Morro Bay National Estuary Program's
Implementation Effectiveness Program
For the Morro Bay Watershed

2007 Eelgrass Monitoring Report

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Project Background

Eelgrass (*Zostera marina*) is widely accepted as a valuable bay habitat, serving as nursery habitat for many marine species as well as improving water clarity by dampening wave action and helping sediment settle out of the water column. It is singled out in the Morro Bay National Estuary Program (MBNEP) Comprehensive Conservation and Management Plan with a priority action to improve the quality and quantity of eelgrass habitat. To this end, bay-wide mapping of submerged aquatic vegetation (SAV), including eelgrass, is conducted by the MBNEP.

The MBNEP contracted with Ocean Imaging, Inc. (OI) to collect and analyze multi-spectral aerial imagery to create a bay-wide map of SAV and other substrate types.

To better characterize the extent of eelgrass in the bay and confirm the locations of small eelgrass beds, the MBNEP and National Marine Fisheries Service (NMFS) conducted extensive ground truthing throughout the bay. The NMFS monitoring included the use of single-beam sonar calibrated to detect submerged aquatic vegetation. The MBNEP conducted focused substrate 'spot-checks' to characterize vegetation in locations that were difficult to classify due to shallow depth or poor water clarity. To track the long-term condition of eelgrass health in Morro Bay, shoot density counts and biomass measurements along permanent transects are conducted in conjunction with the mapping effort.

This report summarizes the monitoring and mapping activities that took place during fall 2007 and winter 2008 to produce the 2007 Morro Bay SAV map. This report includes several maps of the 2007 final SAV classification overlaid on the 2007 aerial imagery.

Ocean Imaging Classification

In summer of 2007, the MBNEP established a contract with OI to collect multi-spectral aerial imagery and analyze it in order to create a SAV extent map for Morro Bay. OI collected aerial imagery for eelgrass mapping efforts in Morro Bay during 2004 and 2006. OI was selected to conduct the 2007 work based on their acquired knowledge of conditions in Morro Bay through previous efforts and their experience with similar mapping projects in other areas.

Image Collection

OI was contracted to acquire multi-spectral (4-bands) imagery for the 2007 SAV mapping effort. OI staff worked closely with MBNEP staff to determine potential flight dates that coincided with the peak of eelgrass biomass in Morro Bay. Flight dates between October 25, 2007 and December 23, 2007 were selected as possibilities. The flight dates, criteria, and conditions are included in the appendix (Attachment A). All imagery represented in the final mosaic was acquired on November 24, 2007 between 1:15 p.m. and 3:05 p.m. PST at an altitude of 3,500 ft. Imagery was acquired from a Cessna plane by OI staff member Jamie Kum, using a filter combination of 451-550-640-850 nm. The final delivery included three images (tagged image format) for display purposes. Each image was sampled with a different band combination to best represent a true color display. Refer to the OI final project report (Attachment B) for more details.

Image Classification

OI staff utilized prior classification schemes from 2004 and 2006 as well as pre-flight reconnaissance work by the MBNEP and NMFS to generate the 2007 preliminary classification scheme. The 2007 classification was created using an algorithm specifically developed to address the weather and tidal conditions during the flight.

As the SAV mapping specifically targeted the extent of eelgrass beds, three classification categories were assigned to eelgrass density. The criteria were based on a sliding scale with two factors: reflectance in the near-infrared and continuous coverage. "Dense eelgrass" was defined as areas with high reflectance values in the near-infrared that were continuous in coverage. "Medium eelgrass" was defined as areas with a lower reflectance in the near-infrared and continuous coverage. "Patchy eelgrass" was defined as areas with low reflectance in the near-infrared and patchy coverage. Classification as “patchy eelgrass” attempted to classify areas where small patches of eelgrass were interspersed with other types of SAV that were more dominant than eelgrass. In this case, areas with a classification of patchy eelgrass may have overestimated eelgrass coverage, while under-accounting spatial coverage of other types of SAV.

Eelgrass density classes were based on relative reflectance values in the near-infrared on a yearly basis, rather than developing a highly calibrated density algorithm that could be applied year to year, which would be a substantial effort in itself. Year to year values should be compared on a relative scale but not considered absolute.

Additional distinct classifications were developed to categorize and map the other vegetation types found throughout the bay. These classifications in most cases encompassed more than a single plant species. Classification of green algae proved to be a challenge. Green algae (*Ulva spp., Enteromorpha spp., and Chaetomorpha spp.*) were found growing as under and over story within eelgrass beds. Additionally, all three types of algae could be found growing in close proximity to each other, providing a mixed spectral signature. Red macro algae appeared to be limited primarily to species of *Gracilaria* in the southern extent of the bay, although further surveys would be required to rule out additional types of algae. Table 1 summarizes the plant genera that characterized the classification schemes in the 2007 classification.

Table 1. Predominant vegetation genera contained within the 2007 classification scheme.

Report Class Name	**Raw Data Class Name**	**Dominant Species**	**Additional and/or Characteristic Species**
Eelgrass Dense	EG_Dense	*Zostera marina*	
Eelgrass Medium	EG_Medium	*Zostera marina*	
Eelgrass Patchy	EG_Patchy	*Zostera marina*	*Ulva sp., Enteromorpha sp.*
Salt Marsh	Saltmarsh	*Salicornia virginica, Frankenia salina, Distichlis spicata*	*Atriplex spp., Sueda californica, Limonium californicum, Triglochin concinna, Jaumea carnosa, Cuscuta salina*
Terrestrial	Terr/Other Veg	*Salix lasieolepsis.,*	*Baccharis douglassii,*

Report Class Name	**Raw Data Class Name**	**Dominant Species**	**Additional and/or Characteristic Species**
		Juncus spp., Scirpus spp., Carex spp.	*Potentilla anserina, Oenanthe sarmentosa, Urtica dioica, Rorripa nasturtium aquatica, Hydrocotyle verticillata, Anemopsis californica, Populus sp., Artemisia douglasiana, Artemisia Californica, Lonicera involucrate, Platanus racemosa, Myrica californica, Equisteum spp., Rubus ursinus*
Red Macro Algae	Red_Macro	*Gracilaria sp.*	*Gelidium sp.*
Surfgrass	Surfgrass	*Phyllospadix sp.*	
Unknown Green Algae	Unknown Green Algae	*Chaetomorpha sp, Enteromorpha sp.*	
Mixed Green Algae	Green Algae	*Ulva sp., Enteromorpha sp.*	
Dunes Vegetation	Dunes_Veg	*Lupinis chamissonis, Ericameria ericoides, Lotus scoparius, Abronia spp., Artemisia californica*	*Atriplex spp., Croton californicus, Ambrosia chammisonis, Horkelia cuneata, Ceanothus cuneatus, Helianthimum scoparium, Camissonia cheranthifolia, Erioginum parvifolium, Salvia mellifera, Eriophyllum spp., Lessingia filaginifolia, Carpobrotus chilensis*

MBNEP Ground Truthing Fieldwork

To aid OI in analysis of the imagery in areas with poor water clarity, a history of wrack accumulation, or multiple vegetation types, the MBNEP conducted a focused reconnaissance survey prior to the aerial flight. Target areas were selected by OI and included areas that had been difficult to classify in the 2006 survey effort. (Shown in Figure 1.)

This pre-flight effort was more focused than previous surveys and involved uploading a polygon shapefile to a planning grade Trimble Geo XH to ensure that target areas would be accurately surveyed. Most field surveying included the use of two double canoes or kayaks paddling through survey areas on mid-tides to assess the SAV. One canoe worked primarily to visually scan the area, while a second canoe collected GPS data. Canoes were staffed with one MBNEP staff member and three Volunteer Monitoring Program volunteers.

Based on weather and tide conditions, various field survey strategies were employed. Calm wind conditions with low to moderate tidal height allowed for flagging of eelgrass beds with flags made from 3’ bamboo plant stakes. Flags were retrieved by the second boat upon collection of

GPS data at the location. This flagging increased efficiency and accuracy and helped ensure that the canoe with the GPS unit did not overlook smaller eelgrass beds spotted by observers in the other boat.

These ideal field conditions also allowed for collection of polygon and line feature data formats in some cases. For the polygon data format, the perimeter of an eelgrass bed was flagged and flags were retrieved as a polygon feature was created in the GPS unit. The line feature allowed for the canoe to drift over a large, consistent area and ground truth a greater extent than would be covered by a point feature. Both of these features were typically only used in relatively calm conditions with good water clarity. More challenging field conditions (windy weather, high tidal volume) prevented collection of line or polygon features and limited data collection to point features or simple visual surveys.

A limited number of field surveys were conducted on foot at extreme low tides. These surveys were limited to shoreline areas near Baywood, Windy Cove and State Park Marina.

Left: Ground truthing during calm conditions with flagging. *Right:* Ground truthing shoreline areas by foot during extreme low tides.

A single data dictionary was created and imported to the Trimble GeoXH to improve the accuracy and consistency of data collection in the field. To expedite collection of field data, drop down menus of the most common options were created within the data dictionary. Attributes collected for all ground truthing features (point, line or polygon) are shown in Table 2.

Table 2. GIS Attribute data collected during ground truthing.

Attribute Name	Data Entry Options	Notes
Water Depth	<1.0 1.0-2.0 2.0-2.5 2.5-3.0 3.0-3.5 3.5+	Attribute collected to assess visibility of vegetation and substrates.
Water Clarity	Clear Good Fair Poor	Attribute collected to assess visibility of vegetation and substrates.

Attribute Name	Data Entry Options	Notes
Primary Vegetation	Eelgrass Surfgrass Ulva Mixed Green Algae Red Algae Bare Eelgrass Wrack	Dominant vegetation or substrate in immediate area.
Secondary Vegetation	Eelgrass Surfgrass Ulva Mixed Green Algae Red Algae Bare Eelgrass Wrack	Secondary vegetation or substrate in immediate area.
Ground Truthing Method	Kayak Foot	Specified how field data was collected.
Date	None	Locked data field, created upon data entry.
Notes	Text as needed.	Unusual conditions or more than 2 types of vegetation.

Additional ground verification work was undertaken when the 2007 preliminary classification had been completed. The second round of field checking worked to clarify specific areas that were obscured when the imagery was captured or that had an unusual or unlikely classification scheme. (See figures on following pages for summary of areas.)

MBNEP staff and volunteers worked to provide clarification in all of the areas that were selected by OI. Areas proximal to the shoreline were surveyed on foot or by kayak based on substrate type and navigability. Post-flight surveys were delayed and challenged repeatedly by poor weather conditions during early 2008. As a result, some areas were limited to visual surveys and no GPS data was collected. In general, field ground truthing confirmed the preliminary classifications made by OI. Areas where significant revisions were made are noted in the following pages and figures.

Figure 1. Areas selected for ground truthing in 2007 and 2008.

