Morro Bay National Estuary Program

Morro Bay Eelgrass Report
2014 to 2016

Morro Bay National Estuary Program

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Introduction

Seagrass beds are among the most valuable coastal habitats worldwide. They perform a wide range of important ecosystem services, including carbon sequestration, sediment accretion and stabilization, and water purification (Nordlund et al. 2017). Eelgrass (*Zostera marina*), like other seagrasses, is a critical foundational habitat. Eelgrass creates habitat that leads to increased abundance and diversity of many invertebrate and fish species, and it serves as a nursery for ecologically and commercially-valuable species.

Unprecedented declines in seagrass distribution have been observed worldwide and are a growing cause for concern. The reason for the decline is attributed to many natural and anthropogenic factors in coastal ecosystems. Natural impacts may come from natural changes in water depth, salinity, wave velocity, turbidity due to sediment or phytoplankton blooms, and herbivory pressure. Anthropogenic impacts may be either direct or indirect. Direct impacts include seagrass removal by dredging, propeller scarring, or shading caused by boat moorings or pier construction. Indirect impacts include the introduction of invasive species and non-point source loading of nutrients, herbicides, and sediment which negatively impact water clarity (Hauxwell et al. 2003). The indirect effects associated with sea level rise and climate change are not well understood but are widely expected to negatively impact seagrass distribution globally (Ralph et al. 2007).

Morro Bay supported the third largest eelgrass dominated ecosystem in the southern California region (Bernstein et al. 2011). However, eelgrass in Morro Bay has declined by more than 90% since 2007. While the cause of the drastic decline is still unclear, it has spurred many restoration and research efforts.

This report aims to compile and summarize all eelgrass related activity between 2014 and 2016. This includes clarifying eelgrass mapping techniques and results, reviewing the three large-scale transplants completed during the summers of 2012-2014, outlining monitoring methods to track eelgrass, and presenting the many research projects related to eelgrass in Morro Bay.

In 2016, new patches of eelgrass were seen growing in areas where it had previously been lost. This exciting observation suggests that the declining eelgrass trend may have ended, although there is a long road of research ahead to understand these recent trends, the current status, and recovery efforts.

Morro Bay Project Area

Morro Bay is a shallow coastal lagoon located on California’s Central Coast in San Luis Obispo County. The town of Morro Bay (population 10,640) was founded in 1870 and is located in the northern extent of the estuary. The unincorporated community of Los Osos (population 14,276) is located on the southern shores of Morro Bay (Fig. 1). Morro Bay was established as California’s first State Estuary in 1994, paving the way for inclusion in the National Estuary Program in 1995. Today, Morro Bay is one of 28 recognized National Estuaries.

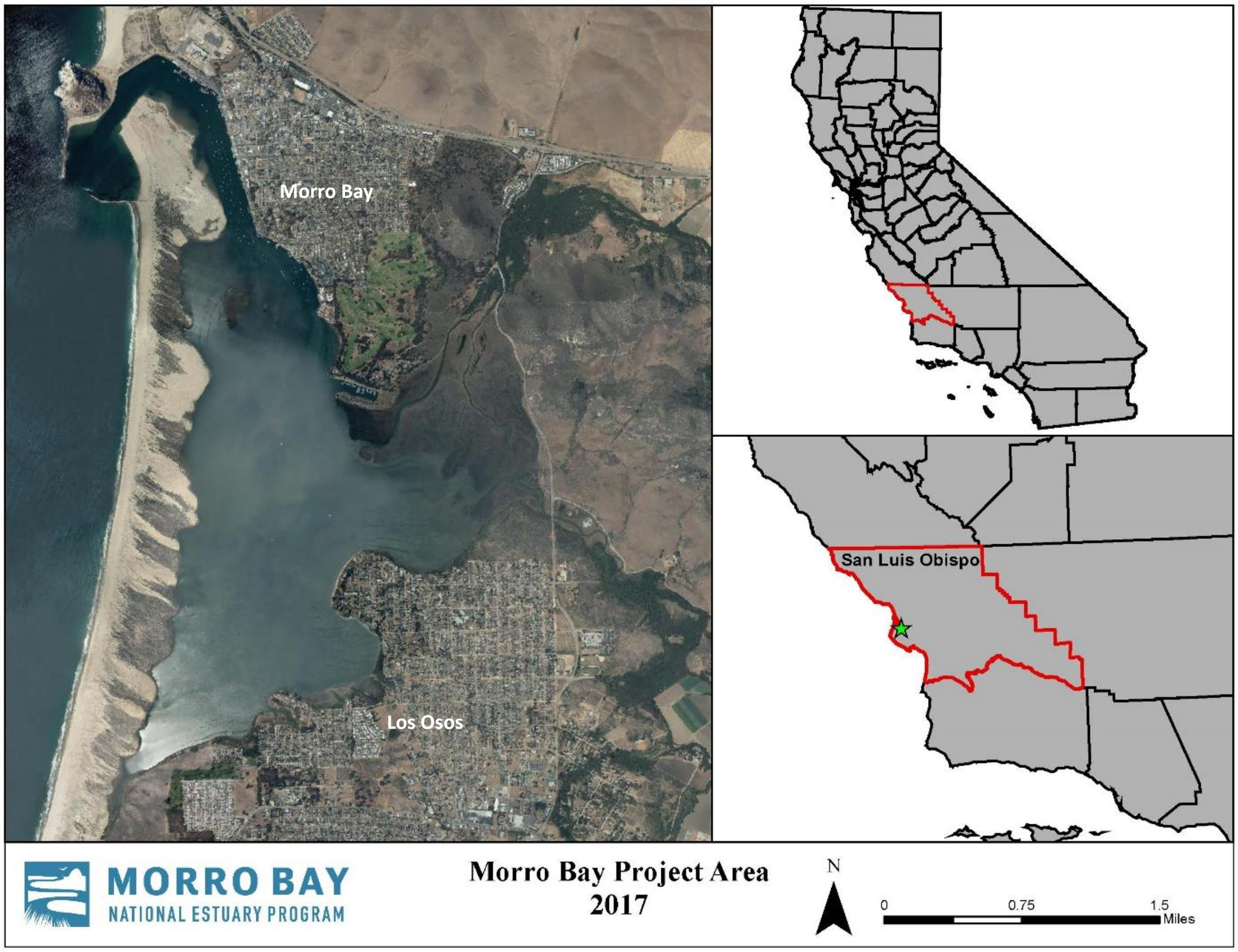

Figure 1. Morro Bay.

Morro Bay Estuary and Harbor

The Morro Bay estuary is comprised of approximately 2,300 acres of shallow, semi-enclosed intertidal and subtidal habitat. The estuary is bordered to the west by a four-mile vegetated natural sandspit that separates Morro Bay from the Pacific Ocean. Seagrass beds in Morro Bay are dominated by eelgrass (*Zostera marina*) with small patches of widgeon grass (*Ruppia maritima*) interspersed throughout the estuary. To date, Japanese eelgrass (*Zostera japonica*) has not been identified in Morro Bay. Habitat types and distribution are shown in Fig. 2.

Morro Bay is a popular destination for outdoor recreation and is also an important port for commercial fishing and aquaculture operations. Recreational uses in the bay include kayaking, sailing, fishing, wildlife observing, and waterfowl hunting. Two commercial aquaculture operations grow Pacific oysters (*Crassostrea gigas*) and operate in conditionally-approved areas of the intertidal mudflats.

The Morro Bay harbor is an important port and is maintained by regular dredge events (see “Dredging Operations” on pg. 17).

