble
12. Man-made
13. Driftwood
14. Surf Grass

15. Unknown Aquatic Vegetation
16. Eel Grass
17. Salt Marsh Vegetation
18. Submerged Aquatic Vegetation
19. Mud Flat
20. Green Algae

Estuary image data were processed similarly. The generally much better water clarity in the estuarine areas allowed the classification of both exposed and submerged bottom substrate past the intertidal zone. The final habitat classes in the estuary/bay and river regions that could be confidently identified and mapped were:

1. Whitewash/Undefined
2. Water
3. Sandy Beach
4. Tidepool/Shadow
5. Terrestrial Vegetation
6. Unvegetated Rock
7. Eel Grass
8. Salt Marsh Vegetation
9. Submerged Aquatic Vegetation
10. Mud Flat
11. Green Algae

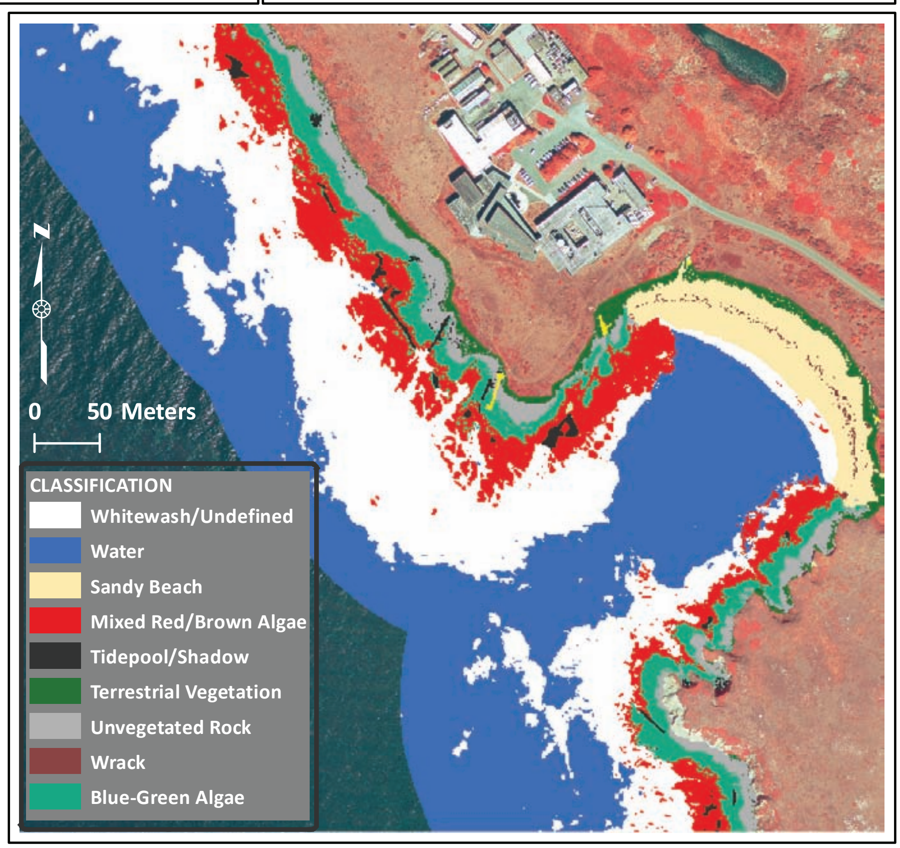
The accuracy of the produced map products was evaluated with Congalton Matrix statistics, using a field sample data set from 2011 specifically reserved for this purpose. The evaluation yielded 86% overall accuracy. The attached figure shows a sample of the original multispectral imagery and resulting final substrate classification.

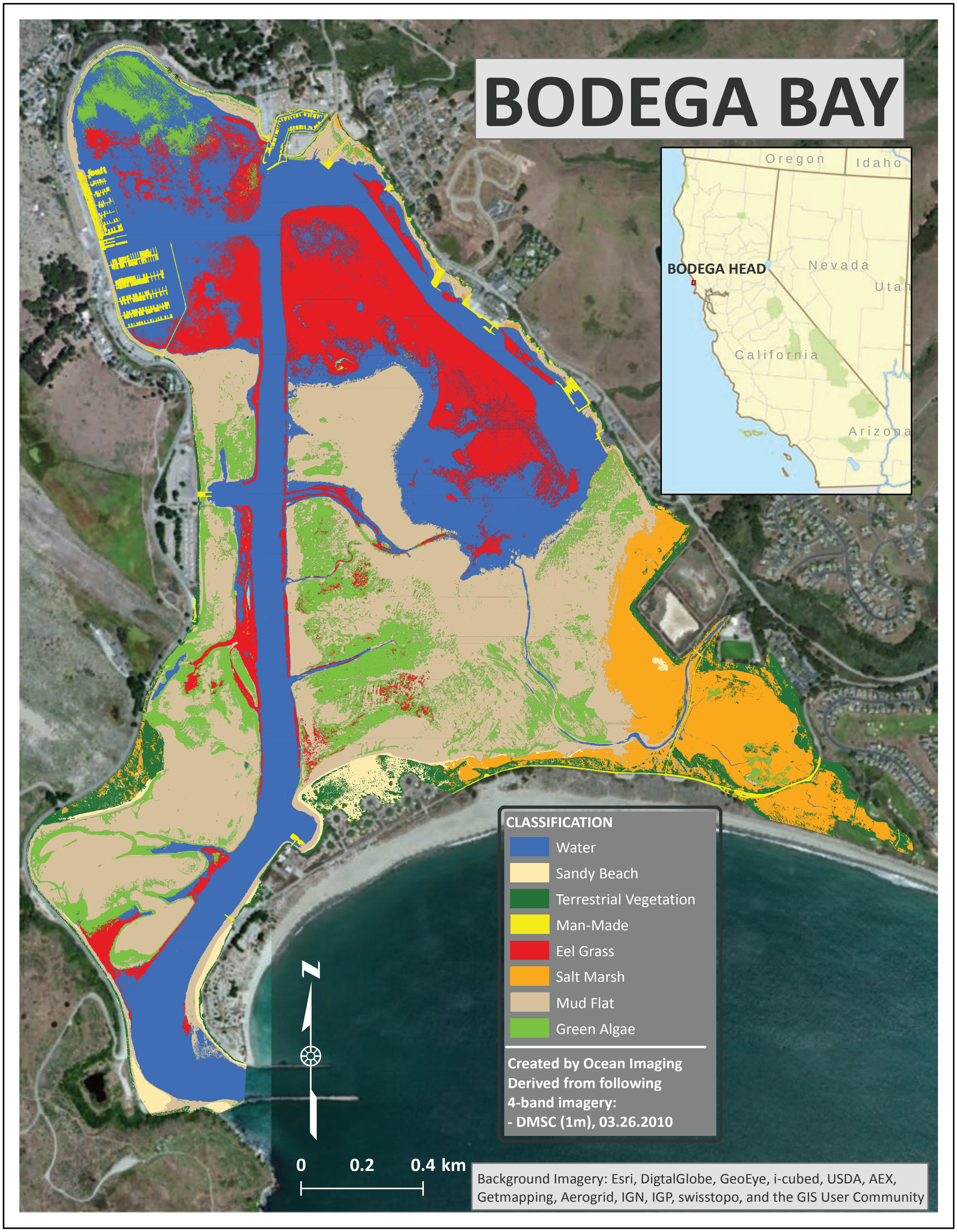
Since the MPAs were created to purposefully encompass areas holding rich and varied ecological resources, the remote sensing-derived data base reflects the greater abundance of such habitats within as opposed to outside the MPAs. For example, the most abundant class along the entire surveyed coastline – Mixed Red/ Brown algae - covered 41.8% of the classified area within the MPAs but only 23.5% outside of the protected zones. Other algae classes, and surf grass are also significantly more abundant within the MPA's than outside their boundaries. Conversely, sandy beach and unvegetated rock substrates are almost twice as abundant outside the MPAs. The composition of substrate types within each MPA was found to vary considerably between MPAs, both for coastal intertidal zone MPAs and MPAs within river mouths, bays and estuaries. For example, blue-green algae cover sampled in the coastal intertidal MPAs varied from 0% in several northernmost MPAs to 20.2% of classified area in the Girstle Cove SMR. These baseline differences must be considered in future studies comparing even relatively closely located MPAs.