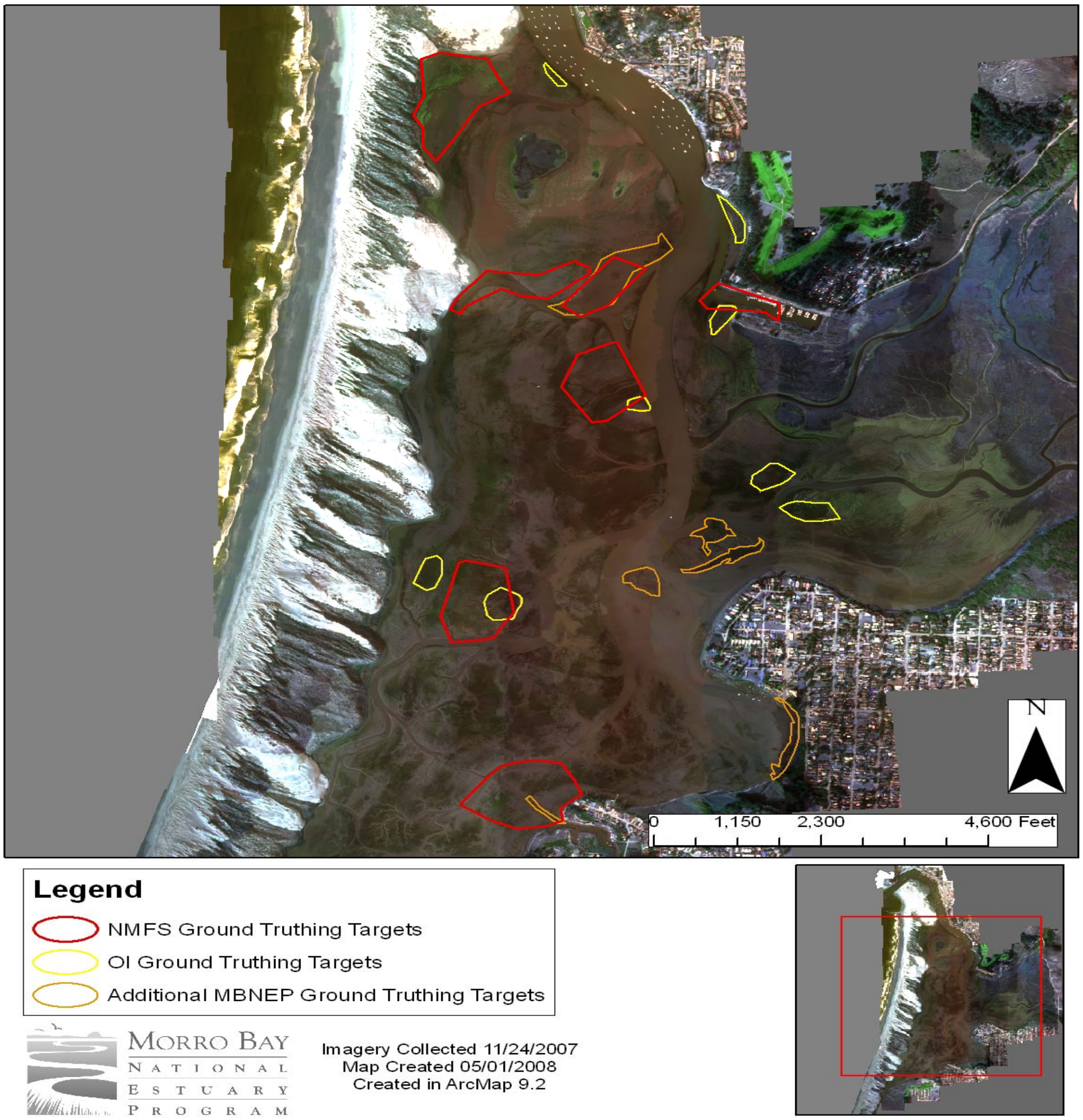
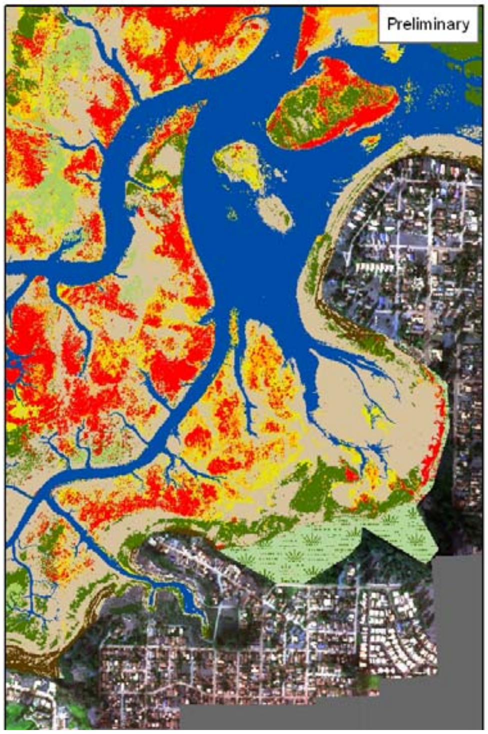
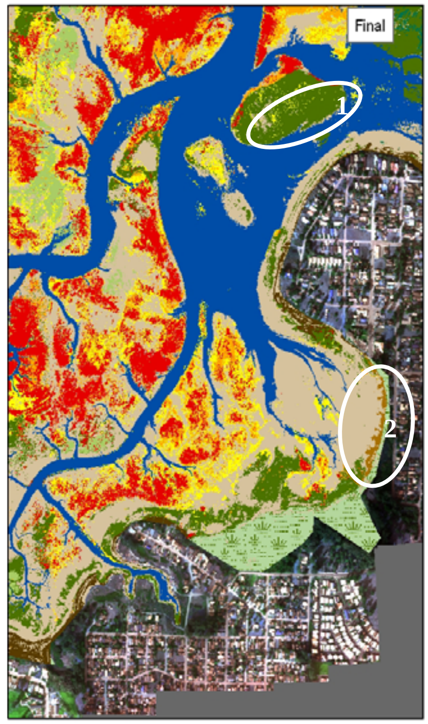
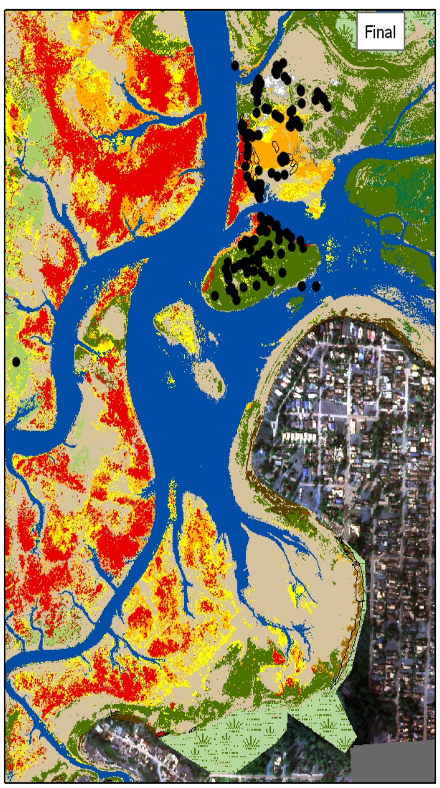


Figure 2. Areas revised following 2007 Preliminary Classification.



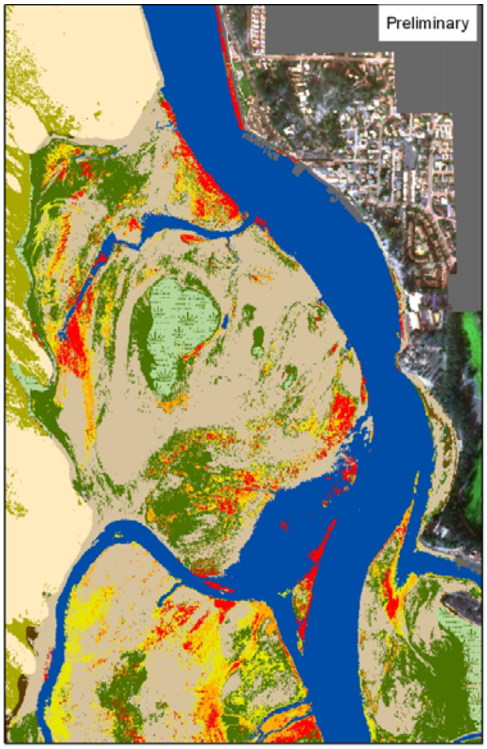


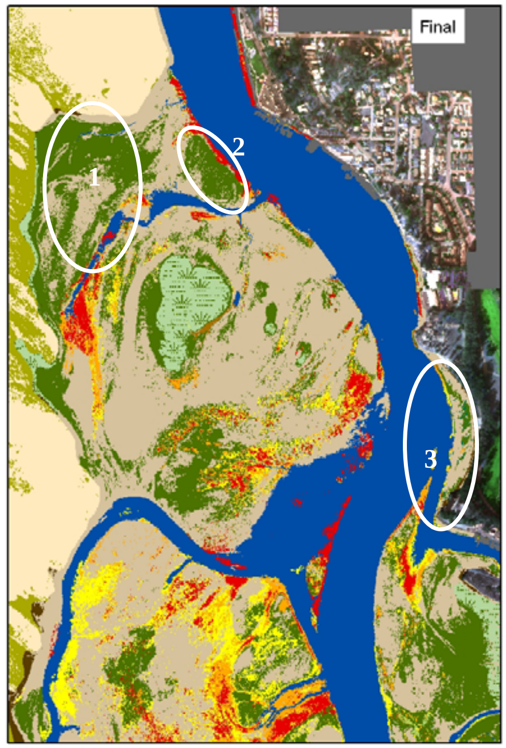


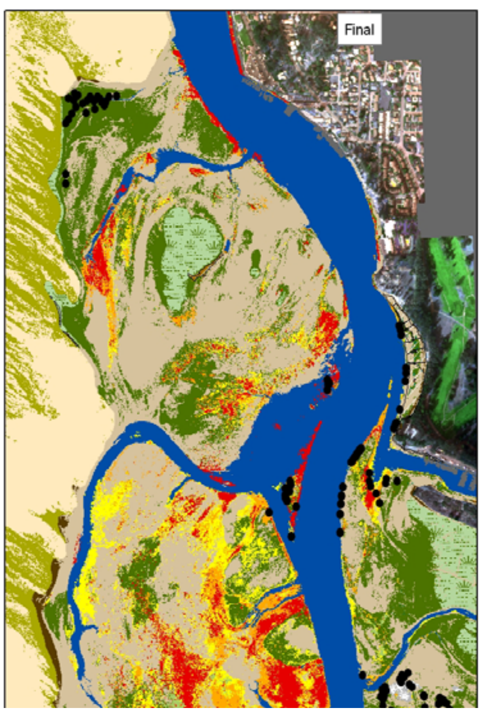
Area 1: Following extensive ground truthing of the area, approximately 3.7 acres of dense eelgrass were clipped from the final classification. Numerous field surveys failed to sight any eelgrass growing in this area. Eelgrass had not been identified in this location in prior mapping efforts.

Area 2: Repeated MBNEP staff visits to this location throughout the year suggested that eelgrass mapped along the shoreline was most likely wrack. During a ground truthing effort on foot during winter 2008, no eelgrass beds were found growing in the vicinity. The classification was changed to reflect the wrack that accumulates in this area.

Figure 3. Areas revised following 2007 Preliminary Classification.