Morro Bay Watershed

The Morro Bay watershed encompasses drainage from approximately 75 square miles. Freshwater inflows are delivered to the estuary via the Chorro Creek and Los Osos Creek sub-watersheds and through groundwater seepage in the Los Osos area. Non-urbanized lands in the Chorro Creek sub-watershed are used primarily as rangeland and public parks. Non-urbanized lands in the Los Osos sub-watershed are dominated by rangeland, row crop agriculture, and commercial greenhouse nurseries. There have been a number of water quality impacts within the Morro Bay watershed and estuary—for more water quality information, please refer to the Estuary Program's 2015 Data Summary Report, available at http://www.mbnep.org/library.

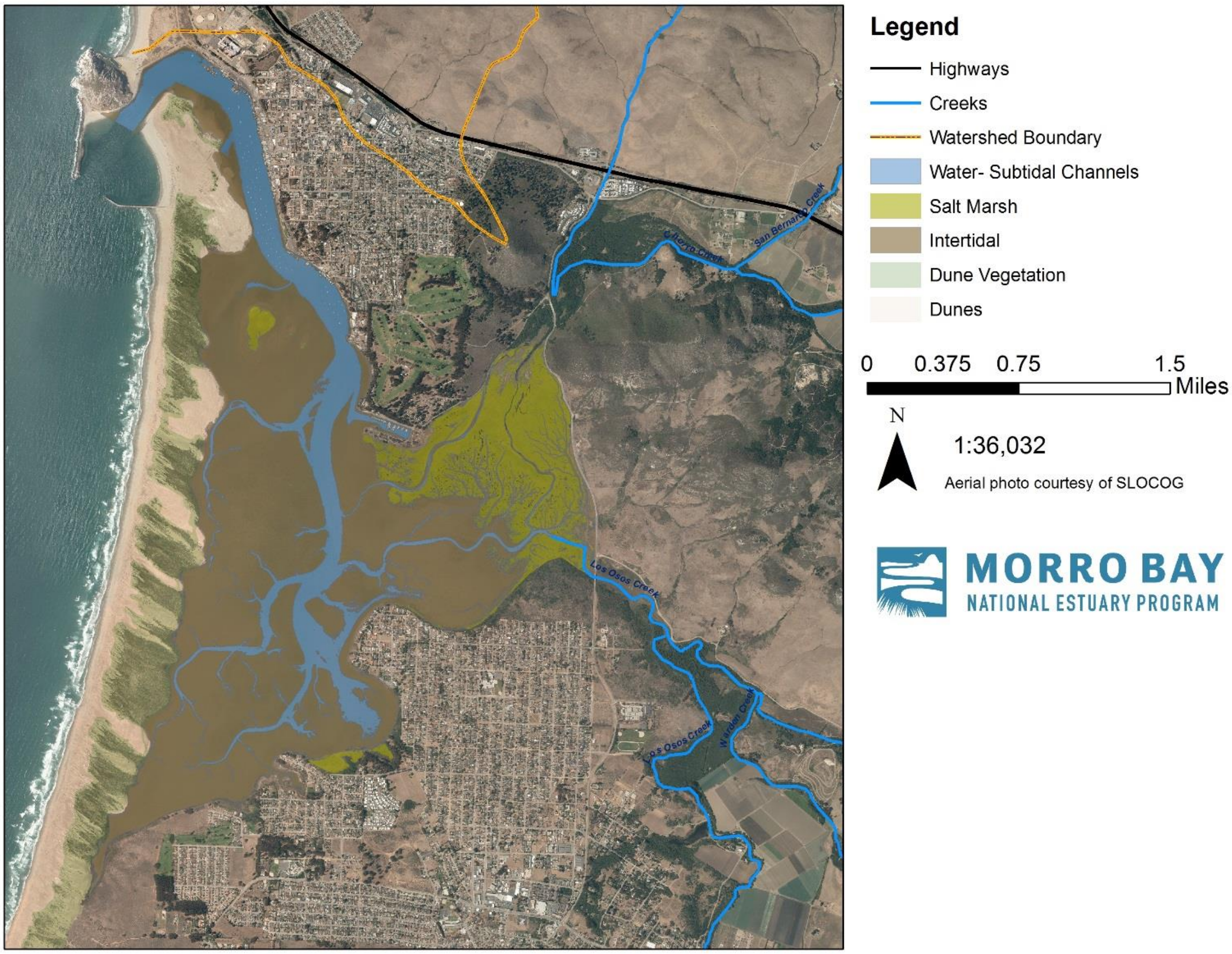

Figure 2. Morro Bay Estuary habitat types and distributions. Data from 2010.

Eelgrass Distribution

Historical data on eelgrass acreage came from several sources. In 1960, Haydock mapped Morro Bay for the California Dept. of Fish and Game using field surveys. In 1970, Fish and Game used aerial photos to estimate acreage. In 1988, Josselyn also used aerial photos and estimated eelgrass acreage to be 732; John Chesnut later reinterpreted these same photos and estimated eelgrass acreage to be 404. Between 1994 and 1998, Chesnut used quadrat sampling to estimate acreage and in 1998, Tetratech used aerial photos. Chesnut has demonstrated that aerial photo interpretation is inconsistent, and there is a poor correlation between eelgrass density (particularly of sparse beds) and photographic tone. (See Chesnut 1999 for more detail on these historical data.) Although many of these early estimates use aerial photo interpretations to estimate eelgrass in the bay, unfortunately discrepancies have not been fully quantified or reconciled for datasets generated prior to

2002. In 2002 and 2003, the Morro Bay National Estuary Program (Estuary Program) contracted true color aerial flights, which were later re-analyzed using multi-spectral analysis to create a map similar to what was done in later years.

The Estuary Program began mapping submerged vegetation using a consistent methodology of aerial imagery classification in 2004. Between 2004 and 2013, intertidal eelgrass was mapped by aerial flights using multispectral aerial images. Flights were typically done during extreme low tides in November. In 2012, the flight had to be canceled due to poor weather and contractor logistics and was instead completed in May 2013.

Merkel & Associates (M&A) surveyed the bay in July 2013 and 2015 using sidescan sonar, a method that targets subtidal eelgrass. The 2013 acreage number and map were compiled by combining the May aerial flight data and the July sidescan sonar data, which creates a comprehensive picture of intertidal and subtidal eelgrass throughout the bay. The 2015 acreage data is from the July sidescan sonar survey (Merkel & Associates 2015a), without any aerial flight data.

Figures 3 and 4 present these eelgrass acreage data. It is important when comparing these data to keep in mind that the only consistent method mapped intertidal eelgrass was from 2002 to 2010. The 2013 data was collected in a different season (spring for the flight and summer for the sonar, rather than a flight in the fall) and included both aerial imagery and subtidal sonar mapping. The 2015 map was compiled solely from a sidescan sonar survey in the summer.

