Revised Work Plan and Budget for Project:

"Nearshore Substrate Mapping and Change Analysis using Historical and Concurrent Multi-spectral Aerial Imagery."

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1. Revised Work Plan

We propose a 2.5 year timeline for this project. Timing of data acquisitions for the various components of the proposed baseline characterizations is critical. Assuming a project start in the fall of 2011, the intertidal/subtidal zone data will be collected in the early fall of the first year. Based on the former surveys of this type done by OI in the CSC region, mid-September through early October tend to provide the greatest water clarity windows, coupled with favorable combined low tide and sun angle conditions. Kelp surveys which were originally proposed as part of this project were later eliminated from the Sea Grant-funded work plan due to budget constraints. However, the US Navy independently has provided funding for Ocean imaging to conduct these surveys and make the data available to this project. Hence the surveys will be done in the fall of each of this project's 2 full years, as originally planned, corresponding to the timing adopted by CDFG in the past. The aerial imaging and multispectral-based substrate classification of several estuarine areas that was proposed as part of the original work plan has been eliminated due to budget constraints.

For the Sea Grant-funded data acquisition flights we propose (and include in the budget) utilizing a San Diego-based Cessna 206 aircraft owned by SanLo Aerial Surveys. OI presently utilizes this aircraft and highly skilled pilot for numerous projects. It may also be possible, however, to utilize CDFG's Sacramento-based Partenavia aircraft for some of the data collections under a contractual agreement between OI and CDFG air services. OI has used their aircraft in the past for a number of CDFG-related missions including oil spill response and the coastwide kelp surveys. The advantages of the Partenavia are a significantly lower cost, and more efficient space setup within the aircraft. OI has had a contract for using CDFG aircraft in place in 2009. If funded, OI will work with CDFG's air services to renew this contract and fit some of the planned data acquisition missions into their schedule.

1.1 Baseline Intertidal Data Collection and Processing
The purpose of the intertidal (and subtidal where possible) surveys will be to acquire baseline characterization data along the CSC coast (both within and outside the MPAs) for the minimum following macro and micro substrate classes (additional differentiations will be made when possible):

- Soft Bottom
  - Surf Grass
  - Eel Grass
- Bare Rock
  - Cobble
- Algae-covered Rock
  - Red/Brown Algae
  - Green Algae (*Ulva* spp.)
- Kelp

Figure 1 shows the proposed extents of the intertidal mapping along the CSC region. We will to cover the entire coastline of the Channel Islands and Catalina and Santa Barbara Islands. We will also image and process all proposed MPA coastline areas, with significant portions of the neighboring coastline included for control area purposes. The data will be acquired at 1m spatial resolution and additional imagery collected at up to 35cm resolution will also be collected over specific sites targeted and requested by collaborating research teams. In previous projects of this nature in the CSC region, OI has found 1m 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). At 1m resolution, the DMSC's imaging swath width is approximately 1000m. Centered on the intertidal zone, this scan width will be sufficient to cover most 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 will be flown and the data will be seamlessly merged.

We will conduct the aerial surveys in the fall months to take advantage of maximal low tide conditions during daytime intervals with relatively low sun angle (morning and afternoon) to minimize sun glint effects. Water clarity is of prime importance for the subtidal mapping, and the imaging flight scheduling will be done on an on-call basis guided by water clarity conditions as assessed through phone reports from life guards, CDFG personnel and other contacts available to