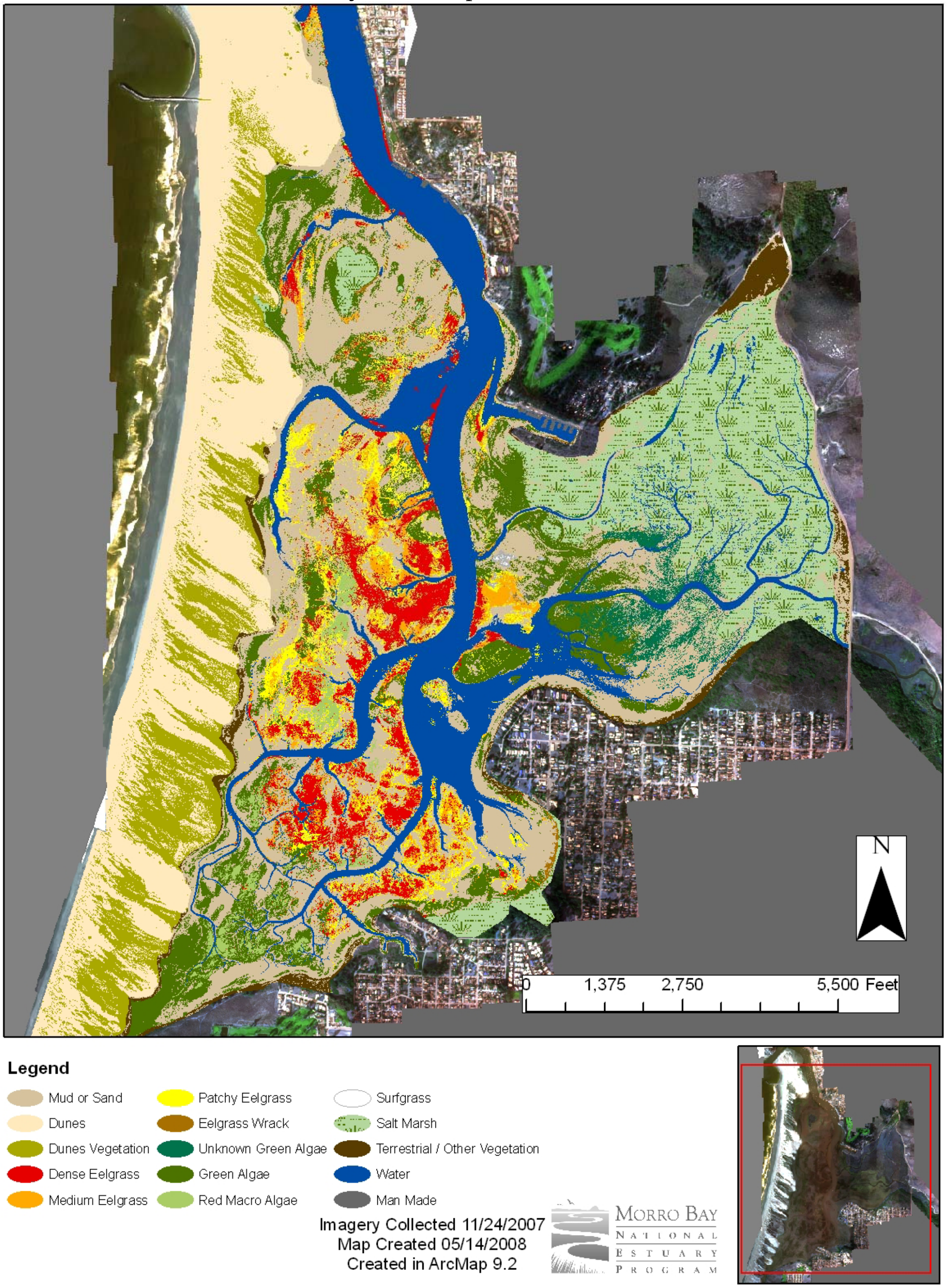


Area 1: Ground truthing efforts in this area were completed by both NMFS and the MBNEP.(See Figure 8, pg. 17) The numerous field efforts failed to identify any significant eelgrass growing in the area. The classification was changed to green algae to reflect the more dominant vegetation type in the area.

Area 2: This area was targeted for ground truthing by OI due to a mixed signature that arose in preliminary classification. The area is proximal to a transect monitored annually by the MBNEP, and it was determined that the dominant vegetation should be changed to green algae.

Area 3: This area was surveyed on foot to separate out eelgrass beds and eelgrass wrack along the shoreline. The field survey included point, line, and polygon features of the entire Windy Cove area. Slight changes were made to the preliminary classification in various classes.

Figure 4. 2007 Full Extent Morro Bay SAV Map



Fluctuations in SAV Acreages from 2006 to 2007

The 2007 SAV mapping effort brought to light a few notable differences when compared with the 2006 classification. Overall, eelgrass acreage (all three classes combined, minus wrack) increased by 56.05 acres. The 2007 acreage values reflected a reduction in patchy eelgrass beds and an expansion of medium and dense eelgrass beds. The increase in these two classifications may be attributed in part to better imaging conditions (lower tidal volume in the bay during imagery) that may have resulted in a stronger reflectance signal from beds that were present in 2006. See Table 3 for a summary of acreage values by year.

Two additional classification categories were added to the 2007 mapping effort to better represent vegetation in Morro Bay. In field surveys throughout the year, MBNEP staff noted the presence of surfgrass *(Phyllospadix sp.)* in areas south of Grassy Island. Additional field surveys conducted near the shellfish growing areas yielded significant patches of surfgrass growing near eelgrass beds. Surfgrass beds were ground surveyed extensively in the area near the oyster farms to truth the digital classification.

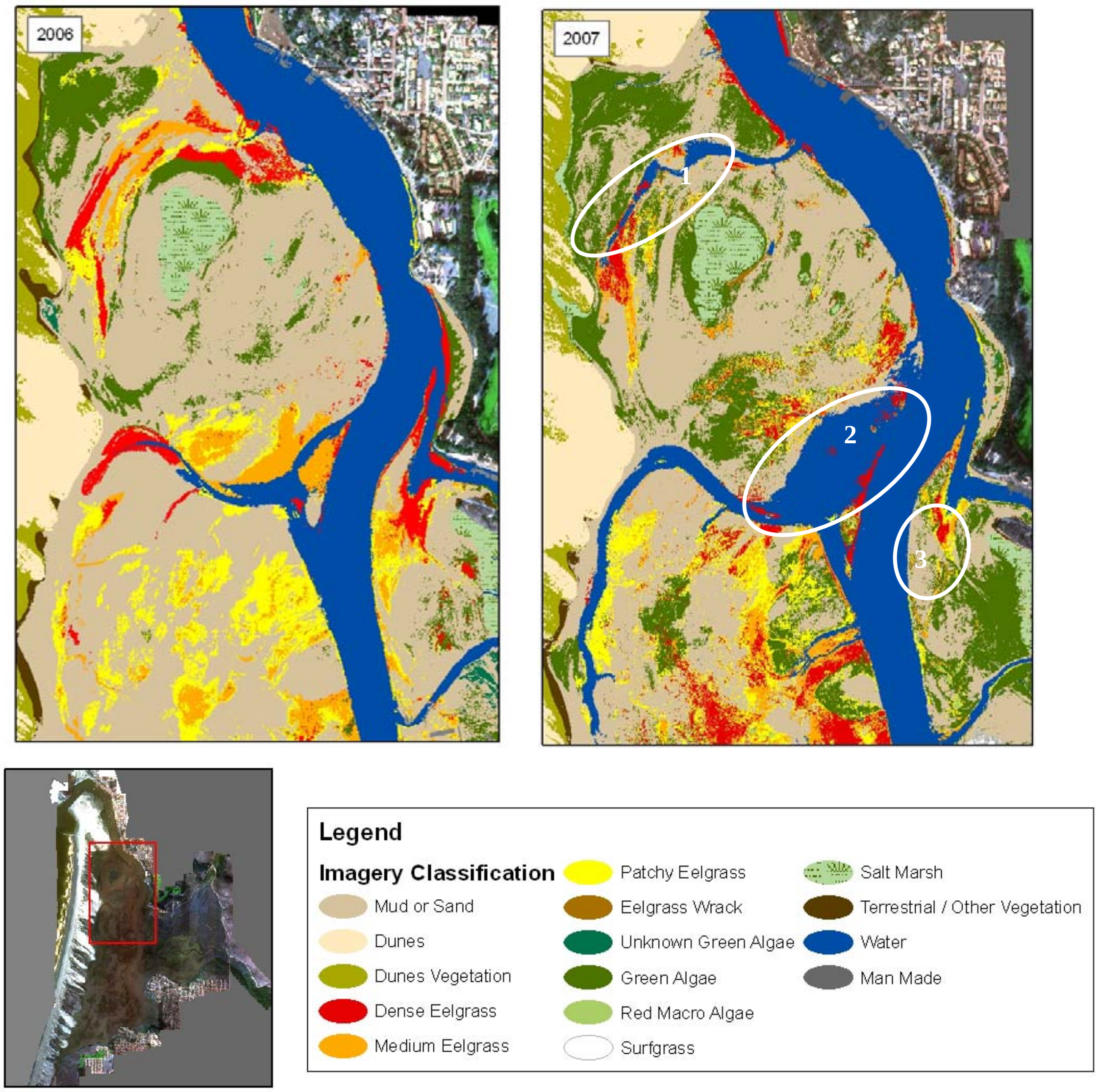
During the fall of 2007, staff observed a significant volume of eelgrass washing up on the shoreline (mean higher high water) throughout Morro Bay and the greater Estero Bay. During review of the preliminary classification in early 2008, staff targeted truthing in several areas where eelgrass had been mapped in high elevation areas along the shoreline. Windy Cove, Baywood Cove, and the State Park Marina were surveyed on foot in early 2008 and contained remnant blades of eelgrass wrack. Following discussion with OI it was decided to add a classification for 'eelgrass wrack' to track areas where wrack accumulates and reduce the need for additional ground truthing in the future.

Table 3. Acreage by class in 2006 and 2007.

Class Name	**2006 Acreage**	**2007 Acreage**	**2006-2007 Change in** Final Acreage
Eelgrass Dense	68.32	129.32	+61.00
Eelgrass Medium	83.81	98.84	+15.03
Eelgrass Patchy	136.04	116.06	-19.98
Eelgrass Wrack	*	2.70	+2.70***
Subtotal Eelgrass Acreage:	**288.17**	**346.92**	**+56.05**
Salt Marsh	388.04	386.71	-1.33
Red Macro Algae	37.813	34.46	-3.35
Surfgrass	*	1.79	+1.79
Green Algae (classes combined)	208.98	356.84	+147.86
Subtidal Mud or Sand	1031.04	709.72	-321.32
Water	388.45	523.42	+134.97
Man Made	10.39	9.97	-0.42
Terrestrial	72.63	60.59	-12.04
Dunes Vegetation	209.24	298.71**	+89.47
Dunes	224.14	654.85**	+430.71
Subtotal Dunes Acreage:	433.38	953.56	
Total Acreage Classified	**3016.18**	**3383.98**	

* Classes added to the 2007 classification scheme, not included in 2006 classification.
** Higher acreage values reflect wider scope of aerial image. In 2007 the scope was expanded to include the entire sandspit.
***Wrack acreage is not included in the 2007 eelgrass acreage total.