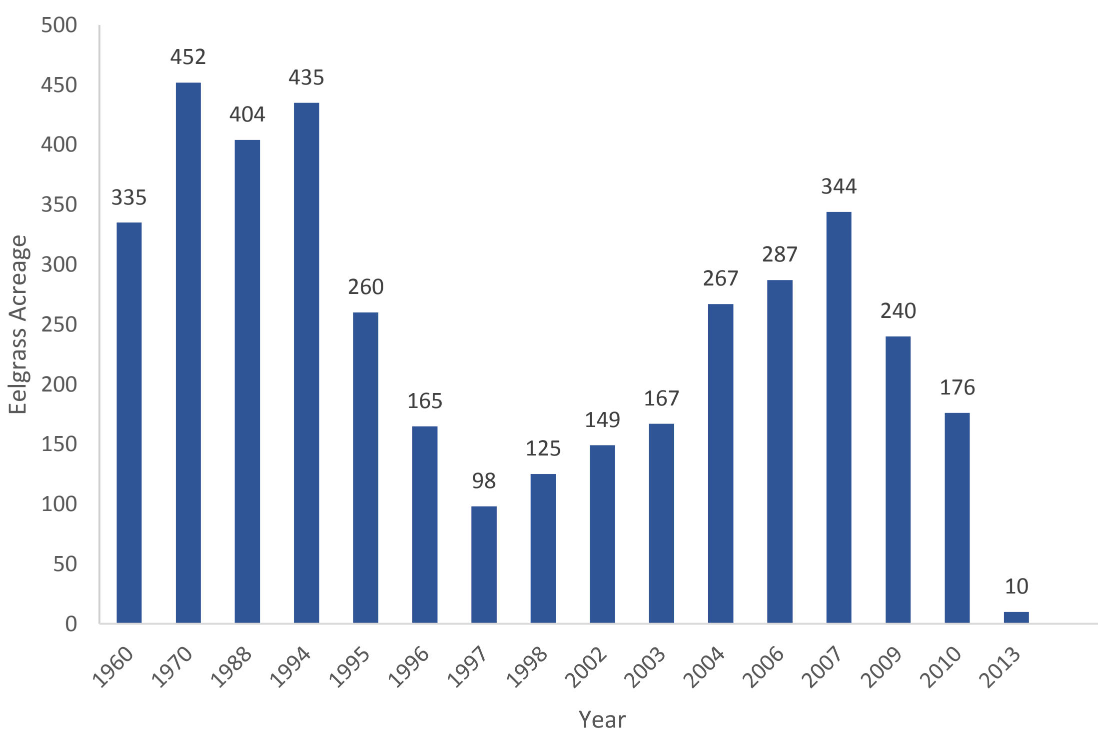

Figure 3. Estimated eelgrass acreage in Morro Bay by year. Between 1960 and 1998, acreage was estimated using field surveys and aerial image interpretation. Multispectral imagery flights were done to map intertidal eelgrass in fall of 2004 to 2010, and in spring of 2013. M&A used sidescan sonar to map subtidal eelgrass in summer of 2013 and combined the Estuary Program's multi-spectral flight data (which mapped 10 acres) with their own subtidal survey data for a total of 15 acres of eelgrass. In 2015, M&A did a sidescan sonar effort and mapped 13 acres of subtidal eelgrass in the bay.

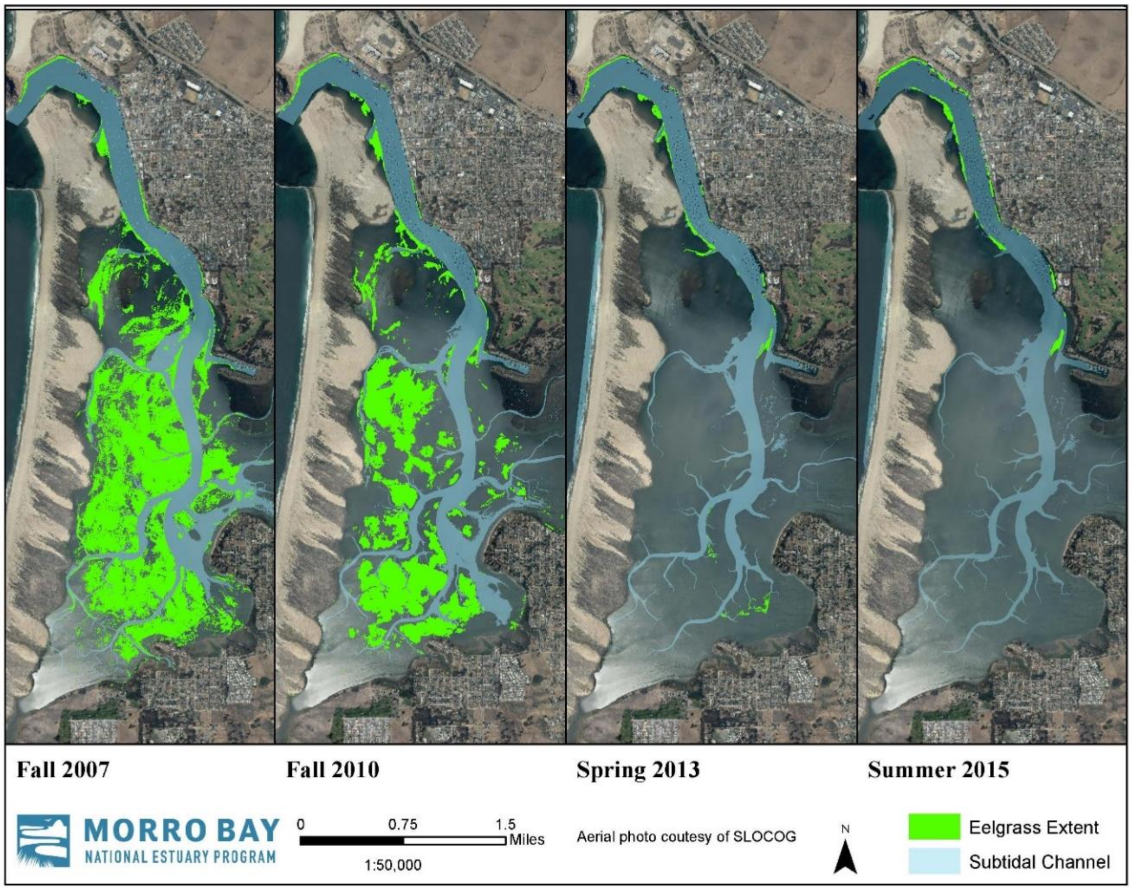

Figure 4. Eelgrass distribution in Morro Bay from 2007-2015. Data from 2007 and 2010 were collected using multi-spectral imagery, which is a method intended to capture intertidal eelgrass. In 2013, both a multi-spectral flight and a sidescan sonar sonar survey mapped the bay, and data were combined to display both intertidal and subtidal eelgrass. The 2015 map was created using only a sonar survey, thus mapping subtidal eelgrass only.

Restoration Efforts

2012-2015: Merkel & Associates

In September 2012, 21 pilot plots of eelgrass were transplanted in a joint effort between the U.S. Army Corps of Engineers, M&A, several local agencies, and local volunteers. The plots were planted in locations ranging from just north of the State Park Marina to just north of Pasadena Point. Each plot was 66 meters long, 3 meters wide, and held 200 planting units. SCUBA divers collected eelgrass at Coleman Beach by raking the rhizome mat, and “planting units” were prepared by bundling 4-8 plants together and attaching a paper and cotton anchor. This same method was used in the 2013 and 2014 transplant efforts in Morro Bay. A total of 4,200 bare-root eelgrass planting units were collected from Coleman Beach and transplanted for a combined total planting area of 1.04 acres for the 2012 effort.

In July 2013, the pilot plots were monitored. Of the 21 plots, 10 had eelgrass. The surviving eelgrass plots were all located in the subtidal (rather than intertidal) zone, which influenced the following transplant effort. Brant grazing was postulated to have been a problem (Merkel & Associates 2015a), and may have been responsible for pulling whole rhizomes from the intertidal plots. During this monitoring session, they found the eelgrass had limited survival and showed slow expansion.

In August 2013, a second transplanting effort was completed over eight days. A total of 9,775 eelgrass units were planted into 49 plots spread throughout the bay. One unanchored plot of leftover eelgrass material was deployed south of the State Park Marina and five buoys of eelgrass seeds placed in mesh bags were deployed. Based on the findings from the July 2013 monitoring, most of the plots were planted in the subtidal/low intertidal zones.

In July 2014, all transplant plots from the 2012 and 2013 planting efforts were again monitored. Of the 70 plots total (21 planted in 2012, 49 planted in 2013), 31 retained eelgrass, plus the additional unanchored plot from 2013. Of the 10 plots planted in 2012 that had eelgrass in 2013, seven still retained eelgrass. As seen in the 2013 monitoring, persisting eelgrass plots were located along low tidal elevations. Surviving plants showed slow basal expansion, which were thought to be due to environmental factors like turbidity levels or to the genetics of the donor bed.

