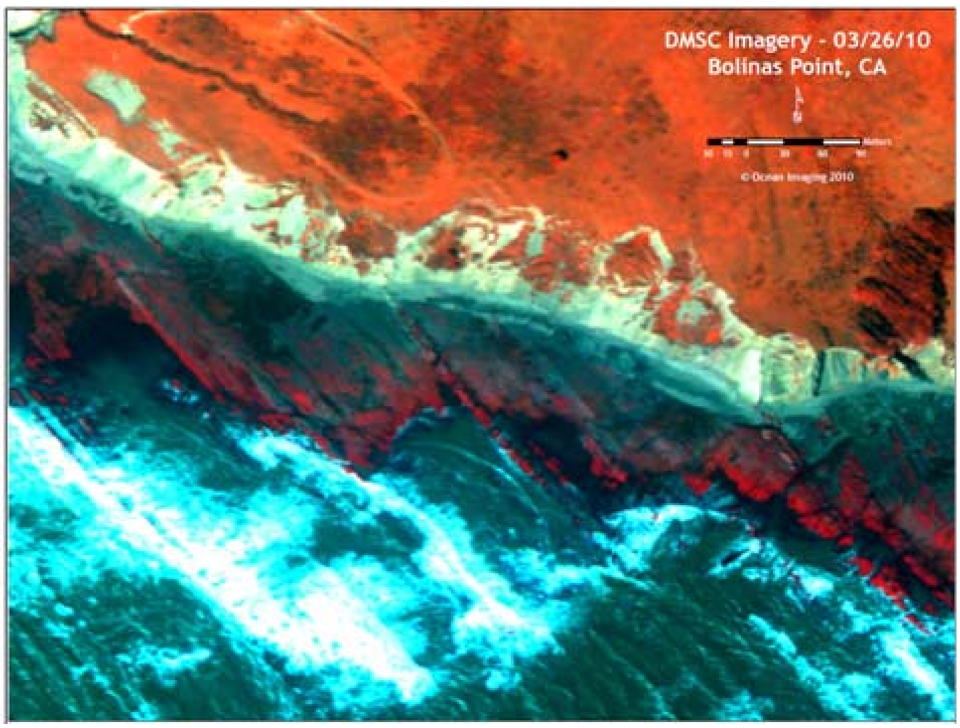
High Resolution Nearshore Substrate Mapping and Persistence Analysis with Multi-spectral Aerial Imagery.

1st Project Year Annual Report
Submitted to the California Sea Grant Program
Grant no: MPA 09-015
CA Sea Grant Account #: SEA 4995
Project Number: R/MPA-17

15 May, 2011



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1st Project Year Annual Report

Project Leader: Dr. Jan Svejkovsky

This report summarizes the activities and milestone status reached during our project's first year: March, 2010 through March 2011.

Original Project Objectives: As per the original proposal, this project's first year primarily concentrated on multiple aerial image data collections. Also part of the first year's work plan was the processing of the intertidal substrate imagery for substrate classes, and initiation of processing of the estuary imagery and kelp canopy distributions acquired in fall, 2010. Also planned for spring-summer, 2010 was some field sampling work to be used for calibrating the image classification algorithms and validation of the final map products. Below is the project's milestone chart as included in the original proposal. Progress achieved on the individual Milestones is discussed in the following sections.

Task	2010												2011												2012											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Intertidal Substrate Data Acquisition		←	—	→																																
Estuary Data Acquisition			←	—	→																						←	—	→							
Intertidal Substrate Data Processing				←	—	—	—	—	—	—	—	—	→																							
Estuary Data Processing							←	—	—	—	—	—	—	—	—	—	—	→										←	—	—	—	→				
Field Data Acquisition			←	—	→										←	—	→									←	—	→								
Kelp Data Acquisition										←	→											←	→													
Kelp Data Processing												←	—	—	—	→								←	—	—	—	→								
Kelp Persistence Analysis																←	—	—	—	—	—	→														
Estuary Variability Analysis																													←	—	→					
Reports												*X*												*X*									*X*			