Figure 5. 2006 and 2007 Comparison Areas

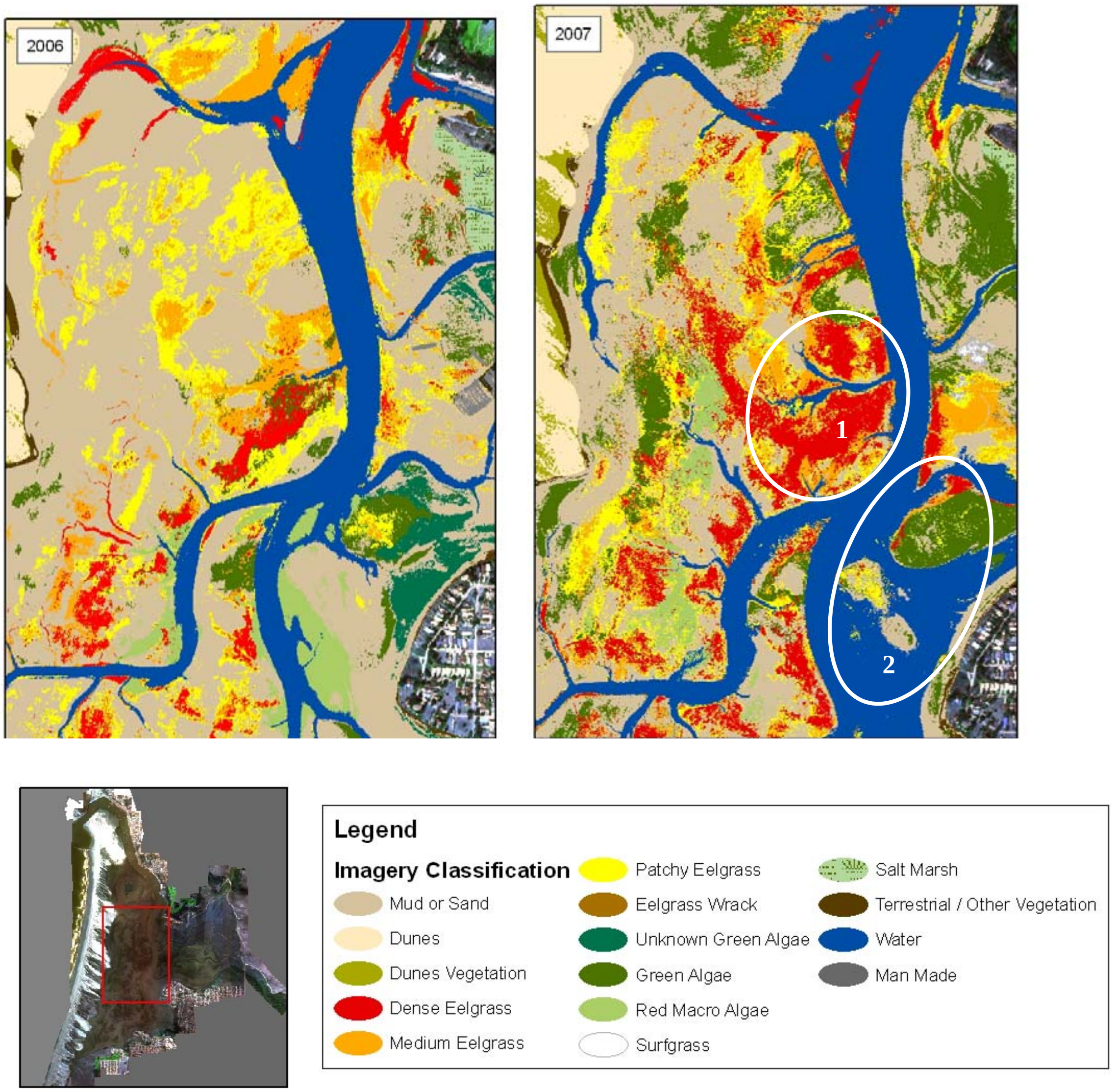


Area 1: The 2007 classification showed a significant reduction in the acreage of eelgrass found in the channel immediately north of Grassy Island. Good visibility and water clarity in this area during imaging made it unlikely that eelgrass was present and simply overlooked.

Area 2: Poor visibility and deeper water in this area made classification difficult. This area was surveyed on the ground by MBNEP and NMFS staff, and field results were consistent with the 2007 classification. There has been a significant decline in eelgrass in this area.

Area 3: This area was selected for additional ground surveying after preliminary classification showed a reduction in eelgrass acreage. The area was spot checked by MBNEP staff during moderate and low tides, and the 2007 classification was deemed accurate of ground conditions.

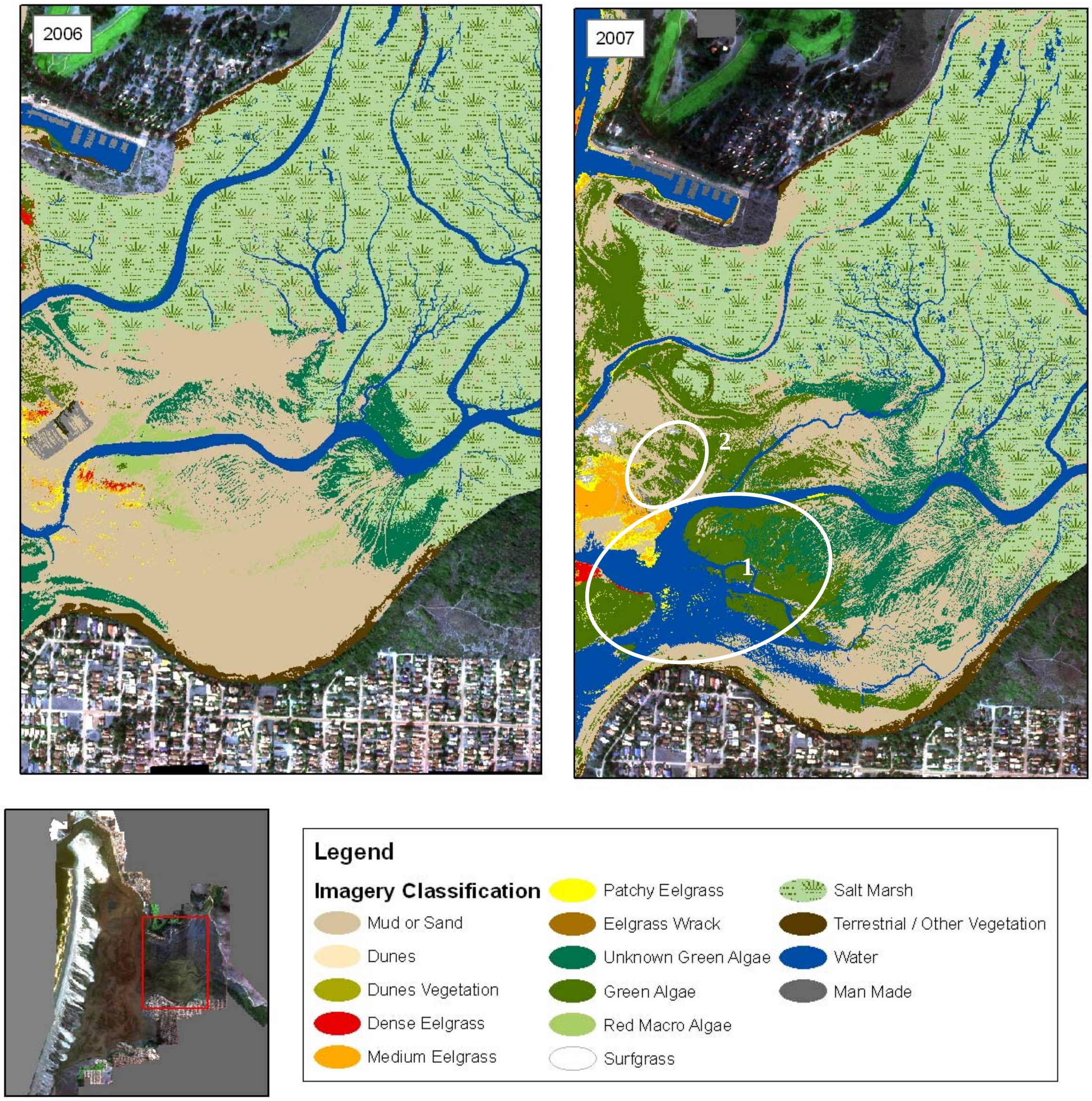
Figure 6. 2006 and 2007 Comparison Areas



Area 1: Eelgrass acreage in this area expanded during 2007 and yielded a stronger reflective signal than in 2006. The increase in density and coverage shown in this area was characteristic of smaller eelgrass beds in the southern extent of Morro Bay in 2007.

Area 2: The additional acreage attributed to 'water' in 2007 was due to extremely poor water clarity in the area during image acquisition. Poor visibility prevented the accurate classification of SAV near Pasadena Point in Los Osos. Numerous attempts were made to ground truth this area but were hampered by bad weather and poor visibility.

Figure 7. 2006 and 2007 Comparison Areas



Area 1: This area was difficult to classify during 2007 due to poor water clarity. Due to poor visibility additional acreage was classified as water, as subsurface vegetation could not be detected. There were moderate gains in eelgrass acreage, and a significant increase in green algae in the area. Multiple types of algae grow intermixed in this area, which complicates classification.

Area 2: The ‘Man Made’ feature (commercial aquaculture operation) seen in the 2006 classification was masked by green algae coverage in the 2007 image. This operation is still present near that location.

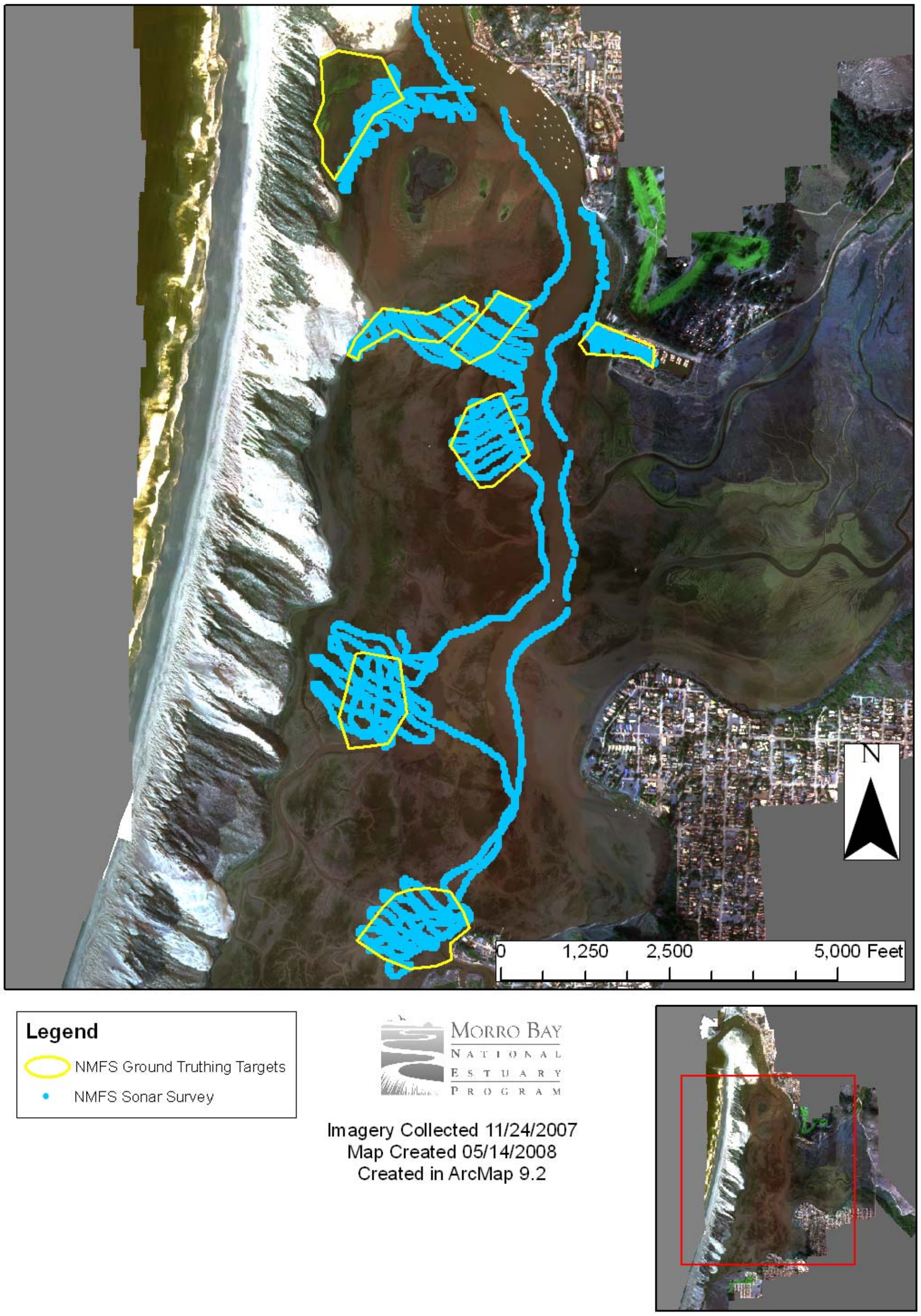
NMFS Sonar Monitoring

The NMFS Habitat Conservation Division has been monitoring eelgrass habitat in Morro Bay since the 1990s. Their previous efforts have included measurements of subtidal eelgrass beds as well as shoot density counts. Current NMFS efforts are limited to surveying target areas in Morro Bay with a single-beam sonar unit for mapping subtidal eelgrass. The NMFS team worked collaboratively with the MBNEP and OI to select target areas where previous classification and ground verification efforts had been difficult due to the limitations of other truthing methods.