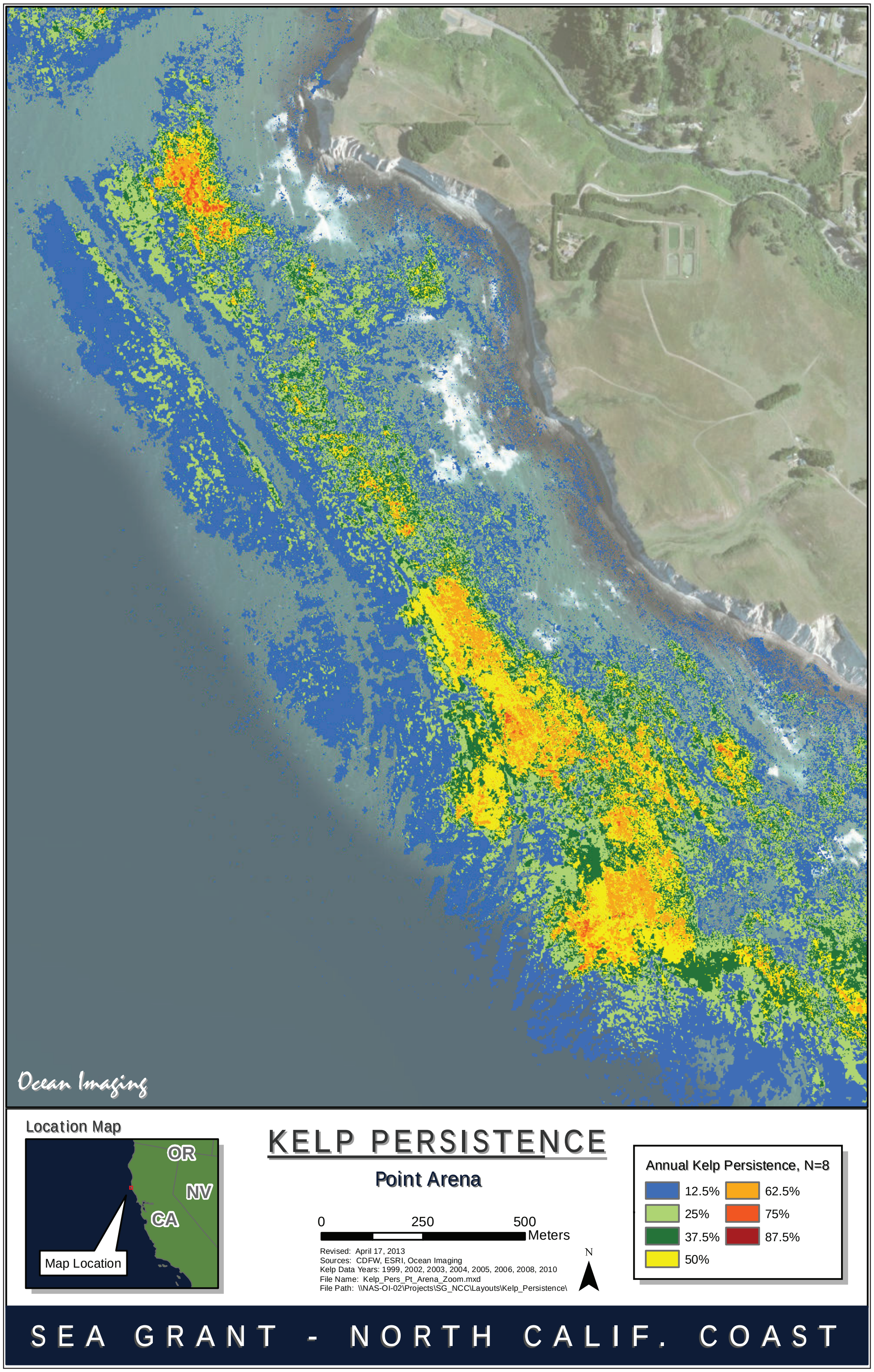
The project also utilized historical archived aerial imagery and newly acquired imagery to produce kelp canopy classifications and to compute its persistence over the period 1999 to 2010. The analysis shows a high degree of inter-annual variability, which must be considered in future assessments of the state of this important resource. A sample of this analysis from the Pt. Arena region is also attached. Final classification and analysis product files were delivered to Sea Grant and OceanSpaces in both ERDAS Imagine (.img) and ESRI shapefile formats in April, 2013.

Bodega Head Classification

Created by Ocean Imaging
Derived from following
4-band imagery:
- ADS40 (30cm), 09.22.2010-09.23.2010
- DMSC (1m), 03.26.2010




BODEGA BAY
Oregon
Idaho
BODEGA HEAD
Nevada
Utah
California
Arizona
CLASSIFICATION
Water
Sandy Beach
Terrestrial Vegetation
Man-Made
Eel Grass
Salt Marsh
Mud Flat
Green Algae
Created by Ocean Imaging
Derived from following
4-band imagery:
- DMSC (1m), 03.26.2010
N
0 0.2 0.4 km
Background Imagery: Esri, DigtalGlobe, GeoEye, i-cubed, USDA, AEX,
Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Ocean Imaging
Location Map
OR
NV
CA
Map Location
KELP PERSISTENCE
Point Arena
0
250
500
Meters
Revised: April 17, 2013
Sources: CDFW, ESRI, Ocean Imaging
Kelp Data Years: 1999, 2002, 2003, 2004, 2005, 2006, 2008, 2010
File Name: Kelp_Pers_Pt_Arena_Zoom.mxd
File Path: \\NAS-OI-02\Projects\SG_NCC\Layouts\Kelp_Persistence\
N
Annual Kelp Persistence, N=8
12.5%
62.5%
25%
75%
37.5%
87.5%
50%
SEA GRANT - NORTH CALIF. COAST

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1. Project Objectives and Technical Approach

1.1 Project objectives and their relevance to Baseline Characterization Goals

Marine Protected Areas (MPAs) in the North-Central California (NCC) region encompass numerous ecosystem types, including Estuarine, Beach, Rocky and Soft-bottom Intertidal, and Kelp ecosystems that have been identified as prime focuses for the region's MPA monitoring. These resources cover very large areas and the utilization of field sampling and measurements to establish a baseline characterization data base 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 data base is of great importance for establishing the exiting 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.

Over the past decade, large amounts of funds and effort were expended in the NCC region to acquire a data base of subtidal and deep bottom characterizations using such technologies as multi-beam sonar arrays (Calif. Seafloor Mapping Project 2007). Over most of the area, however, such surveys provide information on bottom characteristics at depths of 10+ meters, because of logistical, technical, safety and other complications inherent in using the boat-based equipment closer to shore. A shoreline characterization is available for the region from NOAA map surveys (NOAA 2006, 2007) but such linearly mapped, generalized category classifications (e.g. intertidal rocky, sandy, coastal marsh) offer no detail and are not suitable for any future research related to impact of the newly created MPAs. Some very localized eel grass map data exist for several locations in the NCC region (Spratt 1989, Brown and Becker 2007), and spatially coarse surfgrass distribution data were generated by the US Minerals Management Service in 1982 (no more contemporary data covering the entire region are available) (Woodward Clyde 1984, Tenera 2007). Kelp canopy has been surveyed annually by the California Department of Fish and Wildlife (CDFW), until 2007 and by Ocean Imaging Corp. (under contract) in 2008. California's financial problems caused an indefinite suspension of the annual kelp survey program in 2009. Any other shallow subtidal, intertidal and estuarine ground substrate mapping data in the NCC zone are limited to research project-specific plots surveyed by various researchers on a very spatially limited, localized level.

In response to the above limitations, the overall objective of this project was to create a baseline data base of kelp canopy, shallow subtidal and intertidal bottom substrate, and estuarine ground cover at very high spatial resolution (1-2m) covering all MPAs in the NCC region. Kelp canopy, bottom substrate and limited estuarine areas were also mapped outside the MPAs, resulting in a spatially continuous data base for the entire NCC region. 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. The resulting data base will provide much-needed (and up to now nonexistent) baseline characterization information that will be utilized by numerous researchers targeting both ecological and socioeconomic impacts of MPAs in the NCC region. The inclusion of areas outside the MPAs will provide data over possible "control" sites for future studies.

Through the creation of the remote sensing-derived baseline characterization data base and the resource persistence/variability analyses we also aimed to attain insights useful for evaluating these novel technologies for possible implementation and enhancement of a long-term monitoring plan.

1.2 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 utilize multispectral digital image classification algorithms to obtain bottom substrate and kelp coverage map data base 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 statitistics for the final data sets.

The imagery ultimately used for the habitat classification of the intertidal zone as well as the select bays and rivers was collected by Ocean Imaging (OI) and Fugro EarthData. Originally planned as the only multispectral dataset to be used for the project, OI acquired the Digital Multispectral Camera (DMSC) imagery on 03/26/2010. As has been discussed in previous reports, the overall quality of OI's DMSC imagery was good, however, a large wave field caused high surf and hence whitewater areas to reach into parts of the intertidal zone. This, coupled with high water turbidity precluded imaging parts of the intertidal areas that were not fully exposed at the time of image acquisition. Subsequently OI obtained additional data sets for use in creating the intertidal substrate classification product. These were Light Detection and Ranging (LIDAR) topographic data and ADS-40 30cm resolution multispectral imagery collected over the NCC coastline during September of 2010 by Fugro EarthData as part of work funded by the California Coastal Conservancy. They were made available to Ocean Imaging and the SeaGrant Program through Fugro and NOAA's Coastal Services Center. The ADS-40 imagery's high resolution allowed better differentiation of detailed features in the upper intertidal zone. Unfortunately, the data were collected without low tide-level coordination, and hence their value was limited to the upper intertidal areas that were exposed at the time. However, the data still significantly enhanced the initial multispectral imagery collected by OI, and the resulting habitat classification products. Fugro EarthData acquired the imagery on 09/22/2010 and 09/23/2010 and delivered fully georeferenced and orthorectified, 12-bit imagery with a spatial resolution of 0.30 meters to OI in 2011. Details on these systems and the data processing are below. The coverages for each multispectral data set are shown in **Figure 1**.