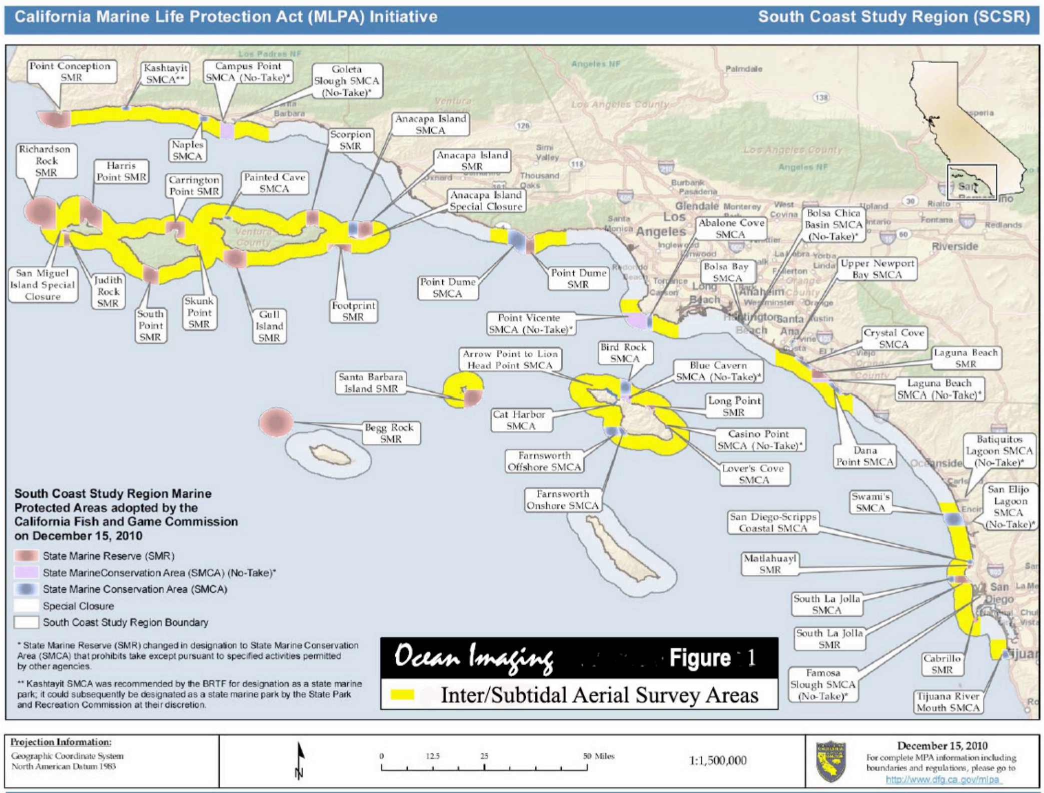

Figure 1. Inter/subtidal areas to be imaged and mapped with OI's aerial multispectral imaging system are shown in yellow.

OI. The flights will be scheduled to allow data acquisition within ±1.5 hours of peak low tide. We estimate that the CSC region can be imaged in 12 flight hours, corresponding to 4-5 days' of flights. Additional multiple flight days with the optimal tide/sun angle conditions will be scheduled to allow for possible cancellations due to inclement weather, wave or cloud conditions. If fall-2011 image acquisitions are not possible due to contractual delays or weather-related problems, the inter/subtidal imagery will be collected in spring of 2012 – corresponding to the next temporal window of favorable low-tide and sun angle combination conditions.

Following the aerial data acquisitions, OI will obtain field sample data that will be used for both, initial classification algorithm training and final classified product accuracy evaluation. As was already noted above, OI will utilize field data from multiple sources, including the PISCO program. Dr. Peter Raimondi and his group from UC Santa Cruz will likely propose a project under this SeaGrant program, and if funded OI will work closely with his group as we are presently doing in the North Central region. Field data targeting the intertidal and shallow subtidal zones is and will be available from the Channel Islands from other research groups and will be obtained by OI for guiding the classification processing as a collaborative effort. Additionally, OI staff will spend several weeks obtaining additional ground substrate field samples over various intertidal and subtidal areas along the CSC coastline, and has budgeted one multi-day trip to the Channel Islands for additional groundtruthing in summer 2012. The field sampling will consist of obtaining positive identification of ground substrate at a DGPS logged location and obtaining photographic evidence. Shallow subtidal field samples will be obtained through vertical-viewing subsurface videos and photographs directly over the side of a small sampling vessel, thus eliminating any potential safety, legal or contractual problems of this grant if divers had to be involved, and also allowing for rapid acquisition of the samples over a relatively large stretch of coast. When timed in coordination with low tides and good water clarity we expect such photos from close to the ocean surface to provide detailed substrate identification documentation to depths comparable with the aerial multispectral imager. OI owns a small outboard-powered Zodiac inflatable which is easily beach-launched and is ideal for reaching areas close to the surfzone. We will use it during the coastal groundtruthing work (a larger vessel will be rented for the Channel Islands unless an arrangement can be made with a CDFG boat). We will aim to obtain 200 – 300 sample points in various locations, one half of which will be utilized during the classification algorithms application, and the rest will be utilized for final product accuracy assessment.

The acquired aerial image frames will be radiometrically calibrated, corrected for vignetting effects and mosaicked into a series of shoreline segments (to ease subsequent substrate classification processing). The data will be rectified to a base layer with known and acceptable spatial error characteristics (most likely 1m USGS orthoquads). Following methodologies successfully implemented in similar past projects, OI technical staff will then utilize a combination of commercial (Erdas) and custom developed neural network-based multispectral image classification software to classify each image segment for bottom substrate type. The algorithms will be trained with subsets of the gathered field data points, with the remainder of the field samples to be utilized for quality control and error assessment of the final classification products. Application of the classification algorithms is an iterative (and relatively labor intensive) process, in which subsets of the validation field measurements are used to refine the classification accuracy during each iteration.