Intertidal Substrate Data Acquisition: The objective was to acquire multispectral imagery along the entire North Central California (NCC) coastline under low tide conditions, exposing as much of the intertidal zone as possible. Because sunglint negatively affects image data over wet or subsurface areas, the imaging had to be done under low sun angle conditions (i.e. morning or afternoon). For useful imagery to be obtained three factors thus had to coincide: maximal low tides during morning or afternoon hours under cloudfree weather conditions. Ocean Imaging (OI) was able to take advantage of such conditions on 26 March, 2010 and collected imagery over the entire NCC coastal region at 1m spatial resolution, as per the original proposal. The data quality is good, however, a large wave filed caused high surf and hence whitewater areas to cover 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.

Estuary Data Acquisition: As per the original proposal, the following estuary regions were to be imaged:

- Russian River Estuary
- Estero Americano
- Estero de San Antonio
- Drake's Estero
- Estero de Limantour

All of these target areas were successfully imaged under low tide conditions during 26 and 27 March, 2010. Data are of high quality.

Intertidal Substrate Data Processing: OI's aerial imaging system consists of a 4-channel, 12-bit DMSC-MkII imager (manufactured by Specterra Ltd. In Australia) integrated with a DGPS/IMU positioning unit (made by Oxford Technologies in England). The DMSC's 4 channels' wavelengths can be customized using narrow-band interference filters. Based on previous experimental work in intertidal and estuarine areas, OI configured the imager with 450, 551, 640 and 780nm bands to best maximize substrate separation. The individual image frames first have to be georeferenced and mosaicked into contiquous image sections, on which the substrate classification algorithms are then applied. The image frames were autogeoreferenced using positioning information from the Oxford IMU. Due to the high resolution of the data (and the importance of being able to match to it field samples with potentially high spatial variability) the image frames were further manually geo corrected using a USGS accuracy standard 1m baseline image layer.

The basic principle of the substrate classification processing is to utilize a multispectral algorithm that compares reflectance differences from the 4 available wavelengths and assigns each pixel in 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 NCC data sets contains a number of effects that complicate such processing: First, in order to maximize an algorithms class separation efficiency, it is usually important to isolate the zone of interest from other image sections which may contain great spectral variability but do not contribute to the classes sought. In the NCC intertidal case, terrestrial areas above the high water line are of no interest and should be masked. This proved to be difficult and ultimately time consuming since no "coastline" data base appears to exist with sufficient resolution to separate the terrestrial and intertidal zones in that region. Second, many sections of the NCC coast contain cliffs and other very high relief features which cause shadows that, in turn, locally alter the reflectance characteristics of the underlying substrate. Third, the aforementioned whitewater features from the high surf conditions increased potential artifacts in the classification (e.g. separating whitewater from bright sand beach areas).

The above considerations resulted in OI's expending significantly more effort on the initial classification algorithm development selection and testing (no readily available algorithm proved satisfactory). Upon rigorous testing, the entire intertidal data set is being classified, with a completed classification product for the entire region being finished before the end of May, 2011.

Following the classification processing, field samples are used to provide information on the specific nature of each derived class. This may simply be a class label assignment (e.g. Ulva sp.) but often also results in several classes being combined into a single, more general class that consistently represents the same substrate throughout the large data set (e.g. red algae-covered rock). Figure 1. shows a sample of initial classifications over part of the NCC coastline. Comparisons of such image classification attempts with some field data samples and photos made available to OI from other researchers (see Field Sampling section below) suggest that the 1m spatial resolution of the 2010 image data may not be adequate to resolve the relatively small spatial extents of some substrate types in areas of high interest to other researchers and the Marine Protected Area baseline data base. It is therefore OI's intent to enhance, during the project's second year, the original classification data set with additional, higher resolution classifications based on additional, higher resolution aerial imagery. At the time of this report, two sources are planned: 1) additional flights by OI's team over selected portions of the NCC coast with the DMSC imagery yielding imagery with 35-40cm resolution; 2) utilization of 35cm color aerial digital photogrammetry products over some of the NCC regions collected (and offered to OI at no cost) by Fugro EarthData in 2010. The OI flights will be coordinated with simultaneous field sampling by OI and research teams led by Dr. Pete Raimondi.