2. Baseline Characterization Considerations

2.1 Data Processing Approach

Ocean Imaging DMSC Multispectral Imagery Acquisition: 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 and 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

Figure 1.

Multispectral imagery types used for the intertidal habitat classification products.

the imagery. OI used a filter combination of 451-551-710-850 nm for this collection. Imagery for the NCC coast was acquired on from a Cessna 206 aircraft by Ocean Imaging staff 03/26/2010 at an altitude of 6500 feet with 60% scene overlap resulting in an initial ground sampling distance of 0.93 meters.

Ocean Imaging DMSC Multispectral Image Processing: Upon completion of each flight, image data were downloaded from the DMSC onto an in-house computer hard drive and 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 using Microsoft's 1-meter VirtualEarth data as a reference layer. Adjusted frames were then mosaicked into USGS orthoquad regions for more efficient classification and data management using ERDAS Imagine. Mosaicked imagery was then used to generate the habitat classification products (described below). The MPAs covered in each of the USGS orthoquads are listed in **Table 1**. Final image mosaic files have been delivered to Sea Grant and Ocean Spaces in both ERDAS Imagine (.img) and GeoTif (.tif) formats.

Fugro EarthData ADS40 Multispectral Image Acquisition and Processing: OI acquired 4-banded, multispectral Orthoimagery from Fugro EarthData's (http://www.fugroearthdata.com/index.php) Leica ADS40-SH52 digital camera system. The ADS40 is a 12 CCD pushbroom sensor with a raw camera resolution of 3,000 x 2,000 pixels for the multispectral data. It utilizes 4 panchromatic CCD: 27 degrees forward view, 16 degrees backward view, two nadiral views with an overlapping of 3,25 microns and 2 x 4

Table 1.

MPAs (SMRs and SMCAs) contained in USGS orthoquad regions.

USGS Orthoquad Name	MPAs Contained in Orthoquad
Point Arena	Point Arena SMCA and Point Arena SMR
Saunders Reef	Saunders Reef SMCA
Stewarts Point	Del Mar Landing SMR and Stewarts Point SMR
Plantation	Stewarts Point SMR and Salt Point SMP
Arched Rock	Russian River SMCA and Russian River SMR
Duncans Mills	Russian River SMR
Bodega Head	Bodega Head SMR, Bodega Head SMCA and Estero Americano SMRMA
Valley Ford	Estero Americano SMRMA and Estero de San Antonio SMRMA
Drakes Bay	Drakes Estero SMCA, Estero de Limantour SMR, Point Reyes SMR and Point Reyes SMCA
Bolinas	Duxbury SMP
Montara Mountain	Montara SMR
Half Moon Bay	Pillar Point SMCA

multispectral CCD (red, green, blue and near infrared – RGB-NIR), with both a nadiral and 16 degree backward views. There are five spectral channels measuring simultaneously: panchromatic, red (λ = [590 – 675]nm), green (λ = [500 – 650]nm), blue (λ = [400 – 580]nm) and near infrared (λ = [675 – 850] nm). The RGB-NIR bands were used for this project. Fugro EarthData acquired the imagery used for this project on 09/22/2010 and 09/23/2010 and delivered fully georeferenced and orthorectified, 12-bit imagery with a spatial resolution of 0.30 meters to OI in 2011. The initial data products received from Fugro were mosaicked into 1500x1500 meter tiled raster image files covering the NCC area of interest. Using ERDAS Imagine, OI subsequently mosaicked the ADS40 data into USGS orthoquad regions for use in the classification process and for more efficient data management. Mosaicked imagery was utlized in combination with OI's DMSC imagery and the LIDAR data to generate the habitat classification products. Final image mosaic files have been delivered to Sea Grant and Ocean Spaces in both ERDAS Imagine (.img) and GeoTif (.tif) formats.

Intertidal Habitat Classification Methods: Following the creation of image mosaics from both sets of georeferenced, four-banded, RGB-NIR multispectral imagery, thematic maps were created to characterize specific vegetation and substrate types in the NCC intertidal zone. 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 NCC 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 the 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 10.0 and 10.1 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):

Supervised classification

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.

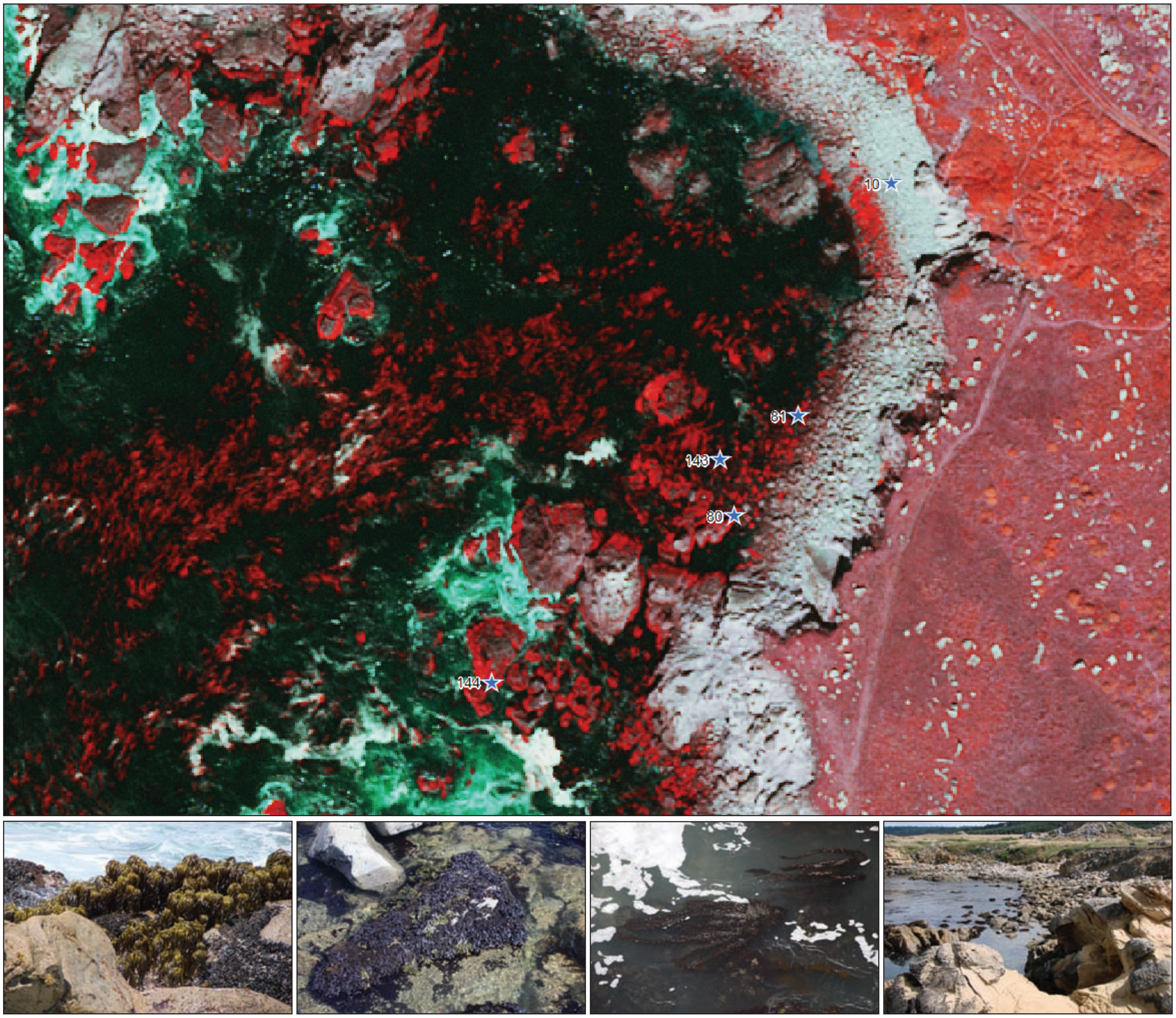
Unsupervised classification

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 with a reduced number of classes.

For the unsupervised classification method, 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/.