As is mentioned above, part of the obtained field sample data will be used to assess final accuracy of the deliverable baseline characterizations. As we have done in the past, we propose to utilize Cogalton Matrix statistics (predicted vs. observed) (Congalton and Greene, 1999) which are often used to assess classification accuracy of remotely sensed data. In past projects, OI has repeatedly achieved accuracies in the 80+% range for intertidal and salt water marsh substrates using the proposed methodologies.

1.2 Baseline Kelp Data Collection and Processing.

OI proposed in this project's original work plan to conduct annual kelp surveys over the SC region to provide continuity of such data with CDFG's past kelp survey archive. Due to the need for decreasing the funding budget of this project, these surveys were eliminated from its work plan. However, the US Navy has independently contracted OI to conduct the kelp surveys as part of their own environmental monitoring interests, and has agreed to make these data available to this project and the MPA baseline data base. Hence, the surveys will be conducted as originally planned (see original Work Plan below) but will be financed with non-Sea Grant funding. They will be done in the fall of each project year, followed by data processing and final product generation.

1.3 Inter/Subtidal Habitat change Analysis and Kelp Persistence Analysis

As was already discussed, a useful baseline characterization data base should include some measure of habitat or resource variability due to natural or anthropogenic causes not related to the creation and maintenance of the MPAs. Without such data, the causal effects of variability in abundance or extents of certain resources could be misinterpreted in future studies. We propose to provide such a metric for several main resources of interest: sandy bottom, vegetated reef, and surfgrass and eelgrass in the intertidal and subtidal regions, and kelp in the targeted nearshore areas.

As is discussed above, in 2001 OI collected high quality multispectral imagery over most of the intertidal/subtidal areas targeted in this project. Some of this imagery is already classified to a high level of detail, including the above classes. OI will further classify areas that were not yet processed (primarily Orange County and Catalina and Santa Barbara Islands) and will then utilize digital image change detection processing algorithms to map significant changes in habitat in the target areas that occurred between 2001 and 2011/12 (the later data having been collected and classified specifically for this project). Since only some of the 2001 data was field-validated, we will compute the change detection on the above general classes only, which can be extracted from the older data sets with very high degree of accuracy without field-sampling. For example, "vegetated reef" will include any algae-covered rock substrate not covered by Macrocystis kelp or surf grass (which can be readily differentiated due to its unique spectral properties). The prime focus will be on identifying any significant changes in the total area of vegetated hard bottom vs. sand-covered bottom, bare rock (i.e. not covered by algae or surf grass) and changes in eel grass bed distributions within and around the proposed MPA areas.

We are aware of annual cycling of beach sand transport in the CSC region which could significantly affect the reef change analysis: significant areas of (unvegetated) hard bottom/reef become exposed in the inter and shallow subtidal zones during wintertime when storm-caused offshore transport of sand exposes these features. This should not, however, significantly affect the analysis proposed here since both the 2001 and the 2011/12 imagery will have been collected in late-summer to fall – prior to any major seasonal sand transport changes. On the other hand, it is possible that the change analysis may suggest areas where recent beach sand replenishment activities could have altered the bottom reef/sand substrate composition due to anthropogenic causes (and would be reported to other science teams for possible further study).

Annual aerial-imaging based inventories of kelp resources along the CSC mainland coast are much more complete over the past 2 decades than in the northern California areas. The surveys include CDFG-sponsored work as well as surveys sponsored collectively by wastewater dischargers along Southern California as part of their discharge permit-mandated environmental monitoring. Data covering the Islands include CDFG and navy-sponsored surveys. OI will utilize these data sets to create a first-ever large-scale data base of kelp persistence in the CSC region. The available kelp classification data will first be inspected for georeferencing errors (some of the earlier data sets may be somewhat compromised) and corrected if necessary. The available data sets will then be run through a statistical algorithm on a pixel by pixel basis which will create a GIS layer of kelp persistence rendered as persistence classes in numbers of years.