NMFS conducted SONAR surveys November 9-11, 2007. The raw data produced by the SONAR equipment was processed via an algorithm calibrated to identify the substrate material. All analysis was reviewed to ensure that the algorithm identifications were correct.

Due to low tidal volume during the survey period, NMFS was not able to cover all of the target areas identified in the initial scope. The target area located northwest of Grassy Island was surveyed by MBNEP staff in winter 2008. See figure 8 of the survey track covered by NMFS single beam SONAR. A brief summary report and maps of NMFS results are presented in the appendix (Attachment C).

Figure 8. NMFS Single Beam SONAR Surveying November 2007



Transect Fieldwork

In February 2005, MBNEP staff and staff from Battelle Marine Sciences began work to establish four permanent eelgrass transects for annual monitoring in Morro Bay. Regions and potential sites for these transects were delineated by Battelle to represent different zones within the bay and capture differences between these zones. The northernmost transect near Tidelands Park was established successfully and monitored for eelgrass density and biomass. The ends of each transect were marked with PVC poles. A second transect was established near the Chorro Creek outlet south of State Park Marina. Unfortunately, this transect was established on a rare -1.8' spring tide, an extremely low tide occurring only during the spring. Attempts to establish the remaining two transects, one each near Pasadena Point and Cuesta Inlet, were unsuccessful due to boat failures and impassably deep mud.

In November 2005 eelgrass monitoring and the establishment of the remaining two sites commenced. The Tidelands site was located and monitored without difficulty. Staff struggled to locate the Chorro Creek site, which was suspected to be on either side of 50 harbor seals. In light of this obstacle, and the realization that the transect was likely still underwater, a new transect was established in the immediate region. Additional transects were established at Pasadena Point and near Mitchell Lane in Los Osos.

Transect fieldwork was conducted during extreme low tide conditions on November 23 and 24, 2007. Along each 50 m transect, a measuring tape was set up and measurements were taken inside a 0.50 m^2 quadrat including percent eelgrass coverage, eelgrass shoot density, and percent of other types of substrate including mud, sand and different types of algae. Biomass samples consisting of 30 to 40 eelgrass shoots were randomly collected throughout the area parallel to the transect. Shoots were collected as close to the rhizome as possible and removed without damaging the leaves. An MBNEP staff member and two volunteers completed transect field work at each site. See Figure 9 for a map of transect locations.

Annual monitoring since fall of 2005 has shown increases in shoot density and coverage at the Chorro and Pasadena transects in the southern extent of the bay. Transects in the northern extent of the bay (Coleman and Tidelands) have shown slight decreases in density and coverage between 2006 and 2007. See Table 4 and Figure 10 for a summary of the percent of eelgrass coverage and shoot density by transect.

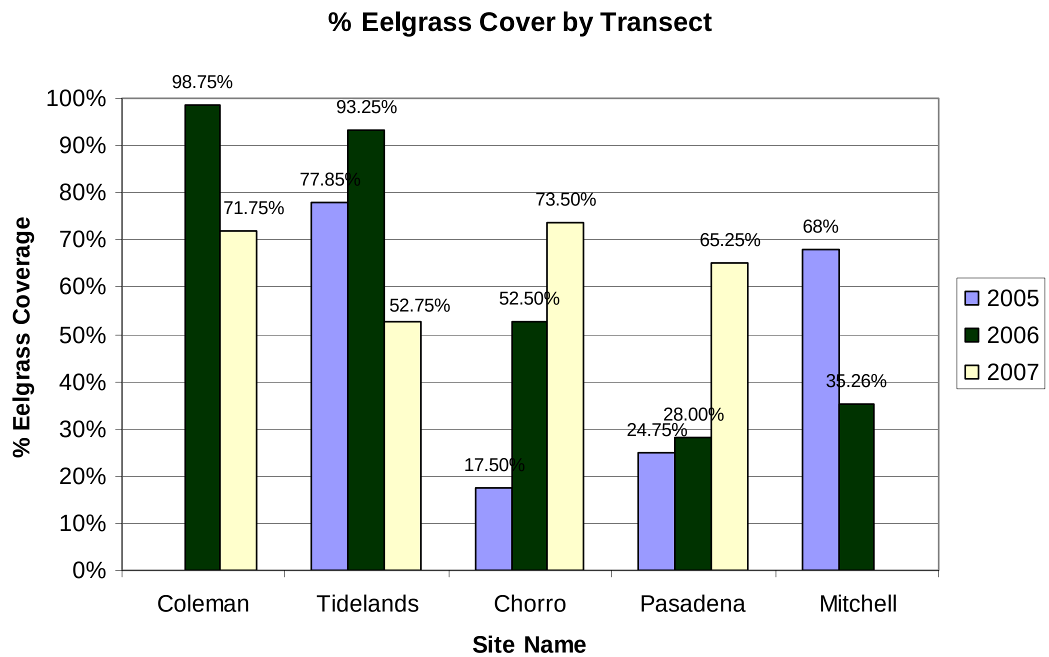
Table 4. Summary of transect monitoring data collected by the MBNEP.

	Eelgrass % Cover			**Eelgrass Shoot Density**		
Location	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Coleman	*	98.75%	71.75%	*	101.55	82.55
Tidelands	77.85%	93.25%	52.75%	145.15	119.9	73.2
Chorro	17.50%	52.50%	73.50%	20.5	31	73.45
Pasadena	24.75%	28.00%	65.25%	12.95	25.1	73.65
Mitchell	68%	35.26%	**	31.25	15.7	*

**The Coleman transect was established in 2006, there is no monitoring data for 2005.*
***Monitoring at the Mitchell transect was discontinued in 2007 due to safety concerns.*

Figure 9. Morro Bay Eelgrass Monitoring Transect Locations

Figure 10. Annual % Eelgrass Cover for each transect.



Biomass Measurements

At each monitoring transect staff randomly collect 30-40 shoot samples from the area immediately adjacent to the transect line. Shoots are collected from an area outside the transect that has not been disturbed by shoot density counts. Shoots are broken off at the shoot at the node closest to the surface of the mud. Samples are transported to the lab and may be stored in sealed Ziploc bags in a refrigerator for up to five days following collection.

Eelgrass shoots are processed, weighed and dried at the MBNEP office or the program's Water Science Lab at Cuesta College. All laboratory procedures for sample preparation and processing are documented in the Volunteer Monitoring Program's Quality Assurance Program Plan. Biomass weights (grams) are shown by site in Table 5.

Table 5. Biomass weights by site and year.

Site	2005	2006	2007
Coleman	-	1.270 g	0.630 g
Tidelands	0.795 g	1.150 g	0.970 g
Chorro	0.239 g	1.190 g	1.130 g
Pasadena	0.589 g	0.794 g	0.992 g

SAV Monitoring Costs and Funding Sources

Table 6 summarizes the expenditures for the 2007 SAV monitoring effort.

Table 6. 2007 SAV Monitoring Project Costs.

Provider	Task	Cost	Notes
Ocean Imaging, Inc.	Imagery acquisition and map creation	$12,800	$9,450 paid by VMP Prop 50 grant, remainder from a Restoration Fund request
NMFS	Sonar data acquisition	$1,331	Travel costs for three NOAA staff members. $1,000 from a Restoration Fund request. Additional $331.00 paid with 320 funds.
Kayak Rentals	Kayak rental for field ground truthing	$770	$550 from VMP Prop 50 grant, $220 from Restoration Fund request.
TOTAL		**$14,901**	

These projects costs do not include MBNEP staff time.

The MBNEP's Volunteer Monitoring Program is currently operating under a Proposition 50 Coastal Nonpoint Source Pollution Control Program grant which provides $10,000 per year for eelgrass monitoring in 2007, 2008 and 2009.

An eelgrass monitoring fund request of $15,000 from the Restoration Fund was presented and approved by the Implementation and Executive Committees as well as the Bay Foundation in May 2006 to partially fund three seasons of eelgrass monitoring in 2007, 2008 and 2009.

The SAV monitoring budget allowed $1,000 for the NMFS sonar monitoring effort. An overrun of $331 was covered by 320 funds.

An overview of the funding sources for the 2007 monitoring effort is as follows:

Table 7. Summary of Funding for 2007 SAV Monitoring Effort.

Source of Funds	Total Spent by Category
Proposition 50 grant funds	$10,000
Restoration Fund request	$4,570
320 funds	$331
Total Funds for 2007 Monitoring Effort	**$14,901**

The plan is for a similar monitoring effort to take place in the fall of 2008. The costs of monitoring will be covered by the VMP's Prop 50 grant as well as the Restoration Fund request.