Incorporation of ADS40 and LIDAR Data: As discussed above, when available, the higher resolution ADS40 imagery was resampled to 1 meter and combined with the DMSC data to improve the precision and accuracy of the final thematic map product. Fugro also collected LIDAR data at the same time and these were also made available to OI for this project. The LIDAR data set (providing high resolution topographical data of the intertidal zone) proved to be extremely useful when applied to the processing for two specific purposes: First, 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. Prior to this project, no very high resolution (i.e. around 1-2 meters) "shoreline" data base existed that could be used as an accurate cutoff boundary between the intertidal and terrestrial habitats. NOAA's and USGS' "shoreline" data bases have spatial resolutions far too inadequate for this work, and do not conform to a suitable intertidal vs. terrestrial cutoff. The Fugro LIDAR data have 1m horizontal resolution and 9.25cm vertical RMS accuracy. Ocean Imaging staff utilized the multispectral imagery and field photos to identify (as best as possible based on vegetation and ground substrate type) the upper limit of the intertidal zone within each shoreline section, then matched these determinations within the LIDAR data set to create a novel, high resolution "coastline" boundary. This boundary was then used to isolate the region of interest for the multispectral classification. Second, the LIDAR data were used to subdivide the intertidal zone into several subzones that were classified separately – which further increased the accuracy of the final classification product. 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 2.** Each subzone classi-



144 Brown Algae (Sea Palm) | 80 Mixed Red/Brown Algae | 143 Brown Algae (Feather Boa) | 10 Cobble
81 Mixed Red/Brown Algae

Figure 2.

Example of multispectral imagery and corresponding locations of intertidal field sampling targets obtained by OI for this project.

fication was then manually edited in order to ensure the highest accuracy product possible and then mosaicked together into USGS orthoquad regions for delivery. The habitat classes this process was able to confidently identify and map using the DMSC and ADS40 imagery were:

1. Whitewash/Undefined
2. Water
3. Sandy Beach

4. Mixed Red/Brown Algae
5. Tidepool/Shadow
6. Terrestrial Vegetation
7. Unvegetated Rock
8. Wrack
9. Kelp/Brown Algae
10. Blue-Green Algae
11. Cobble
12. Man-made
13. Driftwood
14. Surf Grass
15. Unknown Aquatic Vegetation
16. Eel Grass
17. Salt Marsh Vegetation
18. Submerged Aquatic Vegetation
19. Mud Flat
20. Green Algae

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

Estuarine Habitat Classification Methods: Acquisition and processing of the estuary image data and associated habitat classification products follow closely the steps outlined for the coastal intertidal data outlined in the preceding section. The one important difference is that tide levels and water clarity were considerably better in the estuary areas than along the ocean shoreline, allowing the classification of both exposed and submerged bottom substrateS using only the DMSC data. In most cases, ADS40 data were not even collected for these regions. The final habitat classes in the estuary/bay and river regions we were able TO confidently identify and map using the DMSC imagery were:

1. Whitewash/Undefined
2. Water
3. Sandy Beach
4. Tidepool/Shadow
5. Terrestrial Vegetation
6. Unvegetated Rock
7. Eel Grass
8. Salt Marsh Vegetation
9. Submerged Aquatic Vegetation
10. Mud Flat
11. Green Algae

Final classification product files have been delivered to Sea Grant and OceanSpaces in both ERDAS Imagine (.img) and ESRI shapefile formats. ESRI Layer (.lyr) files are available with the shapefiles which provide information on classes. A sample estuarine classification of Bodega Bay is shown in **Figure 3.**

2010 Kelp Classification Methods: Acquisition and processing of the kelp image data and associated habitat classification products follow closely the steps for the coastal intertidal data outlined in the preceding section. In the case of the kelp maps, the supervised Maximum Likelihood classification technique was used. The main difference is that the resulting maps represent a single-class (kelp) product as opposed to the multi-class intertidal products. Thematic maps showing kelp were created from the 2 meter DMSC data as well as 1 meter ADS40 data. Ocean and weather conditions during the November 2010 DMSC data collection time period were poor resulting in extreme whitewash in the imagery as well as depleted kelp beds. Therefore, ADS40 imagery acquired on 09/22/2010 were resampled to 1 meter GSD and kelp classifications were created using these data. As a result when the imagery was available, separate kelp classification products were generated from both the November 2010 DMSC and September 2010 ADS40 imagery. Two-meter, 'merged' kelp products were also produced by combining the DMSC-created and ADS40-created classifications. These products are listed as 'merged' in the file name. Each kelp classification was manually edited in order to ensure the highest accuracy prod-

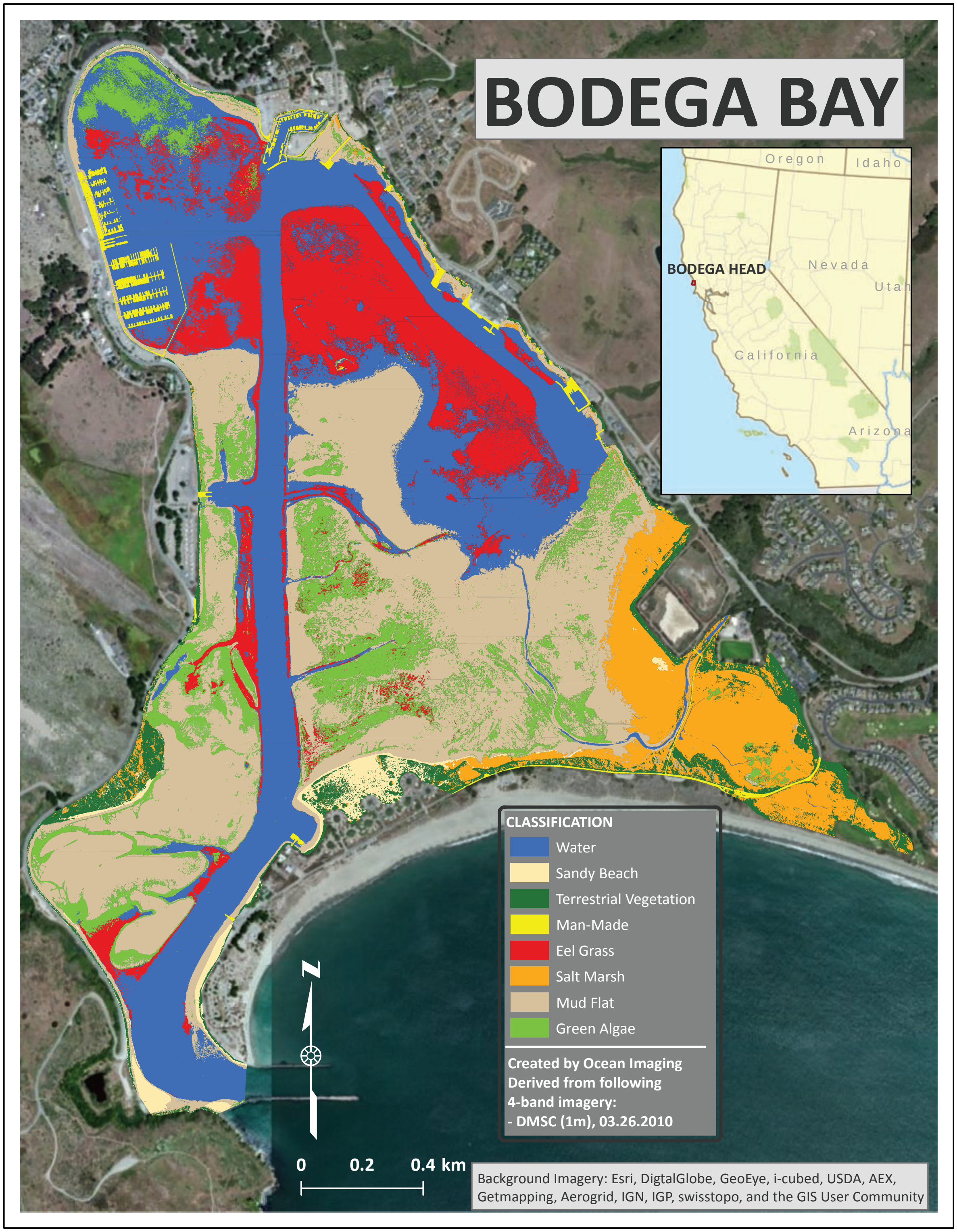


Figure 3.

Final intertidal classification example.

Figure 4.

USGS orthoquads for which kelp classification products were produced using the DMSC imagery, the ADS40 imagery and the DMSC-ADS40 imagery in combination.

uct possible and then mosaicked together into USGS orthoquad regions for delivery. **Figure 4** shows the USGS orthoquads for which each different type of kelp classification product was generated. Despite the temporal gap between the DMSC and ADS40 data used to generate the 2010 'merged' kelp class products, and lack of field reference data for a quantitative accuracy assessment, these analyses are considered to be of high quality, accurately representing the kelp abundance during the Fall of 2010. Final classification product files have been delivered to Sea Grant and OceanSpaces in both ERDAS Imagine (.img) and ESRI shapefile formats.