As is explained in the "Field Data Acquisition" section below, the spring-summer 2010 field data sampling efforts originally planned for the project's first year were not accomplished. Hence, the finalized classification labeling and validation will be done during the project's second year.

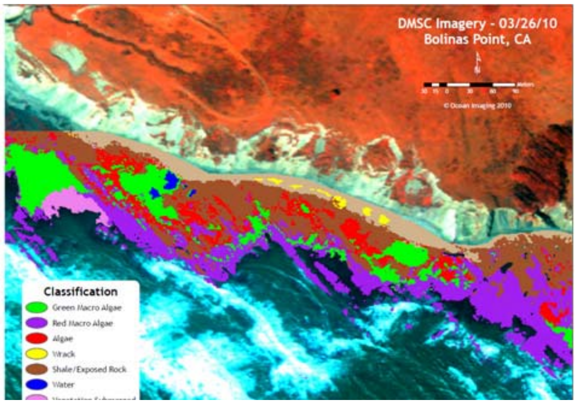

Figure 1. Sample of initial intertidal substrate classification map of the Bolinas Point area derived from 1m multispectral aerial imagery.

Estuary Data Processing: Processing of the estuary image data follows closely the steps outlined for the coastal intertidal data outlined in the preceding section. The one important difference is that water clarity was considerably better in the estuary areas than along the ocean shoreline, allowing the classification of both exposed and submerged bottom substrate. At the end of the project's first year, processing of the estuary data sets was somewhat ahead of the originally planned schedule, with most of the sets having been fully processed and classified. A substrate classification of Drake's Estero, the largest of the targeted estuaries, is shown in Figure 2. As is the case with the shoreline intertidal regions, field sampling of the estuary regions for calibration and validation is planned for summer 2011.

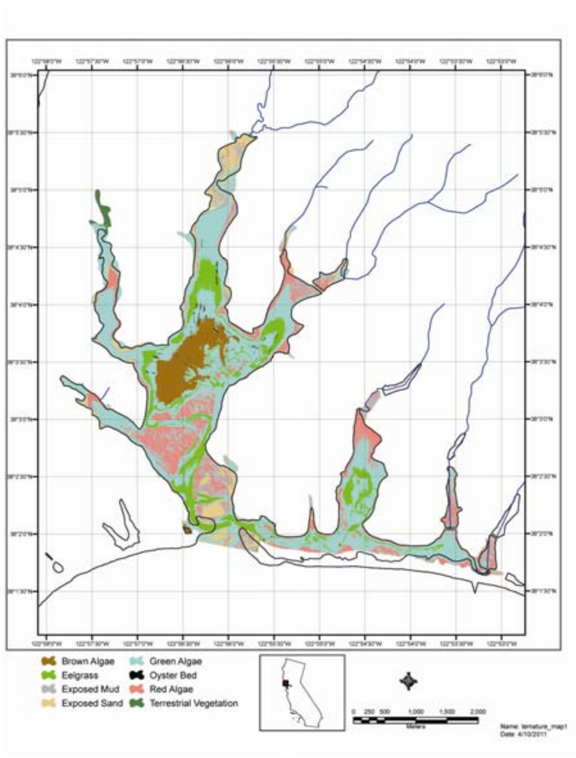

Figure 2. Initial inter and subtidal substrate classification of Drake's Estero derived from multispectral aerial imagery.

Field Data Acquisition: On 1 May, 2010 the entire OI technical team was called on by NOAA and British Petroleum to utilize OI's aerial imagers to assist in response to the massive Deepwater Horizon oil spill in the Gulf of Mexico. OI's team flew missions on a daily basis throughout the summer until the end of July. This unforeseen event prevented OI to have the needed staff resources to conduct the planned field work in the NCC region. The field work was thus postponed into summer 2011 and we are presently planning these activities for late-June to July in collaboration with field teams led by Dr. Pete Raimondi. Some initial field data for sites within the NCC region established by the Raimondi group were made available to OI and were used to guide the initial classification processing.