List of Attachments:

Flight Dates Table
OI Final Report
NMFS Final Report

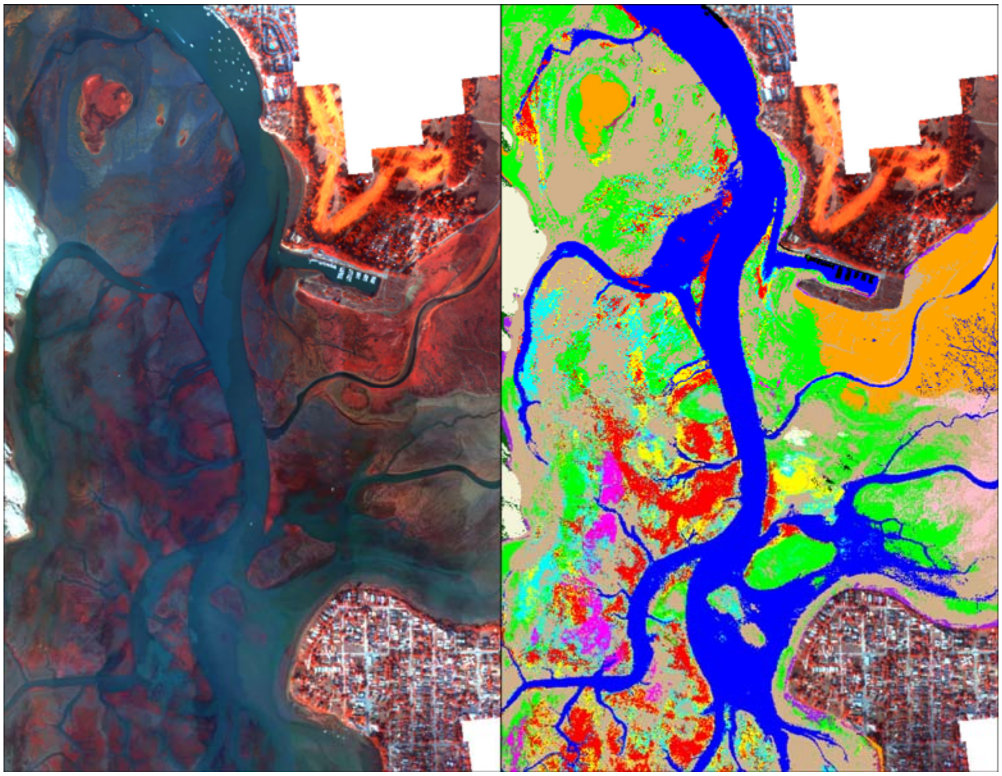
Attachment A. Potential Imagery Acquisition Flights

Month	Date	Low Tide	Occurring At	Sunrise	Sunset	DMSC Imaging Window 1:00pm	1:30pm	2:00pm	2:30pm	3:30pm
October	10/25/2007 Thursday	-0.7'	4:23 PM	7:19 AM	6:16 PM	+2.9	+2.0	+1.2	+0.6	-0.4
October	10/26/2007 Friday	-0.9'	5:10 PM	7:19 AM	6:15 PM	+4.0	+3.1	+2.3	+1.4	0
October	10/27/2007 Saturday	-1.0'	6:01 PM	7:20 AM	6:14 PM	+5.1	+4.3	+3.5	+2.7	+1.0
November	11/9/2007	-0.1	3:57pm	6:32 AM	5:04 PM	+2.0	+1.4	+0.9	+0.4	-0.1
	Sun Angle					35.05	33.48	29.39	26.96	18.58
November	11/21/2007 Wednesday	0	1:48 PM	6:44 AM	4:56PM	+0.2	0.0	0	0.1	+0.7
	Sun Angle					32.25	30.74	26.83	24.51	16.46
November	11/22/2007 Thursday	-0.7'	2:32 PM	6:46 AM	4:54 PM	0.0	-0.4	-0.7	-0.8	-0.5
	Sun Angle					32.05	30.55	26.65	34.34	16.31
November	11/23/2007 Friday	-1.2'	3:19 PM	6:47 AM	4:53 PM	+0.6	-0.1	-0.6	-1.0	-1.2
	Sun Angle					31.86	30.36	26.47	24.17	16.17
November	11/24/2007 Saturday	-1.5'	4:07 PM	6:48 AM	4:53 AM	+1.8	+0.9	+0.1	-0.5	-1.1
	Sun Angle					31.67	30.18	26.30	24.01	16.03
November	11/25/2007 Sunday	-1.5'	4:57 PM	6:48 AM	4:52 AM	+3.1	+2.2	+1.3	+0.5	-0.8
	Sun Angle					34.19	30.01	26.14	23.85	15.89
December	12/7/2007 Friday	-0.3'	3:17 PM	6:59 AM	4:51 PM	+1.06	+0.57	+0.19	-0.08	-0.25
	Sun Angle					29.83	28.39	24.63	22.40	14.64
December	12/08/2007 Saturday	-0.5'	3:50 PM	7:00 AM	4:51 PM	+1.56	+0.98	+0.47	+0.06	-0.39
	Sun Angle					29.74	28.30	24.51	22.32	14.57
December	12/09/2007 Sunday	-0.6'	4:23 PM	7:01 AM	4:51 PM	+2.22	+1.57	+0.97	+0.45	-0.28
	Sun Angle					29.65	28.21	24.46	22.24	17.25
December	12/20/2007 Thursday	-0.5'	1:43 PM	7:08 AM	4:54 PM	-0.29	-0.42	-0.42	-0.29	0.3
	Sun Angle					29.14	27.72	24.00	21.80	14.12
December	12/21/2007 Friday	-1.0'	2:32 PM	7:09 AM	4:55 PM	-0.32	-0.73	-0.99	-1.08	-0.82
	Sun Angle					29.14	27.71	24	21.80	14.12
December	12/22/2007 Saturday	-1.5'	3:18 PM	7:09 AM	4:55 PM	+0.31	-0.35	-0.89	-1.27	-1.5
	Sun Angle					29.14	27.72	24.00	21.80	14.12
December	12/23/2007 Sunday	-1.7	4:07 PM			+1.48	+0.63	-0.13	-0.77	-1.26
	Sun Angle					29.15	27.73	24.01	21.81	14.13
Historical Collects										
November	11/25/2004					+1.3	+0.7	+0.3	-0.1	
	Sun Angle					31.49	30.01	26.14	23.85	
November	11/6/2006					+3.0	+2.2	+1.4	+0.6	
	Sun Angle					35.86	34.27	30.13	27.68	

Attachment B. Ocean Imaging Eelgrass Mapping Report

Ocean Imaging

Eelgrass Mapping and Classification in Morro Bay Utilizing Multi-Spectral Imagery



Final Report

By Ocean Imaging Corp.

April 2008

201 Lomas Sante Fe Drive ♦ Suite 370 ♦ Solana Beach, CA 92075

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1. Background

Dense stands of Eelgrass, Zostera marina, form meadow-like beds in the lower intertidal zone of the Morro Bay estuary. This habitat represents a critical element of the Morro Bay ecosystem. As one of the most productive habitats within Morro Bay, eelgrass is particularly important in estuarine primary productivity, nutrient regeneration, sediment stabilization, and as habitat for many fish and marine invertebrates. The eelgrass beds in Morro Bay are recognized as the largest and least impacted of any in southern California (Hoffman, in litt.). Further, Morro Bay provides the only significant eelgrass habitat available to the Black Brant in southern California (Arnold, 1987).

The Comprehensive Conservation and Management Plan for Morro Bay (CCMP) has identified monitoring the health of the estuary as essential to the success of the implementation strategy of the Morro Bay National Estuary Program (MBNEP). As a result, the MBNEP developed an Environmental Monitoring Plan (Plan) with the goal of ensuring that the implementation of the MBNEP CCMP is based on the best available science. Assessments of water quality, habitat, living resources, physical resources, and human impacts were identified as specific objectives to achieve the Plan's goal.

In order to monitor this important resource, the Plan identified eelgrass surveys as one of the key methods of measurement for assessing the ecological health of the habitat within Morro Bay. Previous eelgrass monitoring efforts have been conducted on several occasions. Most notable are: Bob Hoffman for NOAA, TetraTech for the NEP Habitat Characterization Study, Coastal Resources (Ware) for the city of Morro Bay mooring project, and John Chesnut in an independent research project. More recently, the MBNEP has been conducting surveys utilizing true color imagery in combination with transect surveys to monitor changes in eelgrass. However, the confounding effect of the diverse methodologies of prior surveys as well as density definitions used on estimating the condition of the resource make temporal comparisons questionable. To address this issue the MBNEP is soliciting Ocean Imaging Corp. of Solana Beach, CA to map and classify the Morro Bay estuary using best available technologies that are reproducible for future monitoring efforts.

2. Objectives

The main objective of this project is the collection, mapping, and classification of multi-spectral imagery for the development of a GIS compatible Morro Bay eelgrass habitat layer containing density classifications and acreage estimates.

The methodology is implemented to allow survey-to-survey consistency if this effort is repeated on a yearly basis.

3. Methodology

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.

3.1 Data Acquisition: All imagery represented in the final mosaic was acquired on November 24, 2007 between the hours of 1:15pm and 3:05pm PST at an altitude of 3,500ft. Imagery was acquired from a Cessna plane by Ocean Imaging staff (Jamie Kum), using a filter combination of 451-550-640-850nm.

3.2 Data Pre-Processing: Upon completion of this flight, image data were downloaded from the DMSC onto an in-house computer hard drive and back-up copies were burned on CDs. 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.

3.3 Image Georeferencing/Mosaicking: The pre-processed image data were then imported intoTNTmips image processing software for further manipulation. Each DMSC image frame contains in its metadata the DGPS-logged location of the frame center. This allows rapid auto mosaicking of a multi-image set. However, the accuracy deemed necessary for this project necessitated further, manual geopositioning correction of each acquired frame. The obtained image frames were manually georeferenced to a 2003 aerial photo obtained from MBNEP. Once each frame was georeferenced they were then rectified with a 50cm cell size. The rectified images were then exported out of TNTmips to an ArcInfo/BIL format. The exported frames were imported into the Erdas Imagine mosaic tool, where cutlines were generated for overlapping frames and a final mosaic was produced.

3.4 Classification: The classification of the multi-spectral imagery was done in multiple iterations. A combination of an unsupervised and supervised approach was used to derive each of the target classes. An initial classification was done to identify a "water and bare" class using a customized algorithm developed by OI in previous wetland mapping projects. The next step was to target eelgrass, macro algae, and other aquatic vegetation within the Morro Bay Estuary. Using the "water and bare" class to mask out areas of the estuary, OI was able to focus the classification algorithm only on pixels with the remainder target classes. MBNEP provided OI past field data points along with a fall 2006 NOAA Fisheries single-beam sonar survey, which was used in the classification algorithm training. After multiple iterations, the "eelgrass, macro algae and other aquatic vegetation" class and "water and bare" class was merged together to represent the final 2006 eelgrass habitat classification delivered to MBNEP.

Attachment C. NMFS Sonar Report

National Marine Fisheries Service Single-Beam Sonar Surveys
Morro Bay – Fall 2007

Background

As discussed in the Comprehensive Conservation and Management Plan (CCMP), monitoring the health of the estuary is essential to the success of the implementation strategy of the Morro Bay National Estuary Program (MBNEP). Because of this importance, the MBNEP developed an Environmental Monitoring Plan (Plan) with the goal of ensuring that the implementation of the MBNEP CCMP is based on the best available science. Assessments of water quality, habitat, living resources, physical resources, and human impacts were identified as specific objectives to achieve the Plan's goal.

One of the most productive habitats within Morro Bay is eelgrass (*Zostera marina*). Eelgrass is particularly important in estuarine primary productivity, nutrient regeneration, sediment stabilization, and as habitat for many fish and marine invertebrates. In order to monitor this important resource, the Plan identified eelgrass surveys as one of the key methods of measurement for assessing the ecological health of the habitat within Morro Bay. Currently, MBNEP is utilizing aerial imagery, in combination with volunteer-led transect surveys, to monitor changes in eelgrass.

NOAA's National Marine Fisheries Service (NMFS) Southwest Region has obtained single-beam acoustic technology for the purpose of surveying submerged aquatic vegetation (e.g. eelgrass) throughout various locations in California. NMFS first illustrated the efficacy of single-beam acoustic technology for eelgrass monitoring in fall 2004. NMFS continued its partnership with the MBNEP to utilize single-beam acoustic technology to assist with eelgrass mapping efforts in the spring and fall of 2005 and fall 0f 2006. In order to facilitate a more robust monitoring program, NMFS continued its efforts in fall 2007. This report and associated maps and data illustrate our survey efforts conducted on November 7 – 8, 2007.

Objectives

The main objective of this project was the utilization of single-beam acoustic technology to survey selected areas of Morro Bay for eelgrass. Prior to conducting the field surveys, NMFS staff coordinated with MBNEP staff to define specific survey areas. This effort and the accompanying information constitute the fall surveys for 2007. Results from this survey will facilitate and augment MBNEP's existing aerial photography mapping efforts.