Kelp Persistence Analysis Methods: This dataset is a thematic classification of kelp persistence between the years of 1999-2010 along California North Central Coast's intertidal to offshore region from Pigeon Point up to Point Arena. In that time period, kelp maps from 2000, 2001, 2007 and 2009 were unavailable and so the persistence analysis was created using data from the eight years 1999, 2002, 2003, 2004, 2005, 2006, 2008, and 2010. The imagery used to crate the 2010 kelp classification were collected by Ocean Imaging (OI) and Fugro EarthData. Fugro EarthData acquired the imagery between 09/22/2010 – 09/23/2010 and OI acquired this imagery on 03/26/2010 using the Digital Multispectral Camera (DMSC). Details on these systems and the data processing discussed above. The DMSC-ADS40 merged kelp classfication was chosen for this analysis. Kelp classifications in the form of ESRI shapefiles were acquired from the California Department of Fish and Wildlife (CDFW) server (ftp://ftp.dfg.ca.gov/R7_MR/BIOLOGICAL/Kelp) for the years of 1999, 2002, 2003, 2004, 2005, 2006 and 2008. All of the shapefiles were converted to 2 meter ERDAS Imagine (.img) raster images with the pixels showing kelp assigned the value of 1 and all other pixels assigned the value of 0. The rasters were subsequently summed to show the number of years during the 1999-2010 time period for which each pixel showed the presence of kelp. Persistence maps and digital persistence classification products in ERDAS Imagine (.img) format along with a corresponding ESRI layer file (.lyr) were created for the entire NCC study region as well as for each USGS orthoquad and delivered to the MPA Baseline Program via the OceanSpaces web server. A sample of the persistence analysis result is shown in **Figure 5**.

2.2 End-product Accuracy Assessment Results

NCC 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. One hundred fourteen field observations not used for the creation of classification training sets were set aside and utilized to conduct the assessment. The points used were generated from field survey data collected on July 31, 2011 through August 4, 2011 along the coast from Bodega Bay up to Point AreNa which included, but were not limited to: Bodega Head SMR, Point Arena SMR, Russian River SMCA, Russian River SMR, Salt Point SMP, Saunders Reef SMCA, and Sea Lion Cove SMCA (**Figure 6**). The initial sampling days were coordinated with UCSC's Dr. P. Raimondi's research staff who met Ocean Imaging's staff at some of their established intertidal study sites near Bodega and provided expertise in the substrate characterizations and identifications. The points were acquired by actual field sight surveys using base maps and GPS units accurate to three meters linking the GPS points and detailed notes to both overview and close range digital, time-stamped photographs. Hundreds of inter-

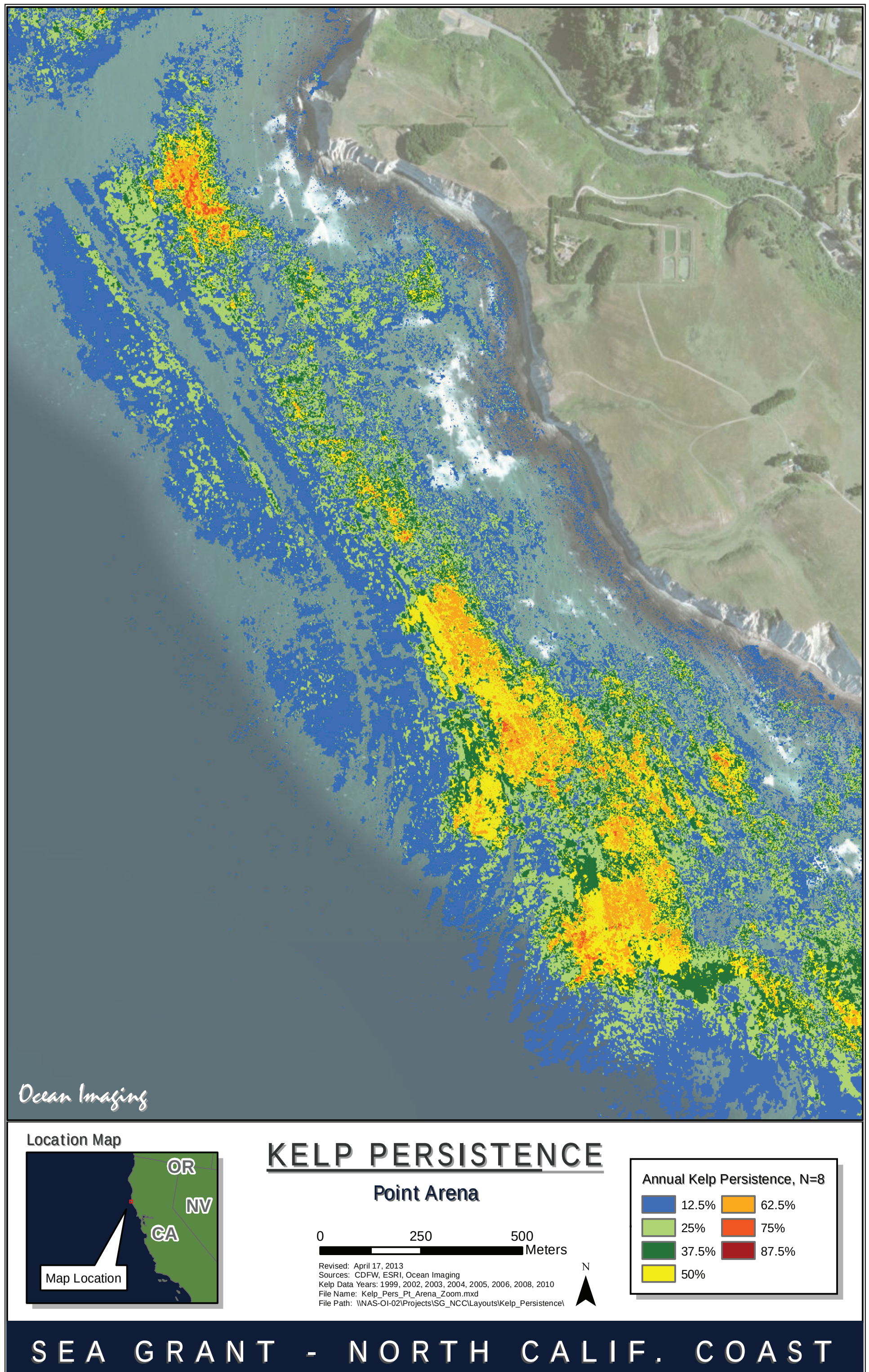


Figure 5.

Sample kelp persistence map showing the Point Arena region.

Figure 6.

Locations of field sample points used for intertidal habitat classification accuracy assessment.

tidal substrate targets were documented between Pt. Arena to the North, and San Antonio Estuary to the South. In many cases, high cliffs paralleling relatively long stretches of intertidal shoreline allowed the inclusion of multiple substrate targets in a single photograph, which was then supplemented by further detailed hands-on documentation by climbing down to the intertidal zone. The field data were then digitized as points in ArcGIS using basemaps and the field photographs to match to the corresponding locations in the mosaicked, georectified imagery and classification rasters. The Congalton method is outlined in detail in Congallton, 2001 and Congalton and Green, 2009. The Congalton accuracy assessment yielded 86% overall classification accuracy. The complete Congalton error matrix and accuracy summary is shown in **Table 2.**

Table 2. Congalton Matrix and accuracy assessment summary.

Note: Accuracies for both Green Algae and Driftwood show a 0% Producer's and User's Accuracy, however there were only two and one sample points for those classes respectively. In the case of Green Algae, the classification misidentified a bright green reflectance in the imagery characteristic green algae, however the field data indicated that these spots were either a red algae with a green color (not unusual) or blue-green algae with a green hue. The misidentification of a non-vegetated rock as driftwood was also due to the rock's reflectance characteristics very close to that of driftwood.

CONGALTON MATRIX FOR SEAGRANT NCC

		REFERENCE DATA													
	Remote Sensing-Derived Data	Water /Whitewash	Beach	Mixed Red-Brown	Tide /Shadow	Terrestrial	Rock	Wrack	Kelp	BlueGreen Algae	Green Algae	Cobble	Man-Made	Driftwood	
CLASS DATA	Water/Whitewash	5	0	0	0	0	0	0	0	0	0	0	0	0	5
	Beach	1	10	0	0	0	0	0	0	0	0	0	0	0	11
	Mixed Red-Brown	1	0	41	0	0	0	0	1	4	0	0	0	0	47
	Tide/Shadow	0	0	0	2	0	0	0	0	0	0	0	0	0	2
	Terrestrial	0	0	0	0	2	0	0	0	0	0	0	0	0	2
	Rock	0	0	1	0	0	12	0	0	1	0	0	0	0	14
	Wrack	0	1	0	0	0	0	3	0	0	0	0	0	0	4
	Kelp	0	0	0	0	0	0	0	15	0	0	0	0	0	15
	BlueGreen Algae	0	0	0	1	0	0	0	0	5	0	0	0	0	6
	Green Algae	0	0	1	0	0	0	0	0	1	0	0	0	0	2
	Cobble	0	1	0	0	0	1	0	0	0	0	2	0	0	4
	Man-Made	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	Driftwood	0	0	0	0	0	1	0	0	0	0	0	0	0	1
		7	12	43	3	2	14	3	16	11	0	2	1	0	114

		Producer's Accuracy	User's Accuracy
SUMMARY CLASS	Water/Whitewash	71.4%	100.0%
	Beach	83.3%	90.9%
	Mixed Red-Brown	95.3%	87.2%
	Tide/Shadow	66.7%	100.0%
	Terrestrial	100.0%	100.0%
	Rock	85.7%	85.7%
	Wrack	100.0%	75.0%
	Kelp	93.8%	100.0%
	BlueGreen Algae	45.5%	83.3%
	Green Algae	0.0%	0.0%
	Cobble	100.0%	50.0%
	Man-Made	100.0%	100.0%
	Driftwood	0.0%	0.0%

Overall Accuracy	
Total Accurate	98
Overall Accuracy	86.0%

2.3 Database Overview

As expected, the MPA substrate classifications revealed major trends linked to the types of MPAs. For example, red/brown algae dominated the intertidal zones of rocky coastal MPAs while eel grass and green algae were major vegetation classes in most of the estuarine and bay MPAs. The data base also reveals, however, major differences in substrate composition between MPAs of the same type. **Table 3** lists the class compositions of regions classified within each MPA, both as total area for each class that was classifiable from the imagery, and as a percentage of total classifiable area within each MPA. It is important to note that the values refer only to inter 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. This fact is important when consulting the data base 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, surf grass tends to not be fully represented in the classifications of rocky coastline areas since 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.