Kelp Data Acquisition: The entire NCC coastal region was imaged for kelp canopy on 11/3-4/2010. Excessively cloudy weather prevented the acquisitions to take place in October, as was originally hoped, however the image data were obtained prior to any major storms passing through the region. As was the case with the intertidal data flights, a large wave field existed at the time.

Kelp Data Processing: Initial kelp imagery processing is the same as with the intertidal and estuarine data sets. The georeferenced, mosaicked imagery is then classified for surface and, where possible, submerged kelp canopy. As per original schedule, the kelp data classifications are on-track to be completed in the early part of the project's second year. Initial examination of the imagery revealed relatively very sparse kelp features, which caused concern that the data may not be representative of the actual 2010 kelp existence in the NCC region earlier in the year. For this reason, OI attempted to obtain high resolution satellite imagery of the region taken during earlier months (July – September) to ascertain whether the paucity of kelp in the aerial data reflected the year's general conditions or whether large amounts of kelp were lost to environmental conditions shortly before the overflights. (Although not usable for quantitative work, satellite imagery from such satellites sensors as Landsat eTM (27m resolution) or Spot (10-15m resolution) provide enough detail to discern the existence of kelp over the larger beds.) Only very limited satellite data were available for assessment due to the anomalous extensive cloud cover that dominated both the NCC region and the entire west coast during summer, 2010. The data available also showed very sparse kelp distributions.

Kelp Persistence Analysis: This task was originally planned to be done in the project's second year. However, in conjunction with the assessment of the relative lack of kelp in the 2010 aerial imagery, OI began work on the persistence analysis at the end of Year 1. Initial comparisons of aerial imaging-based annual fall-time kelp canopy classifications obtained from the California Dept. of Fish & Game for several years in the past decade show that kelp abundance in the NCC region undergoes extreme variability. Unlike along California's coast further to the south where established kelp beds tend to retain at least their core portions during each year, our analysis to-date shows that NCC beds may completely disappear in some years, as judged from the fall-time (i.e. imagery was collected between late September and early November) surveys. Figure 3 shows kelp canopies along a representative section of the NCC coastline in 2004, 2005, 2008 and 2010 (this project's survey). The sparcity of kelp noted in 2010 is quite comparable to conditions that existed in 2005. On the other hand, the kelp bed recorded in 2010 in the middle of the sample region had not existed in any of the previous survey years. OI is continuing work on the kelp persistence analysis, with data from at least 10 additional years being available.

Figure 3. Portion of the NCC coastline showing kelp canopy extents from fall-time surveys in 2004, 2005, 2008 and 2010.

Project's Financial Summary: The project finished its first year slightly under budget, with a total of $113,934.55 billed to Sea Grant out of originally budgeted $115,781. Original allocations for associate (non-PI) labor were exceeded somewhat due to the extra processing labor needs encountered with the intertidal data sets. On the other hand, aircraft charter and related costs associated with the aerial image data collection missions were less than anticipated. Sea Grant was made aware of this and with their approval the unused aircraft funds were appropriated to Year 2 where they will be utilized to conduct the additional high resolution data collections as was described above.

As matching fund contributions, OI proposed to directly co-fund all overhead and travel costs, originally budgeting Year 1 co-funding at $31,221. Actual co-funding (using the audited 26% OH rate) totaled $31,965.42. The following table summarizes the project's Year 1 budget status:

Category Reimbursement	**Category Budget (Total Grant)**	**Total SG Cost to Date (Year 1)**	**Remaining Balance (Total Grant)**	**Co-Funding OI share**
Salaries Project Leader / Co-Investigator	$109,784.00	$ 40,632.20	$ 69,151.80	
Salaries Associates	$ 63,950.00	$ 34,657.60	$ 29,292.40	
Benefits (@ 22%)	$ 38,221.00	$ 16,563.75	$ 21,657.25	
Publications & Documentations	$ 700.00	$ -	$ 700.00	
Other Costs (Aircraft Charter @ $450/hr)	$ 66,486.00	$ 22,081.00	$ 44,405.00	
Travel Expenses				$1859.08
Overhead Costs (26% on $115,793.63)				$30,106.34
TOTAL	$ 279,141.00	$113,934.55	$165,206.45	$31,965.42