Methodology

NMFS utilized a Biosonics DE-X #03005, single beam acoustic unit to conduct the surveys. The transducer operated at 430 kHZ with a beam width of 9.6 degrees. The pulse width was set at 0.1ms and emitted 5.0 pings per second.

The acoustic data was analyzed using Biosonic's EcoSAV software, which utilized Bioplant Version 1.0 algorithms to detect presence of submerged aquatic vegetation. The Eco SAV algorithm recognizes the presence or absence of underwater plants and calculates plant parameters (plant height, coverage, depth to the bottom) based on features of the echo signal. In order to differentiate eelgrass between benthic macroalgae, the plant height detection threshold was set at approximately 18cm. Thus, any eelgrass shorter than 18cm was not identified within the surveys.

NMFS staff reviewed each of the echograms to compare with the output provided by EcoSAV. In various instances, the original output was modified to account for eelgrass misidentification. Based upon the underlying variables within the algorithms, steep slope areas, irregular bottoms, and presence of algae were unintentionally identified as submerged aquatic vegetation and were a common cause of eelgrass misidentification. The explanations for modification are included within the data tables under the field labeled 'Comments'.

The EcoSAV software processes ten pings for each record found within a data table. The field labeled 'NMFS_Plant' depicts the number of pings within the record that were identified as eelgrass. This field is used as a proxy for density, but truly only depicts coverage. The data were classified into three 'density' categories based upon best professional judgment. Specifically, values of 2 to 4 were classified as low density, 5 to 7 medium, and 8-10 high. This classification scheme has not been ground-truthed and should only be used as a relative comparison.

Results

NMFS successfully surveyed the majority of the focus areas that MBNEP requested. Unfortunately, the area selected by MBNEP across from Tidelands Park and adjacent to the spit was too shallow to safely navigate with our vessel. However, it is likely that most of the area in question was above the upper limit of eelgrass distribution. In addition, areas known for subtidal eelgrass growth were surveyed.

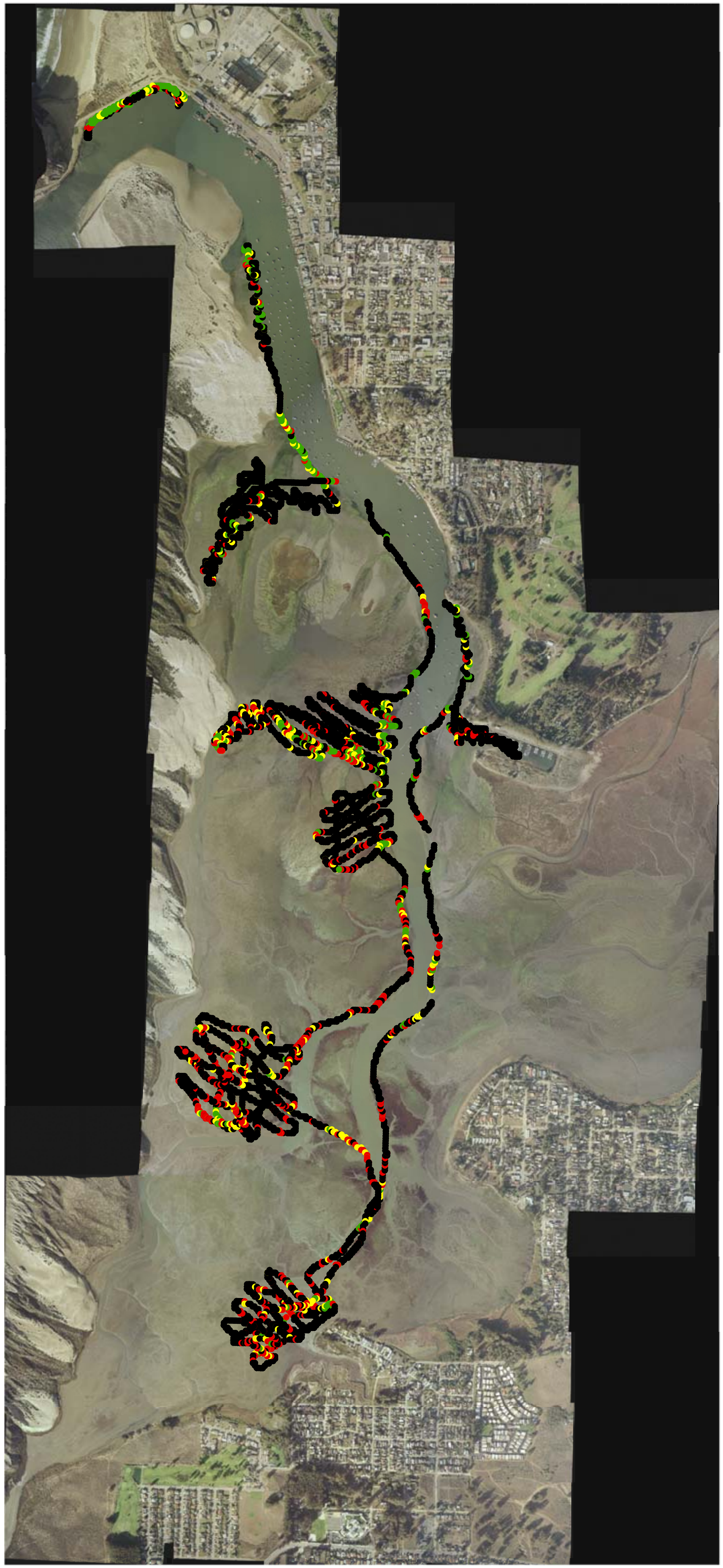
The following figures illustrate the survey tracks for the fall surveys. Low density eelgrass is depicted by red points, medium density eelgrass by yellow points, and high density eelgrass by green points. The black points indicate those locations that were surveyed, but did not detect eelgrass. Figure 1 illustrates the entire survey area. The remaining figures are subsets of the entire survey area that are based upon focus areas the MBNEP provided prior to the field surveys.

The main utility of this survey effort is to assist with the verification of remotely sensed eelgrass habitat obtained from the aerial surveys. Given slight differences in survey location and intensity, it is difficult to establish robust conclusions regarding interannual differences in eelgrass coverage. However, based upon comparisons of the 2006 and 2007 acoustic datasets, there appears to have been a slight reduction in eelgrass coverage from the previous year. This should be evaluated with greater certainty by the more comprehensive survey results provided by the aerial imagery.

In addition to the figures provided, electronic data has been provided under separate cover to be utilized within MBNEP's geographic information system (GIS). If desired in the future, the original echograms can also be shared.

November 7 – 8, 2007
NMFS Eelgrass Survey Effort

Figure 1: Entire Bay



Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density

N

0 0.25 0.5 1 Kilometers

Figure 2:
Anchorage Area

Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density

N

0 0.0375 0.075 0.15
Kilometers

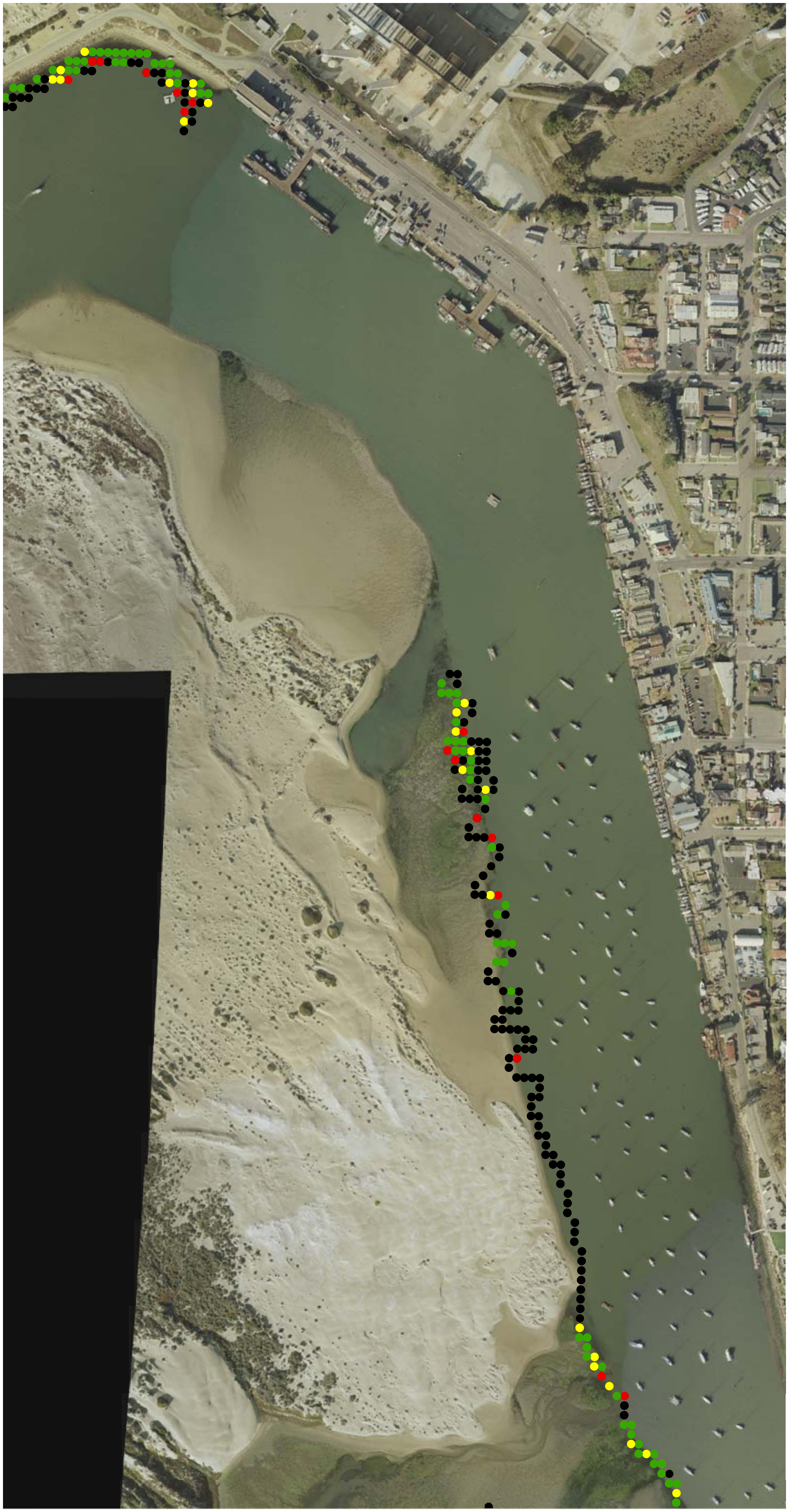
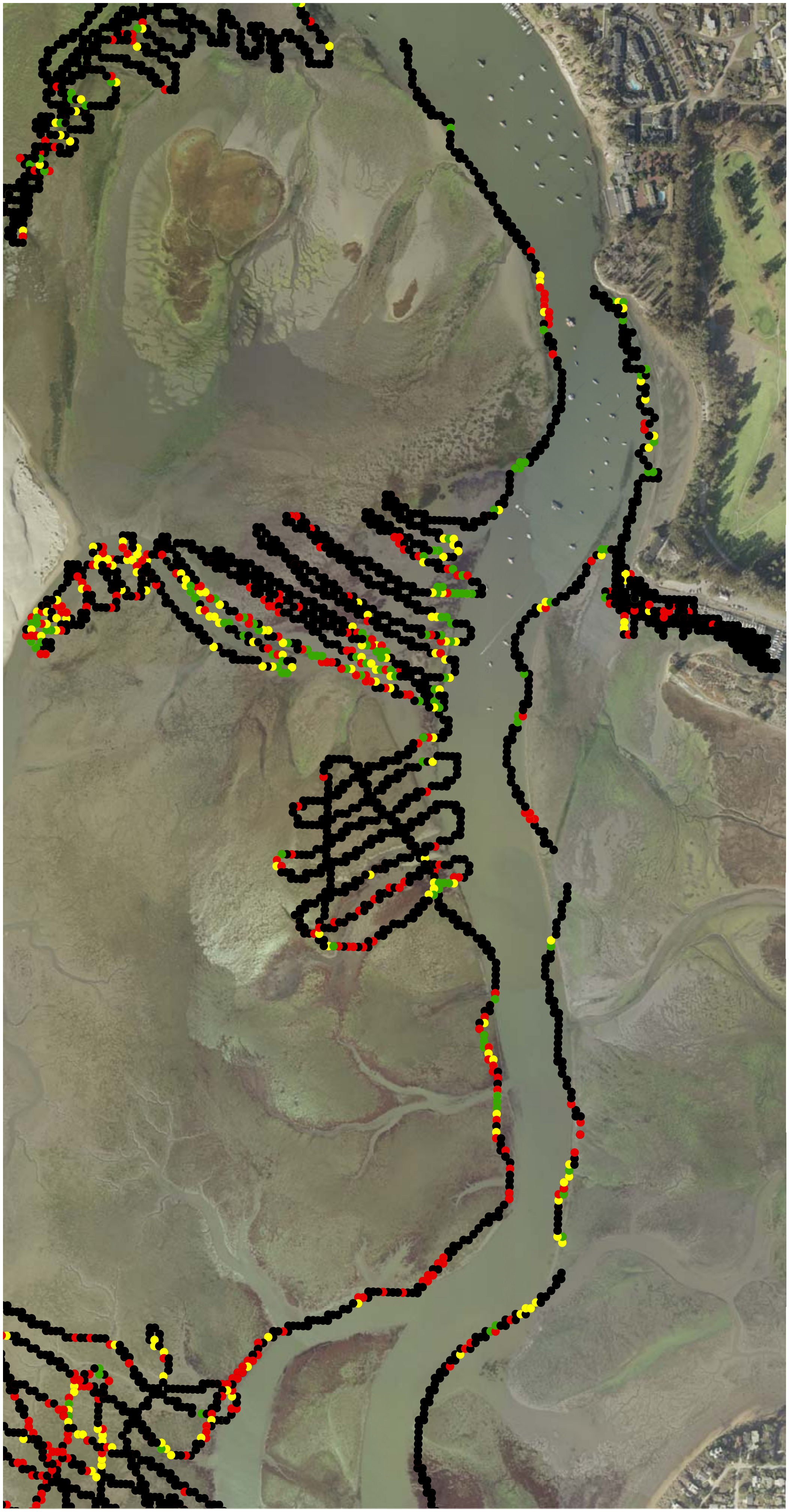