Despite the above considerations, the data base represents the most spatially comprehensive and highest resolution survey of the entire NCC region 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 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.

The substrate classes of the data base 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 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 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 data base thus represents a coarser classification scheme (but much more spatially complete) than site-specific field surveys. If a cross-correlation comparison is desired, the field sampling-based classifications can be "degraded" to the remote sensing-based classes for the analysis. In addition to the important data base applications noted above, the data base will 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.

Table 3.1.

Classified substrate composition for the sampled NCC MPAs. The percentages represent total portions of each substrate class from total area classified within each MPA – i.e. areas covered by whitewater or impenetrable water column were not included in the total.

MPA	OrthoQuad	Sandy Beach		Mixed Red / Brown		Tidepool / Shadow	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	1332.72	0.9%	69991.30	48.9%	29.41	0.0%
Sea Lion Cove SMCA	Point Arena	1356.92	1.3%	21705.90	20.0%	745.46	0.7%
Saunders Reef SMCA	Saunders Reef	2557.86	0.5%	177630.00	32.3%	53391.50	9.7%
Del Mar Landing SMR	Stewarts Point	860.28	2.0%	29147.60	67.1%	862.05	2.0%
Stewarts Point SMR	Stewarts Point	18675.20	3.3%	254832.00	44.6%	10626.00	1.9%
Salt Point SMP	Plantation	7058.24	2.0%	81307.40	23.6%	1453.09	0.4%
Gerstle Cove SMR	Plantation	225.97	2.0%	7406.87	64.2%	113.43	1.0%
Russian River SMCA	Arched Rock	137295.00	77.7%	21771.70	12.3%	972.18	0.5%
Bodega Head SMR	Bodega Head	53414.30	34.3%	55606.40	35.7%	3874.47	2.5%
Bodega Head SMCA	Bodega Head	188.61	1.4%	9100.89	69.0%	224.55	1.7%
Point Reyes SMR	Drakes Bay	581009.00	74.5%	95389.60	12.2%	12644.70	1.6%
Duxbury SMP	Bolinas	58326.30	12.1%	379263.00	79.0%	402.43	0.1%
Montara SMR	Montara Mountain	40651.50	8.7%	402879.00	86.0%	3801.54	0.8%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	12775.00	6.2%	0.00	0.0%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	35667.70	41.9%	0.00	0.0%	0.00	0.0%
Estero de San Antonio SMRMA	Valley Ford	38042.60	34.5%	0.00	0.0%	4620.08	4.2%
Drakes Estero SMCA	Drakes Bay	67391.30	1.6%	0.00	0.0%	25835.80	0.6%
Estero de Limantour SMR	Drakes Bay	22039.30	1.1%	0.00	0.0%	49386.30	2.4%

MPA	OrthoQuad	Terrestrial Veg.		Unvegetated Rock		Wrack	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	609.02	0.4%	15981.80	11.2%	48.42	0.0%
Sea Lion Cove SMCA	Point Arena	13985.70	12.9%	15499.50	14.3%	84.30	0.1%
Saunders Reef SMCA	Saunders Reef	4130.35	0.8%	28050.10	5.1%	86.30	0.0%
Del Mar Landing SMR	Stewarts Point	194.19	0.4%	7787.12	17.9%	98.44	0.2%
Stewarts Point SMR	Stewarts Point	5064.25	0.9%	68205.30	11.9%	1779.05	0.3%
Salt Point SMP	Plantation	187.02	0.1%	12912.80	3.7%	493.59	0.1%
Gerstle Cove SMR	Plantation	12.31	0.1%	980.70	8.5%	9.27	0.1%
Russian River SMCA	Arched Rock	1489.43	0.8%	3489.82	2.0%	3220.31	1.8%
Bodega Head SMR	Bodega Head	258.21	0.2%	8132.13	5.2%	2577.36	1.7%
Bodega Head SMCA	Bodega Head	9.44	0.1%	1496.08	11.3%	0.00	0.0%
Point Reyes SMR	Drakes Bay	6780.39	0.9%	43472.50	5.6%	506.46	0.1%
Duxbury SMP	Bolinas	242.16	0.1%	36213.30	7.5%	1186.07	0.2%
Montara SMR	Montara Mountain	882.62	0.2%	19657.60	4.2%	77.93	0.0%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	24365.70	11.8%	453.87	0.2%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	20614.70	24.2%	62.50	0.1%	7.75	0.0%
Estero de San Antonio SMRMA	Valley Ford	23579.10	21.4%	323.38	0.3%	0.00	0.0%
Drakes Estero SMCA	Drakes Bay	73742.30	1.7%	0.00	0.0%	0.00	0.0%
Estero de Limantour SMR	Drakes Bay	51070.30	2.5%	0.00	0.0%	0.00	0.0%

Table 3.2.

Classified substrate composition for the sampled NCC MPAs. The percentages represent total portions of each substrate class from total area classified within each MPA – i.e. areas covered by whitewater or impenetrable water column were not included in the total.

MPA	OrthoQuad	Kelp / Brown Algae		Blue-Green Algae		Green Algae	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	55194.60	38.5%	0.00	0.0%	0.00	0.0%
Sea Lion Cove SMCA	Point Arena	54877.60	50.7%	0.00	0.0%	0.00	0.0%
Saunders Reef SMCA	Saunders Reef	277749.00	50.5%	0.00	0.0%	0.00	0.0%
Del Mar Landing SMR	Stewarts Point	2449.93	5.6%	1987.68	4.6%	0.00	0.0%
Stewarts Point SMR	Stewarts Point	145524.00	25.5%	63943.80	11.2%	0.00	0.0%
Salt Point SMP	Plantation	201604.00	58.4%	39913.50	11.6%	0.00	0.0%
Gerstle Cove SMR	Plantation	396.18	3.4%	2337.02	20.3%	0.00	0.0%
Russian River SMCA	Arched Rock	122.00	0.1%	2621.66	1.5%	0.00	0.0%
Bodega Head SMR	Bodega Head	433.60	0.3%	31152.20	20.0%	0.00	0.0%
Bodega Head SMCA	Bodega Head	2178.15	16.5%	0.00	0.0%	0.00	0.0%
Point Reyes SMR	Drakes Bay	3694.57	0.5%	31265.50	4.0%	0.00	0.0%
Duxbury SMP	Bolinas	53.12	0.0%	0.00	0.0%	0.00	0.0%
Montara SMR	Montara Mountain	0.00	0.0%	0.00	0.0%	0.00	0.0%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	0.00	0.0%	0.00	0.0%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	0.00	0.0%	0.00	0.0%	0.00	0.0%
Estero de San Antonio SMRMA	Valley Ford	0.00	0.0%	0.00	0.0%	0.00	0.0%
Drakes Estero SMCA	Drakes Bay	0.00	0.0%	0.00	0.0%	152142.00	3.5%
Estero de Limantour SMR	Drakes Bay	0.00	0.0%	0.00	0.0%	534497.00	26.2%

MPA	OrthoQuad	Cobble		Man-made		Driftwood	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	9.95	0.0%	0.00	0.0%	0.00	0.0%
Sea Lion Cove SMCA	Point Arena	68.51	0.1%	0.00	0.0%	0.00	0.0%
Saunders Reef SMCA	Saunders Reef	5843.86	1.1%	0.00	0.0%	106.89	0.0%
Del Mar Landing SMR	Stewarts Point	0.00	0.0%	0.00	0.0%	0.00	0.0%
Stewarts Point SMR	Stewarts Point	1997.95	0.3%	0.00	0.0%	14.76	0.0%
Salt Point SMP	Plantation	7.29	0.0%	0.00	0.0%	0.00	0.0%
Gerstle Cove SMR	Plantation	58.90	0.5%	0.00	0.0%	0.00	0.0%
Russian River SMCA	Arched Rock	0.00	0.0%	362.00	0.2%	4612.10	2.6%
Bodega Head SMR	Bodega Head	0.00	0.0%	13.52	0.0%	18.39	0.0%
Bodega Head SMCA	Bodega Head	0.00	0.0%	0.00	0.0%	0.00	0.0%
Point Reyes SMR	Drakes Bay	2451.96	0.3%	1842.59	0.2%	90.57	0.0%
Duxbury SMP	Bolinas	0.00	0.0%	0.00	0.0%	0.00	0.0%
Montara SMR	Montara Mountain	647.44	0.1%	38.07	0.0%	0.00	0.0%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	0.00	0.0%	1599.80	0.8%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	0.00	0.0%	0.00	0.0%	0.00	0.0%
Estero de San Antonio SMRMA	Valley Ford	0.00	0.0%	0.00	0.0%	0.00	0.0%
Drakes Estero SMCA	Drakes Bay	0.00	0.0%	31465.80	0.7%	0.00	0.0%
Estero de Limantour SMR	Drakes Bay	0.00	0.0%	0.00	0.0%	0.00	0.0%

Table 3.3.