In addition, future researchers may be interested in any growth/persistence trends for individual kelp beds. For this reason an additional data base will be created which will list each year's total kelp canopy area within each administrative bed section. This will allow assessment whether a particular bed which, for example, has shown 50% persistence over its maximum extents in the past 9 years, has been steadily increasing or decreasing in the most recent time period, or has fluctuated randomly throughout the measurement period.

1.4 Evaluation of Aerial Remote Sensing for Future Long-term MPA Monitoring.

As part of the final assessment of deliverables from this project, OI will conduct an evaluation of the used remote sensing technologies to help the MPA Baseline Program assess the usefulness of aerial remote sensing for future long-term monitoring of the created MPAs. The assessment will include an e-mail survey of all research groups that were provided with or utilized the aerial imaging-based baseline characterization products during the project. The survey will address the researchers' use of the data, and their opinions for usefulness for future periodic updates. The assessment will also include a thorough labor and cost analysis for the various potential monitoring products. OI intends to conduct a similar analysis as part of its exiting project covering the NCC region. The cost analysis for both regions will be compared as part of this project. Due to weather and water clarity conditions more favorable for efficient aerial (and field) data acquisition, as well as the closer proximity of aircraft-related resources to many of the CSC MPA sites, we postulate that remote sensing will prove even more cost efficient as one of the long-term MPA monitoring techniques in the CSC region. Results will be reported in the project's final report.

2. Outcomes and Deliverables

As per the MPA Monitoring Enterprise's instructions, deliverables from this project will include raw image data files (calibrated and mosaicked), final GIS-compatible kelp, intertidal and estuarine ground substrate classification files, EML-standard metadata for each classification set including accuracy statistics, as well as annual progress and final reports.

The final data analysis/map sets will be made available to the MPA Monitoring Enterprise as soon as they are finished and validated. Based on the planned work/milestone schedule shown in the next section, this is as follows:

- Contemporary (2011 imagery) inter/subtidal substrate classifications – fall 2012
- Annual kelp canopy classifications – winter 2012 and winter 2013
- Kelp persistence analysis – fall 2013
- Decadal Inter/subtidal change detection – (to be delivered in parts) fall 2012, spring 2013, fall/winter 2013

CDFG's Office of Spill Prevention and Response (OSPR) has expressed keen interest in the proposed baseline data bases, since such information would significantly increase their abilities to assess resource damage potential during an oil spill in the CSC region, as well as could be used in follow-on damage mitigation work. We will also make the final deliverable data available to OSPR on the same schedule. Additionally, we will make preliminary data sets available to all other research teams collaborating with OI on this project for the purposes of mutually enhancing each others' work.

3. Milestones and Project Management

The proposed timeline for this project covers a period of 2.5 years, beginning in September, 2011 and terminating in January, 2014. The initial year will cover the most inter/subtidal image and field data collection effort, as well as the annual (Navy-funded) kelp survey. Processing of these data and historical imagery will also be started in the first year and continue into the second. The second year will include (Navy-funded) annual kelp data collection. Also planned for summer of the second year is additional field sampling by OI (likely in conjunction with other collaborating research teams) in the Channel Islands region. By that time we expect to have fully processed preliminary classifications of that area completed and these will be directly validated in the field. Generation of final deliverable data base products and the change detection/persistence analyses will be completed into the final half-year. As was already discussed, the final products will be made available to other research teams sequentially through the project.

The project primary liaison with members of the Baseline Program management team and collaborating research groups will be Dr. Jan Svejkovsky. He will also be responsible for all reporting requirements and day-to-day management of the project. Logistics planning for the data acquisitions and interaction between OI and CDFG and other agencies/groups relevant to specific work tasks will be done by Svejkovsky and OI's Technical Director, Mark Hess. He will also manage all data processing, as he has done in similar past projects. Image processing related to the generation of final products and the temporal change analyses will be done by OI's technical staff headed by Michael Tuffly. OI's tech staff will also participate in the field data collections and validations. The timeline of key tasks is shown below:

Task (Sea Grant-funded)	2011					2012												2013											
	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
Inter/Subtidal Image Data Acquisition		←	─	→																									
Inter/Subtidal Field Data Acquisition		←	─	─	→						←	─	─	─	─	→													
2011 Inter/Subtidal Image Processing			←	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	→							
Kelp Persistence Analysis																	←	─	─	─	─	─	─	─	─	─	→		
2001 vs 2011 Inter/Subtidal Change Detection						←	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	→
Reports									X																X				X
US Navy-funded components																													
Kelp Data Acquisition		←	─	→										←	─	→													
Kelp Data Processing				←	─	─	─	→								←	─	─	─	→									