Figure 3:
Entrance Channel

Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- ● No Eelgrass Detected
- ● Low Eelgrass Density
- ● Medium Eelgrass Density
- ● High Eelgrass Density

Figure 4: Middle Bay



Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density

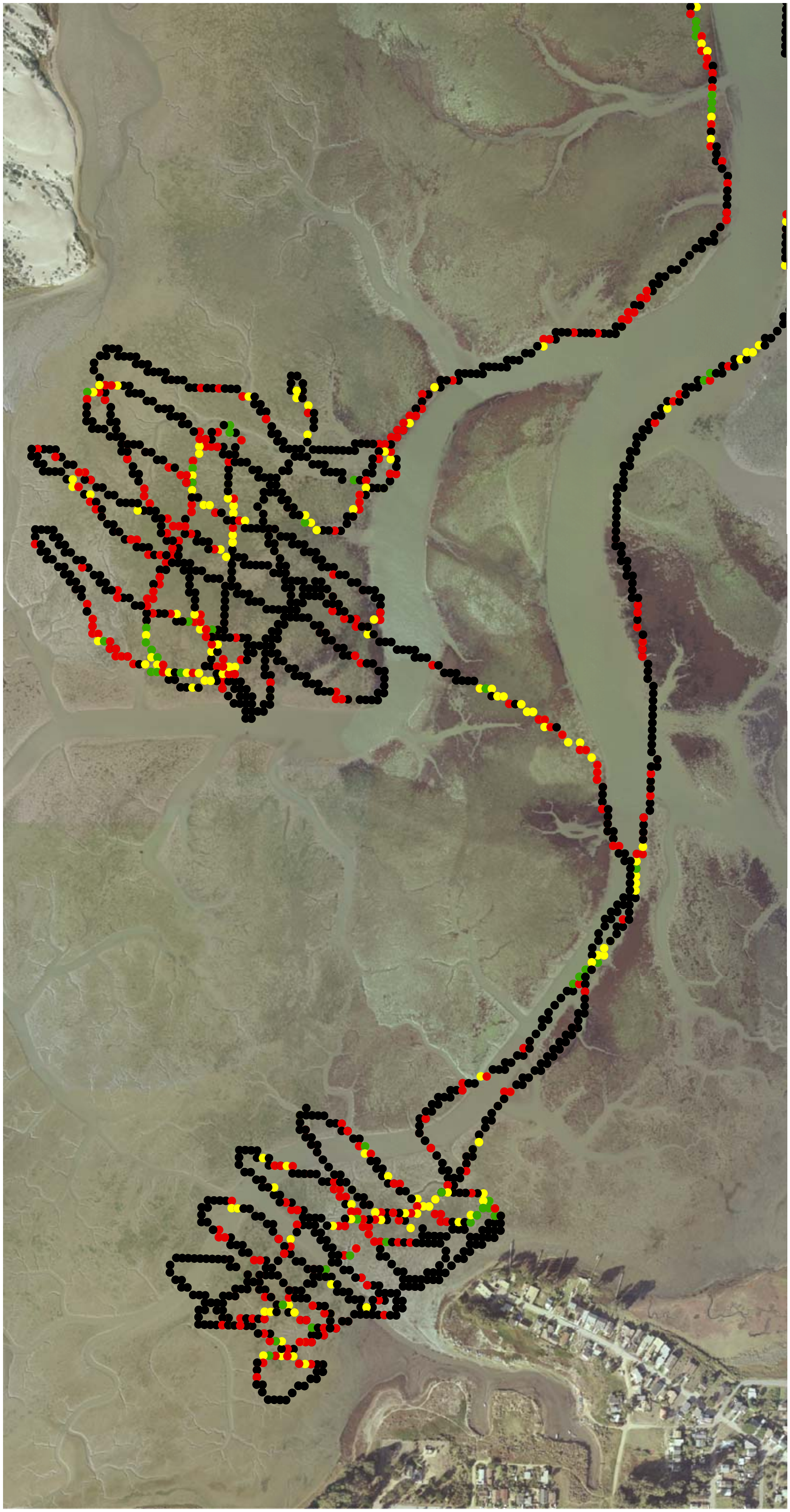
N

0 0.1 0.2 0.4 Kilometers

Figure 5: Back Bay

Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

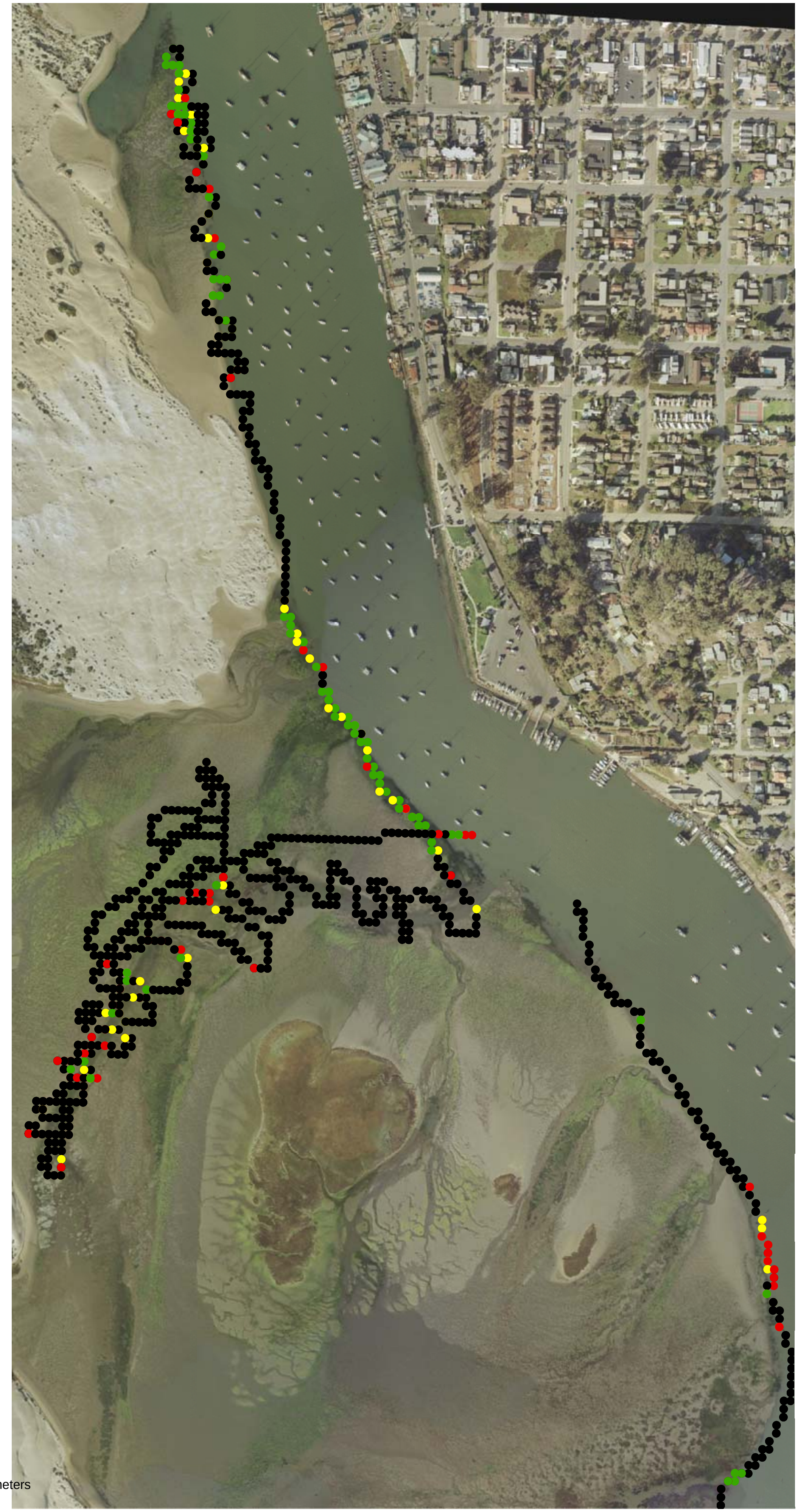
- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density



N

0 0.1 0.2 0.4 Kilometers

Figure 6: Tidelands Park



Morro Bay
NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density

Figure 7:
NMFS Eelgrass Survey and MBNEP's Survey Focus Areas

NOAA Fisheries
Eelgrass Survey
November 7-8, 2007

- No Eelgrass Detected
- Low Eelgrass Density
- Medium Eelgrass Density
- High Eelgrass Density
- Survey Focus Areas

N

0 0.25 0.5 1 Kilometers