In August 2014, a third transplanting effort was completed over six days. A total of 8,949 eelgrass units were planted into 45 plots. As in the previous 2012 and 2013 transplants, the plots were laid out as linear arrays 66 meters in length and 3 meters wide, with 200 planting units in each plot. To try to eliminate genetic factors that could be limiting transplant success, rather than collecting from Coleman Beach, eelgrass was collected from the beds along the State Park Marina entrance channel and across from Tidelands Park on the west side of the bay. Although we now know there are no significant genetic differences between eelgrass beds within Morro Bay, per genetic research conducted by Dr. Jenn Yost of California Polytechnic State University San Luis Obispo (Cal Poly). Again, plots were planted in the low intertidal and subtidal zones. While planting in some areas, an interesting observation was made: yellow shore crabs (*Hemigrapsus oregonensis*), not previously identified as a consumer of eelgrass, exhibited aggressive herbivory on the new planting units (Fig. 5). See Appendix A for details on the planting method.

In July 2015, all transplant plots were again monitored. Using interferometric sidescan sonar, one eelgrass plant was found in one plot of the 116 plots planted since 2012. Low tide inspections of the plots revealed some residual eelgrass plants, but overall, the transplant survival was minimal. During the monitoring period, the night water temperatures were exceptionally warm in the southern and central bay (21-25°C), much warmer than optimal for eelgrass, which may suggest some environmental factors that were not ideal for the eelgrass (Merkel & Associates 2015a).

While a transplant effort had been planned for 2015, based on these monitoring results, it was canceled, and efforts were redirected toward monitoring and research.

Figure 5. Yellow shore crabs (*Hemigrapsus oregonensis*) cutting and consuming eelgrass blade tissue. Photographs taken within minutes of planting during the 2014 planting effort (Merkel & Associates 2015a).

2016 Monitoring

The Estuary Program received California State Duck Stamp funds to monitor the transplant plots again in 2016. They found eelgrass present, although limited, at 22 of the transplant plots (about 19% of the total planted). While it is possible that the detected eelgrass was related to the transplant efforts, it may also be that the eelgrass was planted in favorable locations for natural recruitment and may or may not have been associated with the restoration plantings. While out on monitoring surveys, the Estuary Program noticed new patches of eelgrass throughout the bay, not just near the transplant sites. Below is a map showing many of the new patches of eelgrass (orange dots) seen in relation to the Merkel transplant locations (blue lines in Fig. 6).

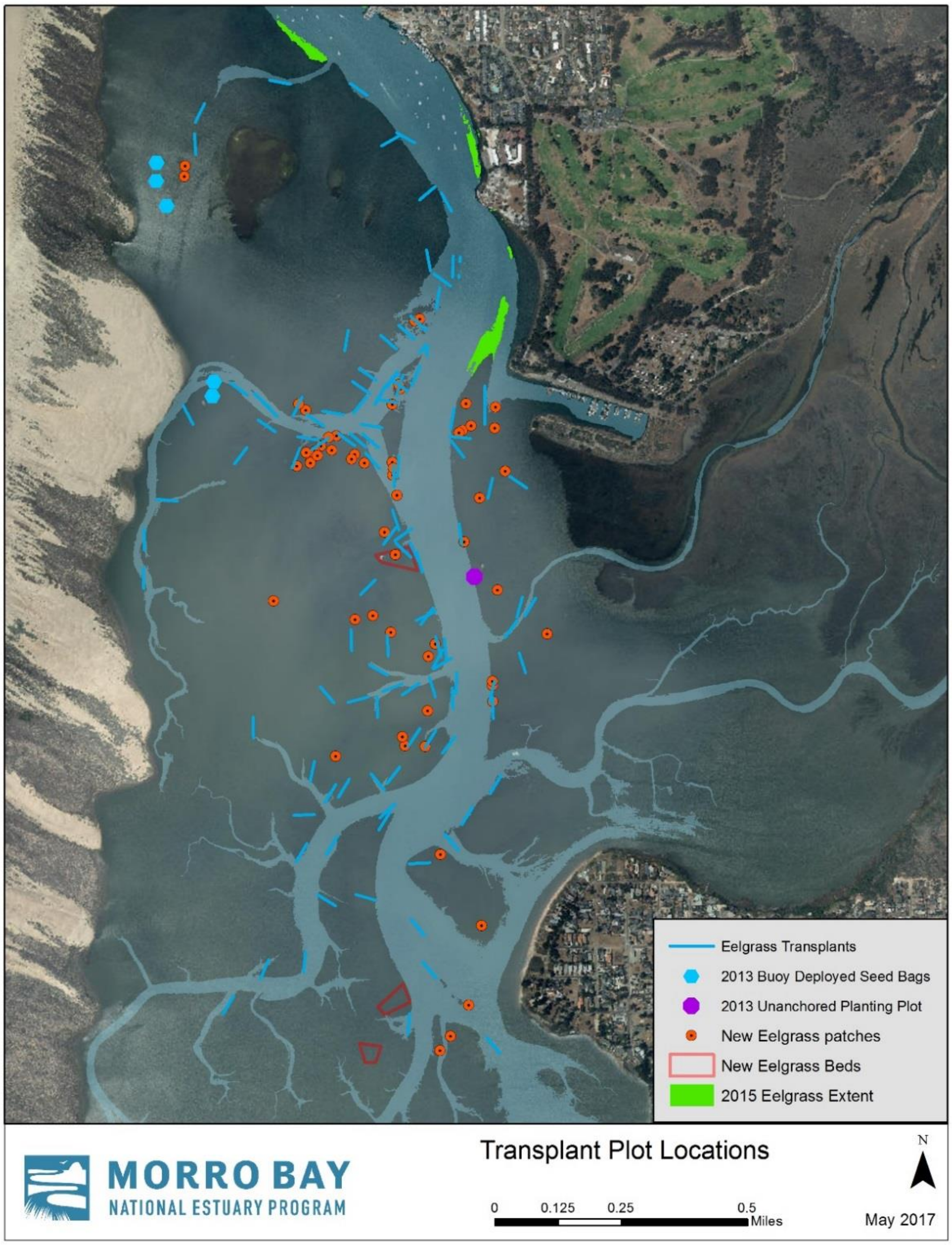

Figure 6. M&A transplant plots and new eelgrass patches observed.

Seed Bag Restoration Research (literature survey)

After the unsuccessful 2012 to 2014 transplant efforts, thought was put into trying a different primary technique for restoration, seed bag deployment. Using eelgrass seeds rather than adult plants has been successful in a number of studies and restoration efforts. While a few seed bags were deployed in the 2013 M&A transplant, a focused restoration effort would be more extensive and more intensively mapped and monitored.

There are two primary methods typically used for restoration with seeds. The first is the buoy method which consists of a bag of flowering shoots attached to a buoy on one end and an anchor on the other, such that the bag floats in the water column but has limited movement. As the seeds mature, they drop from the bag onto the sediment. This method allows for quick deployment as flowering shoots can be collected and the seed bags deployed in the same day. This is the method the Estuary Program was planning to use in a seed-bag restoration attempt in fall 2015, but the necessary permits from the California Department of Fish and Wildlife (CDFW) did not come through. While seed bags were never deployed, the Estuary Program tested this method with empty bags and collected data to inform future seed-bag efforts (see Appendix B for details). There are some challenges with the buoy method. Seed dispersal is not precise and thus difficult to monitor and measure success rates, the buoy line catches *Gracilaria*, the anchor may move, and the seeds are not protected in the sediment (e.g., Pickerell et al. 2005; Viani 2009).