Classified substrate composition for the sampled NCC MPAs. The percentages represent total portions of each substrate class from total area classified within each MPA – i.e. areas covered by whitewater or impenetrable water column were not included in the total.

MPA	OrthoQuad	Surf Grass		Eel Grass		Unknown Aquatic Veg	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	0.00	0.0%	0.00	0.0%	0.00	0.0%
Sea Lion Cove SMCA	Point Arena	0.00	0.0%	0.00	0.0%	0.00	0.0%
Saunders Reef SMCA	Saunders Reef	0.00	0.0%	0.00	0.0%	0.00	0.0%
Del Mar Landing SMR	Stewarts Point	54.00	0.1%	0.00	0.0%	0.00	0.0%
Stewarts Point SMR	Stewarts Point	425.00	0.1%	0.00	0.0%	0.00	0.0%
Salt Point SMP	Plantation	73.00	0.0%	0.00	0.0%	0.00	0.0%
Gerstle Cove SMR	Plantation	0.00	0.0%	0.00	0.0%	0.00	0.0%
Russian River SMCA	Arched Rock	830.00	0.5%	0.00	0.0%	0.00	0.0%
Bodega Head SMR	Bodega Head	80.00	0.1%	0.00	0.0%	0.00	0.0%
Bodega Head SMCA	Bodega Head	0.00	0.0%	0.00	0.0%	0.00	0.0%
Point Reyes SMR	Drakes Bay	895.29	0.1%	0.00	0.0%	0.00	0.0%
Duxbury SMP	Bolinas	4590.00	1.0%	0.00	0.0%	0.00	0.0%
Montara SMR	Montara Mountain	0.00	0.0%	0.00	0.0%	0.00	0.0%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	0.00	0.0%	44887.60	21.7%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	0.00	0.0%	6517.23	7.7%	0.00	0.0%
Estero de San Antonio SMRMA	Valley Ford	0.00	0.0%	7333.45	6.7%	0.00	0.0%
Drakes Estero SMCA	Drakes Bay	0.00	0.0%	1784940.00	41.6%	0.00	0.0%
Estero de Limantour SMR	Drakes Bay	0.00	0.0%	331051.00	16.2%	0.00	0.0%

MPA	OrthoQuad	Salt Marsh Veg		Submerged Aquatic Veg		Mud Flat	
INTERTIDAL ZONES		Area (m^2)	% Area	Area (m^2)	% Area	Area (m^2)	% Area
Point Arena SMR	Point Arena	0.00	0.0%	0.00	0.0%	0.00	0.0%
Sea Lion Cove SMCA	Point Arena	0.00	0.0%	0.00	0.0%	0.00	0.0%
Saunders Reef SMCA	Saunders Reef	0.00	0.0%	0.00	0.0%	0.00	0.0%
Del Mar Landing SMR	Stewarts Point	0.00	0.0%	0.00	0.0%	0.00	0.0%
Stewarts Point SMR	Stewarts Point	0.00	0.0%	0.00	0.0%	0.00	0.0%
Salt Point SMP	Plantation	0.00	0.0%	0.00	0.0%	0.00	0.0%
Gerstle Cove SMR	Plantation	0.00	0.0%	0.00	0.0%	0.00	0.0%
Russian River SMCA	Arched Rock	0.00	0.0%	0.00	0.0%	0.00	0.0%
Bodega Head SMR	Bodega Head	0.00	0.0%	0.00	0.0%	0.00	0.0%
Bodega Head SMCA	Bodega Head	0.00	0.0%	0.00	0.0%	0.00	0.0%
Point Reyes SMR	Drakes Bay	0.00	0.0%	0.00	0.0%	0.00	0.0%
Duxbury SMP	Bolinas	0.00	0.0%	0.00	0.0%	0.00	0.0%
Montara SMR	Montara Mountain	0.00	0.0%	0.00	0.0%	0.00	0.0%
BAYS, RIVERS, ESTUARIES							
Russian River SMR	Duncans Mills	121859.00	58.9%	834.50	0.4%	0.00	0.0%
Estero Americano SMRMA	Valley Ford	22321.00	26.2%	0.00	0.0%	0.00	0.0%
Estero de San Antonio SMRMA	Valley Ford	18112.50	16.4%	18106.90	16.4%	0.00	0.0%
Drakes Estero SMCA	Drakes Bay	518540.00	12.1%	0.00	0.0%	1784030.00	41.6%
Estero de Limantour SMR	Drakes Bay	373804.00	18.3%	0.00	0.0%	1214560.00	59.5%

2.4 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 Dr. Tony Hale of the California Ocean Science Trust 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 raster image files were delivered in both ERDAS Imagine (.img) and GeoTif (.tif) format. The habitat classifications were delivered as both ERDAS Imagine (.img) and ESRI shapefiles. The kelp persistence maps were delivered as ERDAS Imagine (.img) and Adobe Acrobat (.PDF) files. PDF files showing the habitat classifications for each USGS orthoquad region were also uploaded to the OceanSpaces server. This was done, in part, to facilitate the upload of the metadata in the requested Environmental Markup Language (EML) format to OceanSpaces. Ocean Imaging will work closely with Dr. Hale and the California Ocean Science Trust to ensure the availability of 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. Additionally, browse-style images of the intertidal, kelp and bay/estuary classifications in PDF format were uploaded to the OceanSpaces.org web site along with metadata referring to the deliverables in the required EML format as outlined in the document http://oceanspaces.org/sites/default/files/NCC_metadata_standards_Jul2011.pdf.

3. Financial Details

3.1 Financial Discussion

The project was completed with the original budget. The data acquisition flights in 2010 were not as costly as originally estimated, however, and a reallocation was requested and received by OI to carry over unused flight charter funds into the second year. Some of these funds were used in attempts to conduct the 2011 kelp survey and reflight of Drake's Estero, both of which were unsuccessful due to excessive fog conditions on multiple days when the plane was brought on-location from San Diego. As is described above, the addition of the Fugro ADS-40 and Lidar data sets required significant additional processing labor that was not planned for in the original proposal. Therefore, a rebudget from the project's second into third year was done to shift the unused aircraft cost funds into labor categories commensurate with the additional processing and analysis load. Details of the rebudgetting can be found in a separately submitted financial report.

4. References

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Appendix 1 - Deliverables' Metadata

NCC_Aerial_ArchedRock_20100326_DMSC_RGBNIR.img

Raster Dataset

Thumbnail Not Available

Tags

environment, Northern California Coast, oceans, biota, imagery, base maps, Earth cover, California, Sea Grant, MPA, kelp, multispectral imagery, MPA Baseline Program, substrate, ADS40, DMSC, Ocean Imaging

Summary

This raster dataset was developed for the Sea Grant MPA Baseline Program as part of the project "High Resolution Nearshore Substrate Mapping and Persistence with Multispectral Aerial Imagery" (#R/MPA17 09-015). The study region is the California North Central Coast (NCC). Ocean Imaging acquired this imagery on 03/26/2010 using the Digital Multispectral Camera (DMSC). Details on this system and the data processing are below in the Lineage section of this document. Individual DMSC scenes were mosaicked into sections based on the USGS orthoquads for the California North Central Coast region in order to generate the multispectral image product. The MPAs contained in each of the USGS orthoquads are outlined in a table in the Lineage section of this document. These imagery were subsequently used to generate habitat classification thematic maps of the for the California North Central Coast's intertidal region and kelp beds from Pigeon Point up to Point Arena, including select bays and river mouths designated as MPAs. Description

Description

This raster image dataset represents mosaicked, multi-spectral imagery in the red, green, blue and near-infrared (RGB,NIR) spectral bands, targeting giant kelp beds and the intertidal zone along the California North Central Coast region from Pigeon Point up to Point Arena, including select bays and river mouths designated as MPAs.

Credits

There are no credits for this item.