The second method of seed restoration is the burlap bag technique, where a bag of seeds is staked down into the sediment. Because mature seeds are collected and put into the bags (and not simply flowering shoots), the preparation for this method is more labor intensive. Flowering shoots have to be collected and held in tanks until the seeds mature and drop. While the preparation may take longer, the success of this method can be tracked more precisely, as the number of seeds going into an exact planting area is controlled. As the bags are placed flush with the sediment, there would be little interference from *Gracilaria,* and seeds would be protected from predation (e.g., Harwell and Orth 1999; Pei-Dong et al. 2015). The Estuary Program is considering using a form of this second method for a seed bag restoration effort in the summer and fall of 2017.

<u>Seed availability</u>

Eelgrass beds throughout the bay were checked periodically for seed availability in 2015 and 2016. It is assumed that most eelgrass beds flower in July and August. In September to October 2015, the eelgrass at Coleman Beach appeared to be the highest producing bed, with many flowering shoots in all stages of seed development. The Tidelands and State Park Marina beds had few flowering shoots, mostly along the edges of the beds. In 2016, of all the stable eelgrass beds, only Coleman Beach had seeds in September and October. Eelgrass at Cuesta Inlet was discovered in October, and young, immature flowers were found in October and November. More observations are necessary to understand the timeframe when eelgrass in Morro Bay flowers and goes to seed.

Other Monitoring Efforts

In addition to monitoring the restoration plots, there are several supplementary monitoring efforts to track eelgrass changes throughout the bay. Permanent transects were established beginning in early 2005 to measure average shoot density at sites located throughout the bay. Bed condition monitoring was established with California Sea Grant and Cal Poly beginning in late 2015 to measure average density and overall condition of eelgrass.

Permanent Transects

History

Permanent transects were established to track eelgrass shoot density annually throughout Morro Bay. There are currently five permanent transects, most having been established in 2005 (Fig. 7). In February 2005, the Estuary Program and Battelle Marine Sciences staff established two transects, across from Tidelands (also known as Reference Bed) and at Chorro Creek. In November 2005, two more transects were established, at Pasadena Point and near Mitchell Lane, and the Chorro Creek transect was moved for better accessibility. In November 2006, a transect at Coleman Beach was established. In 2007, the Mitchell Lane transect was discontinued due to safety concerns. Thus, four transects were monitored annually from 2006 to 2010. No data was collected in 2011 due to staffing logistics. In November 2012, a transect was established near the State Park Marina. Some sites were not surveyed due to poor weather or tide conditions in 2012 through 2016.

Figure 7. The five current permanent transect monitoring locations.

Methods

Fieldwork was usually conducted during extreme low tides (-0.4’ and below) during the late fall, as this period provides the best tidal windows for accessing sites. During years of the fall aerial imagery flight, the timing of transect monitoring often coincided with the flight, which provided a useful qualitative assessment of conditions on the intertidal mudflats.

At each site, a GPS unit was used to identify the transect location (most sites have no permanent markings) and a meter tape was set out along the 50 m transect. A 0.5 m x 0.5 m quadrat was used to take measurements at points along the tape. Percent coverage of eelgrass, macroalgae (*Gracilaria*, *Ulva*), and bare substrate were measured. If eelgrass was present, shoots were also counted to calculate density.

While there are five permanent transect locations, some locations have more than one transect. If the eelgrass bed was fairly wide, more transects were established that run parallel to each other to measure eelgrass at a variety of depths. Note that when analyzing the data, all data from a site in a particular year were combined to represent eelgrass at that general location. Therefore, if there were two transects surveyed for one site in one year, those data were combined.

Initially, the effort included a biomass measurement. From 2005 to 2012, biomass samples were collected adjacent to each transect. However, as eelgrass declined, it became too damaging to collect samples, and the biomass study was stopped.

Results

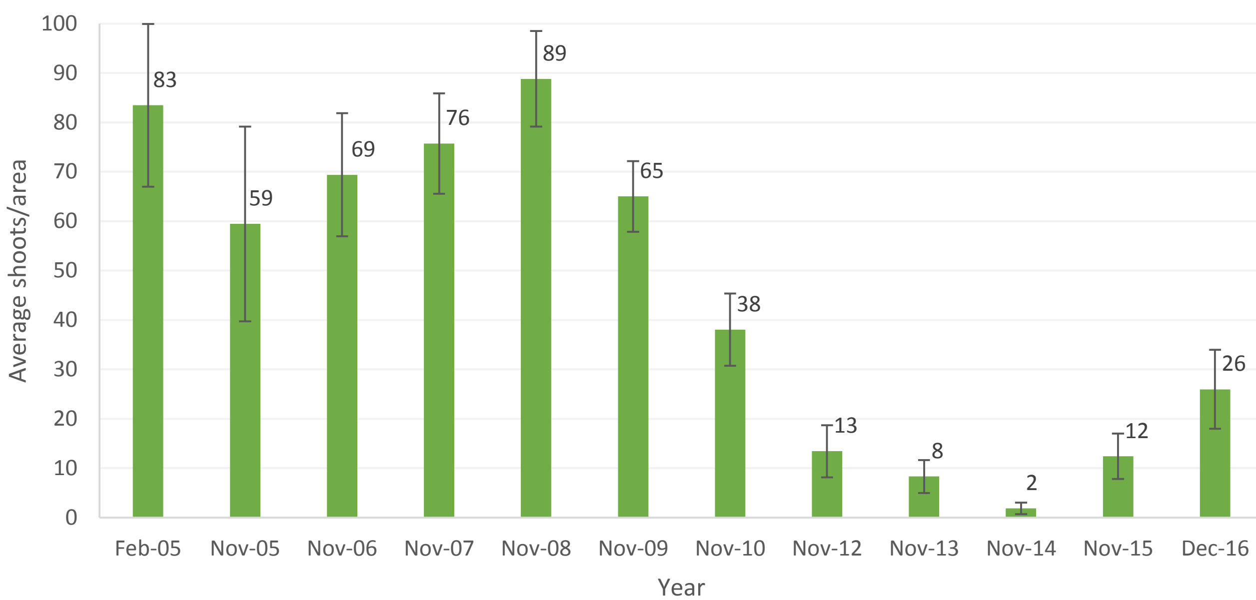

Figure 8. Intertidal eelgrass shoot density counts per year, averaged across all sites sampled. Shoots were counted within a 0.5 mx0.5 m area. Error bars represent the 95% confidence interval.

Across all sites, there was a decrease in average shoot densities between 2008 and 2014 (Fig. 8). Individual transect sites have seen a similar trend, with some slight variations and are summarized by location below (Fig. 9).

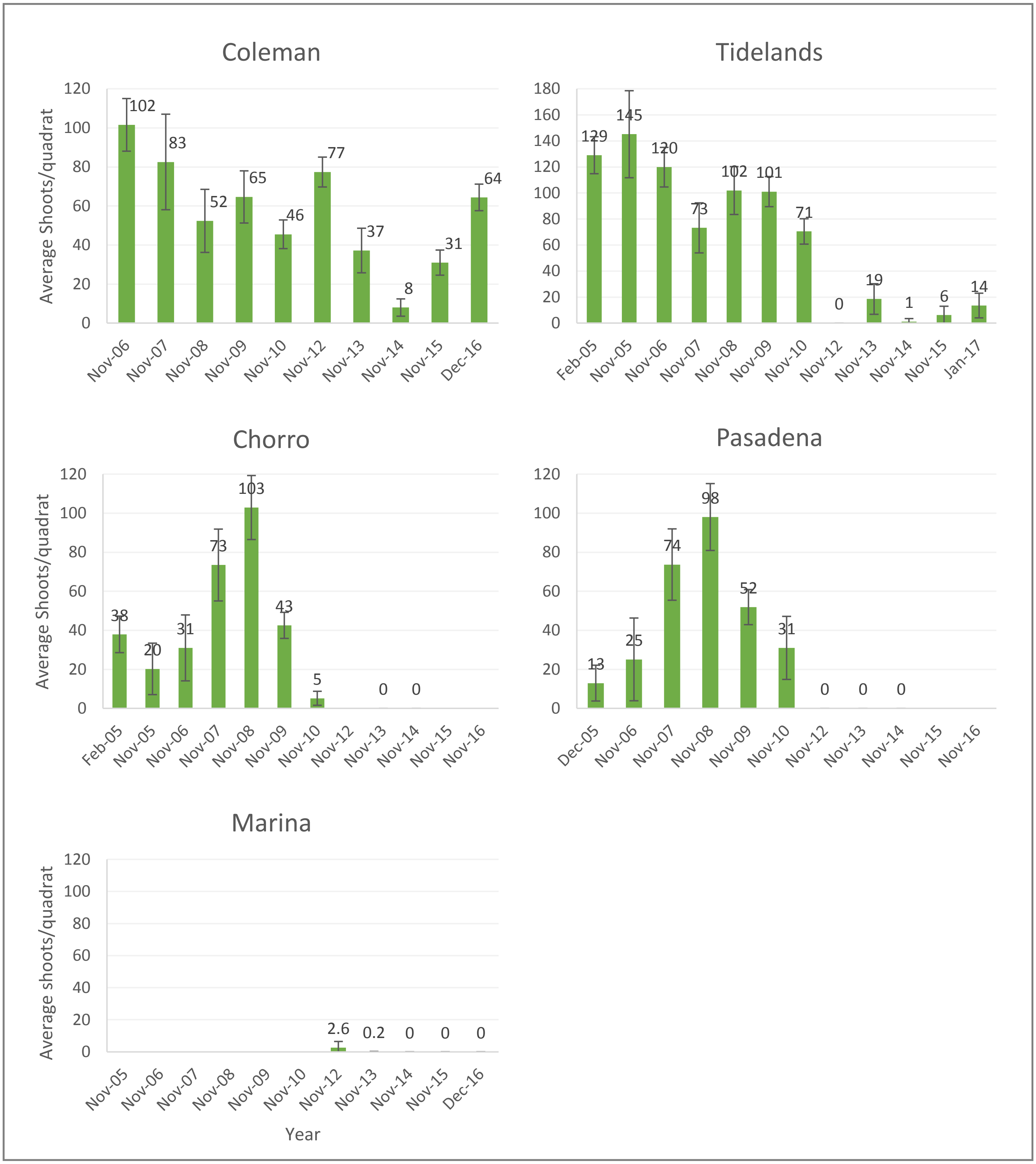

Figure 9. Average shoot density counts at each site per year. Shoots were counted within a 0.5 mx0.5 m quadrat. Error bars represent the 95% confidence interval.

Transects in the northern extent of the bay (Coleman and Tidelands) have generally maintained higher shoot densities than sites in the southern extent of the bay, but both northern sites saw drastic declines in recent years. Since 2014, however, these two sites have both seen an increase in shoot densities, which is particularly pronounced at Coleman.

Transects in the southern extent of the bay (Pasadena and Chorro) both saw a peak in eelgrass density around 2008 and have declined since. Unfortunately, we do not have data for 2015 to 2016 to know whether densities are increasing at these sites. The Marina transect has had very low densities every year since it was established in 2012.

See Appendix C for site pictures and observations.

Bed Condition Monitoring

Introduction

As eelgrass declined, a new method of monitoring eelgrass beds was needed to supplement the permanent transects. Bed condition monitoring and an expanded research program was established as a joint effort between California Sea Grant Extension Specialist Dr. Jennifer O'Leary and the Estuary Program in late 2015. The detailed protocol measured the location and condition of the eelgrass. Both intertidal and subtidal eelgrass were surveyed, as so much of the intertidal eelgrass is gone. Monitoring occurred twice per year, once in late fall and again in the spring. The plan is to continue this monitoring in future years.

Methods

Intertidal monitoring occurs at four significant eelgrass beds in Morro Bay: Coleman Beach, North Sandspit, Reference Bed, and Windy Cove (Fig. 10). Measurements are taken along a 150 meter, 7 quadrat survey through the bed (if the bed length allows). Ideal tides for intertidal monitoring are below -0.5 feet. A 1 mx1 m quadrat is placed every 25 m to measure eelgrass. Data collected includes eelgrass density, macroalgae and other organism presence, eelgrass blade lengths, diseased spots on eelgrass blades, and overall patchiness of the bed.

Subtidal monitoring occurs at five significant beds in Morro Bay: Coleman Beach, North Sandspit, Reference Bed, Windy Cove, and the State Park Marina (Fig. 10). Measurements are taken in a 150 meter, 7 quadrat survey through the bed (if the bed length allows). Often due to lack of visibility, a less robust data set is measured during subtidal surveys. Data collected includes shoot density and patchiness of the bed.

Data are currently being analyzed and will be included in a future report.

Figure 10. Bed condition monitoring sites.

Additional Activity

Dredging Operations

The Morro Bay harbor is a designated Harbor of Safe Refuge and is the only safe harbor between Santa Barbara and Monterey. Maintenance of this significant harbor as a port for fishing and recreational vessels requires frequent dredging operations. The harbor mouth is dredged annually by the Army Corps of Engineers (ACOE) to maintain a channel depth of approximately 40 ft.

During May of 2014, 2015, and 2016, the Yaquina hopper dredge removed 173,600 cubic yards (CY), 138,200 CY, and 260,000 CY of material (respectively) from the entrance channel and main channel. The Yaquina did not dredge the mid channel or back channels of Morro Bay Harbor, and there were no documented impacts to eelgrass. Dredge spoils were deposited at the designated nearshore placement site, south of the Morro Bay Entrance, offshore of Montana de Oro State Park (U.S. Army Corps of Engineers 2016).

Dredge Mitigation

The 2009-2010 dredge operation resulted in damage to eelgrass, and a mitigation agreement was established between the ACOE and the National Marine Fisheries Service (NMFS) to plant an eelgrass area of approximately 1.74 acres. The final 60-month monitoring report was completed in September 2015 (Merkel & Associates 2015b).

Figure 11. Eelgrass mitigation, donor, and reference sites (Merkel & Associates 2015b).

The mitigation site was prepared by the ACOE so that it would be suitable for eelgrass. The transplant effort was led by M&A, and in July 2010, 5,584 eelgrass planting units were planted. Eelgrass was collected from the two donor sites by SCUBA divers. Plants were bundled into planting units of six to ten leaf-shoots per unit and planted within 24 hours of collection. SCUBA divers planted the eelgrass units using biodegradable soft anchors over a planting area of 2.4 acres. A supplemental transplant in September 2012, again led by M&A, added 2,187 planting units to gaps in the 2.4 acre planting area. In addition, 2,000 planting units were planted into ten central bay pilot plots. The Morro Bay Eelgrass Recovery Program expanded the central bay plantings by adding 11 more plots, for a total of 21 pilot plots (see section “2012-2015: Merkel & Associates” on pg. 8 for more details).

Monitoring occurred 3, 6, 12, 24, 36, 48, and 60-months post-planting. Two eelgrass reference sites were monitored in conjunction with the mitigation site as a control to track natural changes in eelgrass. Overall eelgrass distribution data were collected using interferometric sidescan sonar, and eelgrass density data were collected within the mitigation site and reference sites.

The final 60-month monitoring survey showed a total of 1.3 acres of eelgrass within the mitigation site and mitigation targets were attained. Compared to the reference sites, the mitigation site almost always has higher eelgrass densities. The ten pilot plots planted in the central bay were all without eelgrass in 2015.