Use limitations

TBD by MPA Baseline Program

ArcGIS Metadata ▶

Topics and Keywords ▶

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

PLACE KEYWORDS Northern California Coast

Hide Topics and Keywords ▲

Citation ▶

* TITLE NCC_Aerial_ArchedRock_20100326_DMSC_RGBNIR.img

PRESENTATION FORMATS digital image

Hide Citation ▲

Citation Contacts ►

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

Contact information ►
Phone
Voice 303-948-5272

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

Online resource
Location http:\\www.oceani.con

Hours of service M-F 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 Microsoft Windows Vista Version 6.0 (Build 6001) Service Pack 1; ESRI ArcGIS 10.0.3.3600

ArcGIS item properties
* Name NCC_Aerial_ArchedRock_20100326_DMSC_RGBNIR.img
* Location file://\\NAS-OI-02\Projects\SG_NCC\Data\Delivery4_4_13\Imagery\DMSC\img\NCC_Aerial_ArchedRock_20100326_DMSC_RGBNIR.img
* Access protocol Local Area Network
* Content type Downloadable Data

Hide Resource Details ▲

Extents ►

Extent
Geographic extent
Bounding rectangle
West longitude -123.22693
East longitude -123.117789
South latitude 38.429949
North latitude 38.507244

Extent
Geographic extent
Bounding rectangle
Extent type Extent used for searching
* West longitude-123.226930
* East longitude-123.117789
* North latitude38.507244
* South latitude38.429949
* Extent contains the resourceYes

Extent in the item's coordinate system
* West longitude480214.151201
* East longitude489719.151201
* South latitude4253544.793488
* North latitude4262103.793488
* Extent contains the resourceYes

Hide Extents ▲

Resource Points of Contact ►

Point of contact
Individual's nameMark Hess and Keith Jackson
Organization's nameOcean Imaging
Contact's role point of contact

Contact information ►
Phone
VoiceЗ03-948-5272

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Delivery point13976 W. Bowles Ave. Ste 100
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Online resource
Locationwww.oceani.com

Hours of serviceM-F 9:00 AM - 5:00 PM
Hide Contact information ▲

Hide Resource Points of Contact ▲

Resource Maintenance ►

Resource maintenance
Update frequency not planned

Hide Resource Maintenance ▲

Resource Constraints ►

Constraints
Limitations of use
TBD by MPA Baseline Program

Hide Resource Constraints ▲

Spatial Reference ►

ArcGIS coordinate system

* Type Projected
* Geographic coordinate reference GCS_WGS_1984
* Projection WGS_1984_UTM_Zone_10N
* Coordinate reference details

Projected coordinate system

Well-known identifier 32610
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
Well-known text 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”,0.0174532925199433]],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],AUTHORITY[“EPSG”,32610]]

Reference system identifier

* Value 32610
* Codespace EPSG
* Version 7.4.1

Hide Spatial Reference ▲

Spatial Data Properties ►

Georectified Grid ►

* Number of dimensions 2

Axis dimensions properties

Dimension type row (y-axis)

* Dimension size 8559
* Resolution 1.000000 Meter

Axis dimensions properties

Dimension type column (x-axis)

* Dimension size 9505
* Resolution 1.000000 Meter

* Cell geometry area
* Point in pixel center

* Transformation parameters are available Yes

* Check points are available No

Corner points
* Point480214.151201 4253544.793488
GML Properties
Unique identifierID0ERFAC
* Point480214.151201 4262103.793488
GML Properties
Unique identifierID0ELFAC
* Point489719.151201 4262103.793488
GML Properties
Unique identifierID0EFFAC
* Point489719.151201 4253544.793488
GML Properties
Unique identifierID0E6EAC

* Center point484966.651201 4257824.293488

Hide Georectified Grid ▲

ArcGIS Raster Properties ►
General Information
* Pixel depth16
* Compression typeRLE
* Number of bands4
* Raster formatIMAGINE Image
* Source typecontinuous
* Pixel typeunsigned integer
* No data value0
* Has colormapNo
* Has pyramidsYes

Hide ArcGIS Raster Properties ▲

Hide Spatial Data Properties ▲

Spatial Data Content ►

Image Description
* Type of information image

Band information
* DescriptionLayer_1
* Maximum value4350.000000
* Minimum value69.000000
Units
* SymbolMeter
Codespace http://aurora.regenstrief.org/UCUM

GML Properties
Unique identifierDAF1A554-27F1-44EC-8C8D-C54A28520909
IdentifierUnified Code of Units of Measure
CodespaceGML_UomSymbol

* Number of bits per value16

Band information
- * Description Layer_2
- * Maximum value 5119.000000
- * Minimum value 70.000000
- Units
  - * Symbol Meter
- * Number of bits per value 16

Band information
- * Description Layer_3
- * Maximum value 5163.000000
- * Minimum value 47.000000
- Units
  - * Symbol Meter
- * Number of bits per value 16

Band information
- * Description Layer_4
- * Maximum value 1325.000000
- * Minimum value 15.000000
- Units
  - * Symbol Meter
- * Number of bits per value 16

Triangulation has been performed No
Radiometric calibration is available No
Camera calibration is available No
Film distortion information is available No
Lens distortion information is available No

Hide Spatial Data Content ▲

Lineage ►

Lineage statement

See Data Source and Processing Step below

Process step ►

Description Data Processing: Upon completion of each flight, image data were downloaded from the DMSC onto an in-house computer hard drive and 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. Image Georeferencing/Mosaicking: 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 adjusted (shifted and or rotated) where needed. Adjusted frames were then mosaicked into USGS orthoquad regions with a 1 meter GSD for more efficient classification and data management using ERDAS Imagine. Mosaicked imagery was then used to generate the habitat classification products. Final image mosaic files have been delivered to Sea Grant and Ocean Spaces in both ERDAS Imagine (.img) and GeoTif (.tif) formats.

Hide Process step ▲

Source data ▶

Description Ocean Imaging (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 and 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. OI used a filter combination of 451-551-710-850 nm Data Acquisition: Imagery for the California North Central Coast was acquired on 03/26/2010 at an altitude of 6500 feet with 60% scene overlap resulting in an initial ground sampling distance of 0.93 meters. Imagery was acquired from a Cessna 206 aircraft by Ocean Imaging staff.

Hide Source data ▲

Source data ▶

Description MPAs Contained in USGS Orthoquad Regions: Point Arena Quad contains: Point Arena SMCA and Point Arena SMR; Saunders Reef Quad contains: Saunders Reef SMCA; Stewarts Point Quad contains: Del Mar Landing SMR and Stewarts Point SMR; Plantation Quad contains: Stewarts Point SMR and Salt Point SMP; Arched Rock Quad contains: Russian River SMCA and Russian River SMR; Duncans Mills Quad contains: Russian River SMR; Bodega Head Quad contains: Bodega Head SMR, Bodega Head SMCA and Estero Americano SMRMA; Valley Ford Quad contains: Estero Americano SMRMA and Estero de San Antonio SMRMA; Drakes Bay Quad contains: Drakes Estero SMCA, Estero de Limantour SMR, Point Reyes SMR and Point Reyes SMCA; Bolinas Quad contains: Duxbury SMP; Montara Mountain Quad contains: Montara SMR; Half Moon Bay Quad contains: Pillar Point SMCA

Hide Source data ▲

Hide Lineage ▲

Geoprocessing history ▶

Process

Process name

Date 2011-10-24T10:44:05

Tool location C:\Program Files\ArcGIS\Desktop10.0\ArcToolbox\Toolboxes\Data Management Tools.tbx\Clip

Command issued

```
Clip arched_dmsc_preclip.img "105015.461637981 2623618.74768058 5448343.45558165
6546975.39424744" Y:\SG_NCC\Data\Rasters\Mosaics\DMSC\ArchedRock_dmsc.img quad24 #
ClippingGeometry
```

Hide Geoprocessing history ▲

Distribution ▶

Distribution format

* Format name Raster Dataset

Hide Distribution ▲

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 2013-04-18

ArcGIS metadata properties
Metadata format ArcGIS 1.0
Standard or profile used to edit metadata FGDC

Created in ArcGIS 2013-03-14T13:36:14
Last modified in ArcGIS 2013-04-18T15:11:24

Automatic updates
Have been performed Yes
Last update 2013-04-18T15:11:24

Item location history
Item copied or moved 2013-03-14T13:36:14
From N:\SG_NCC\Data\Deliverables\Imagery\DMSC\tif\ArchedRock_dmsc.img
To \\192.168.0.6\Projects\SG_NCC\Data\Deliverables\Imagery\DMSC\img\ArchedRock_dmsc.img

Hide Metadata Details ▲

Metadata Contacts ►

Metadata contact
Individual's name Mark Hess and Keith Jackson
Organization's name Ocean Imaging
Contact's role point of contact

Contact information ►
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Voice 303-948-5272

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

Online resource
Location www.oceani.com

Hours of service M-F 9:00 AM - 5:00 PM
Hide Contact information ▲

Hide Metadata Contacts ▲

Metadata Maintenance ►

MAINTENANCE

UPDATE FREQUENCY not planned

Hide Metadata Maintenance ▲

Metadata Constraints ►

CONSTRAINTS

LIMITATIONS OF USE

TBD by MPA Baseline Program Managers

Hide Metadata Constraints ▲