Embarcadero Projects

Eelgrass grows in patches along the Morro Bay Embarcadero, and impacts to eelgrass must be considered before any construction may occur. Surveys, typically done by Tenera Environmental, are done before, during, and after construction projects to monitor eelgrass and document any impacts. Between 2008 and January 2017, 23 surveys (almost all done on SCUBA) were completed over the course of seven construction projects. The surveys identified about 1,150 m^2 of eelgrass and more than 900 m^2 of possible habitat that could potentially be impacted by the projects. The biggest potential threat to eelgrass and habitat across all the projects was shading. Sediment resuspension and construction disturbances were other possible risks to the eelgrass. While the seven projects are all at various stages of completion, no eelgrass has yet been significantly affected. One project even aims to increase possible habitat by 340 m^2.

In December 2014, Tenera Environmental brought up challenges in permitting Morro Bay Embarcadero construction projects due to uncertainty in eelgrass mitigation. Because eelgrass is now extremely limited and showing a decline in the bay, transplanting efforts to mitigate any project may not be successful. The issue was discussed with representatives from the Estuary Program, NOAA, CDFW, CA Coastal Commission, City of Morro Bay, US Fish and Wildlife Service (USFWS), and ACOE. It was decided that each project should be dealt with individually, especially because the total amount of eelgrass and habitat for eelgrass involved with all the Embarcadero projects is estimated to be less than one acre. While originally thought to be an option, a comprehensive program to deal with eelgrass impacts collectively may be too difficult to create, manage, and fund.

2015 Eelgrass Public Forum

In lieu of a 2015 restoration effort, the Estuary Program held a public update on eelgrass in August 2015. The presentations highlighted what eelgrass is, the history of the decline, previous restoration efforts, the many partners of the eelgrass project, and the next steps to eelgrass recovery. The talk mentioned the proposed seed restoration effort of fall 2015 (which were never completed due to permitting difficulties). The talk also covered the partnership with Cal Poly and California Sea Grant, as research and adaptive monitoring are fundamental to achieving successful long term eelgrass recovery in Morro Bay.

Partnerships

Between 2014 and 2016, the Estuary Program and many other agencies continued efforts on eelgrass research and restoration. The Estuary Program has partnered with Cal Poly and California Sea Grant in order to support eelgrass research efforts. This partnership promotes sharing of data and expert opinions to help guide eelgrass activity.

Research Efforts

Genetic Diversity of Eelgrass

Dr. Jenn Yost, plant biologist and professor at Cal Poly, spearheaded a genetics study of the eelgrass in Morro Bay. Her team of undergraduate and graduate students investigated the genetic diversity and population structure of Morro Bay eelgrass, as genetic diversity has been shown to be an important factor in eelgrass bed health. They found that there is relatively high genetic diversity in the eelgrass in Morro Bay. The diversity is comparable to other Pacific Coast bays, suggesting that the Morro Bay eelgrass is not experiencing negative genetic consequences after the population decline. All of the remaining eelgrass beds in Morro Bay are genetically homogeneous, as are eelgrass shoots at different depths in the bay. The team also compared Morro Bay eelgrass with Bodega Bay eelgrass and, as expected, found the populations are genetically distinct. This, along with a previous study from 2014, indicates that Morro Bay eelgrass is genetically distinct from both southern and northern populations. This study has important restoration implications: there is no need to bring eelgrass in from other bays to increase genetic diversity (it may actually be detrimental to do so) and if transplanting, eelgrass can be collected from any part of the bay. Julia Harenčár presented this data as her Master’s thesis in June 2017 (Harencar, in preparation).

Fish Biodiversity

Dr. Jennifer O’Leary, California Sea Grant Extension Specialist and Cal Poly professor, studied fish populations in Morro Bay. In 2007, seven sites throughout the bay were trawled to catalog species. Since the eelgrass decline, O’Leary has trawled the bay to compare species and diversity. O’Leary has also seined beaches of Morro Bay to compare fish diversity and abundance in bare sand-bottomed areas to eelgrass beds. These are both on-going projects and data will be reported in a future report (Jennifer O’Leary, personal communication, 2017).

Water Quality Monitoring

In 2007, the San Luis Obispo Science and Ecosystem Alliance (SLOSEA) installed water quality instrument packages at the mouth of the bay and in the back-bay to measure temperature, oxygen, conductivity, water depth, turbidity, fluorescence, current, and nitrates. The sensor station in the back bay also contained a weather station that measured air temperature, relative humidity, wind speed, wind direction, rainfall, barometric pressure, and solar radiation. The back-bay station was removed in 2011 due to limited funding, but the mouth bay station continues to collect data and is funded by the Central and Northern California Ocean Observing System (CENCOOS). In 2015, thermistors for temperature measurements from CDFW were deployed at the mouth of the bay and the back-bay for ongoing data collection.

Dr. Ryan Walter, professor in Cal Poly's physics department, has led a more recent effort to quantify the water quality and circulation in Morro Bay in order to support eelgrass studies. In the summer of 2016, a set of oceanographic moorings were deployed for about a month to assess water circulation throughout the bay. This study found that for the month of July 2016, the bay mouth and back-bay each contained distinct water masses with minimal exchange between the two areas. New instruments were deployed in winter 2017 to assess water mass composition and quality and seasonal changes over an annual cycle, in conjunction with eelgrass experimental transplants (Ryan Walter, personal communication, May 2017).

Crab Biodiversity

Dr. Lisa Needles from Cal Poly's Biological Sciences Department has been quantifying the diversity, size, and abundance of crabs inside and outside eelgrass beds and in different areas of Morro Bay. Preliminary findings from trapping efforts in 2015 and 2016 suggest that there are more abundant crab populations and larger crabs towards the back of the bay both inside and outside of eelgrass beds. In 2017, undergraduate students will be studying the preference of crabs for certain prey items. The goal is to understand direct impacts of crabs to eelgrass via the clipping of the blades and bioturbation and disturbance of shoots. Through a coast-wide collaboration with researchers at several other institutions including University of California, Santa Cruz, the indirect effect of the Southern sea otter on eelgrass (e.g., through the consumption of crabs) is also being assessed (Lisa Needles, personal communication, June 2017).

Suaeda Survey

Cal Poly and San Francisco State University partnered to begin to identify a connection between eelgrass and California sea-blite (*Suaeda californica*). *Suaeda californica*, a federally-listed endangered plant, is a salt-tolerant wetland shrub that grows in the narrow high marsh zone. Morro Bay and San Francisco Bay are the only two estuaries that currently support this rare species. In Morro Bay, eelgrass wrack – dead plant material that washes up to the high marsh zone – may help provide nutrients and moisture to *Suaeda*, encouraging growth and survival. The researchers were interested in testing this relationship to understand and predict how *Suaeda* populations will change with the decline in eelgrass and eelgrass wrack.

The study intended to collect preliminary data on the relationship between eelgrass and *Suaeda* through review of historic images and observations, surveys of *Suaeda* and wrack line composition and distribution, and field experiments testing the relationship between eelgrass wrack and *Suaeda* success in both estuaries.

In 2016, a team from Cal Poly mapped the distributions of eelgrass wrack and *Suaeda* around Morro Bay (Fig. 12). This map may be used to compare future *Suaeda* distributions as eelgrass populations fluctuate. The experimental component of the study aimed to compare how wrack inclusion vs. exclusion impacted *Suaeda* seedling growth, but it was inconclusive. However, several new *Suaeda* plants were successfully transplanted on the eastern side of the Bay, near Pasadena Park in Los Osos. Matt McKechnie compiled the report of the study for his Cal Poly senior thesis and was assisted by Jennifer O'Leary, Jenn Yost, Kathy Boyer, and students Frances Glaser, Erin Aiello, Kyle Nessen, Taylor Danielson, and Sean Whitlock (McKechnie 2017).

Figure 12. Distributions of *Suaeda* and eelgrass wrack (McKechnie 2017).

Black Brant Population and Behavior Changes

The black brant (*Branta bernicla nigricans*) is a small goose that feeds primarily on eelgrass. Morro Bay is an important stop on its annual migration between summer nesting sites in Alaska and wintering sites in Baja California. Due to its reliance on eelgrass as a food source, the eelgrass decline has severely impacted brant populations.

John Roser, a local biologist, has been counting brant in Morro Bay for the past 20 years and estimates brant numbers by using a seasonal use-day estimate. This is calculated by counting brant one day during the middle of each month brant occupy Morro Bay (Novemberto April), using those counts to estimate the number of brant in Morro Bay each day, and then totaling the numbers per day to achieve a seasonal use-day estimate. See Figs. 13 and 14 for brant numbers seen in Morro Bay for the past 20 years (Roser 2017a).

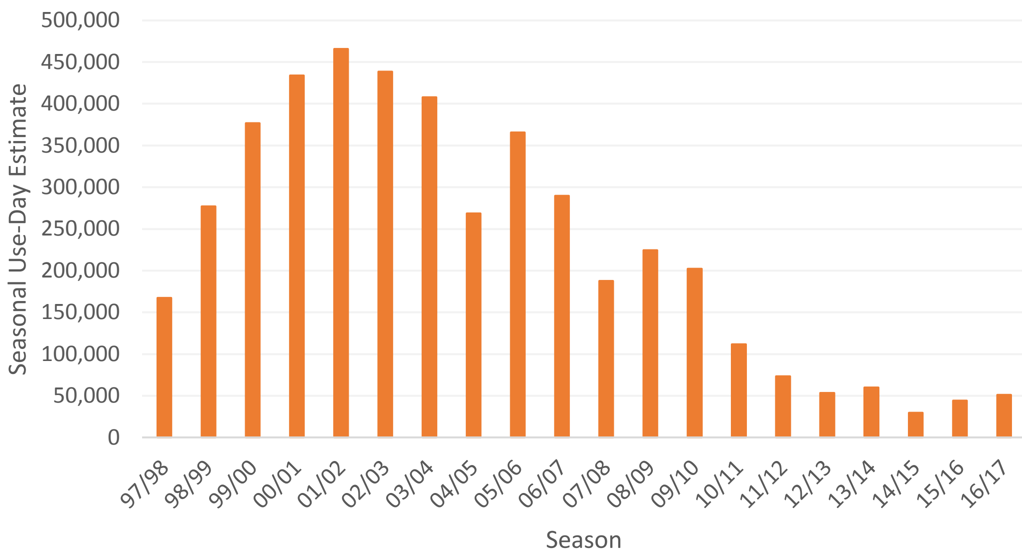

Figure 13. Brant seasonal use-day estimates in Morro Bay from 1997 to 2017 (data adapted from Roser 2017a).

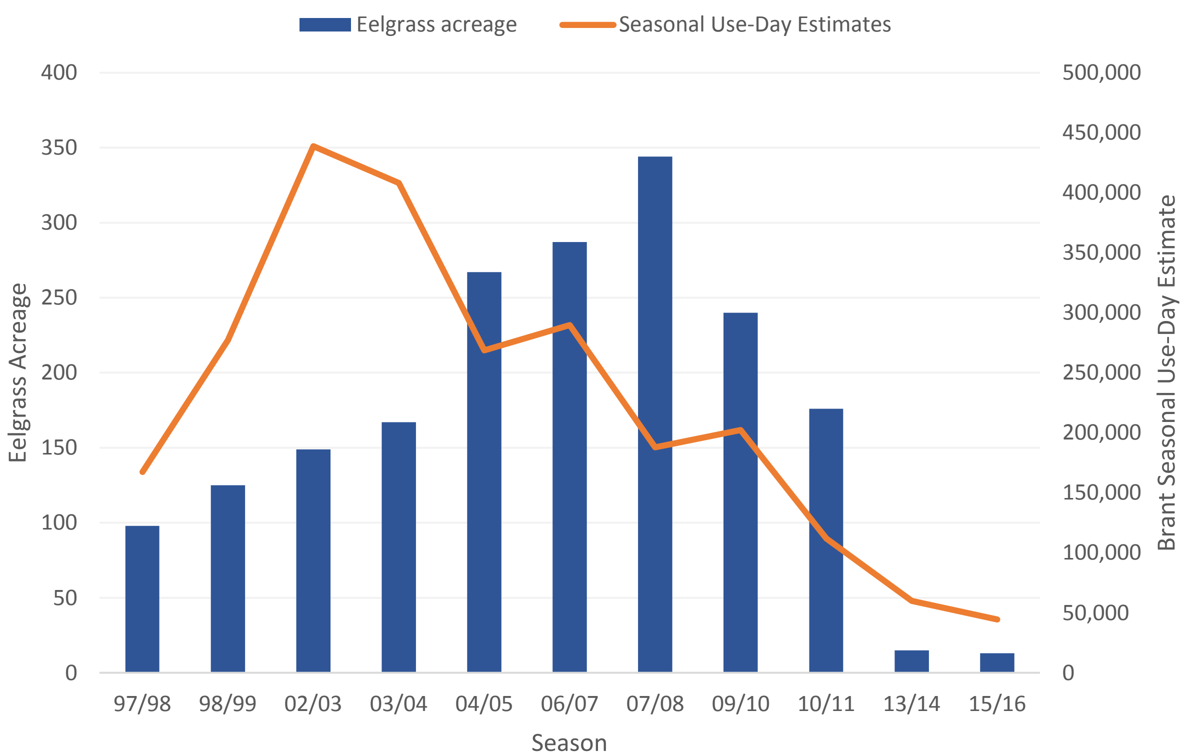

Figure 14. Brant estimates (orange line) overlaid on eelgrass acreage (blue bars) in Morro Bay from 1997 to 2016.

2016 Cal Poly brant study

In 2016, a Cal Poly student, Robert Heim, studied brant and their foraging locations in Morro Bay. This project aimed to determine where brant forage during a season of extremely limited eelgrass availability. He conducted weekly observations from late-January to mid-March 2016, and found brant only in the saltmarsh. He never observed brant in or around eelgrass.

Heim believes the absence of brant from the eelgrass areas may be due to a variety of factors. Some of the last remaining, large intertidal eelgrass beds are in the northern extent of the bay, where there is often the most human activity. Brant are sensitive to human disturbance and thus may avoid areas with heavy human traffic. As brant began arriving in Morro Bay around late November and Heim's observations did not begin until late January, it is also possible that brant depleted their preferred eelgrass grazing locations prior to Heim's observations. Heim's findings of brant foraging in the salt marsh shows an interesting behavioral shift as brant find alternative food sources (Heim 2016).

Another Cal Poly student, Amy Yoger, will add to Heim's project with more brant observations in January to March 2017.

2016 Cal Poly avian abundance and composition study

Cal Poly graduate students Alissa Petrelli and Julia Harencar analyzed the impact of the Morro Bay eelgrass decline on the avian community. They used counts from the Audubon's annual Christmas Bird Counts and compared bird abundances before and after the eelgrass decline. As controls, they also looked at the bird composition of nearby terrestrial habitat and Elkhorn Slough, a California estuary that has maintained eelgrass throughout the last decade.

While coastal bird abundance and composition of both the local terrestrial species and the Elkhorn Slough area did not change, Morro Bay's coastal bird abundances declined and composition shifted. The eelgrass decline explained the change whereas environmental factors (i.e., annual temperature, precipitation) had no effect. This suggests that the decline in eelgrass has changed food availability, leading to trophic interactions and community changes in Morro Bay.

The graduate students were assisted by Cal Poly professors Drs. Clinton Francis, Ryan Walter, and Jennifer O'Leary.

Upcoming Projects in 2017

Many new eelgrass efforts will be occurring in 2017.

Mapping

In Spring 2017, M&A will survey Morro Bay for the Estuary Program to collect data on eelgrass acreage using a combination of sidescan sonar and drone flight imagery. A multispectral aerial imagery flight will also be conducted once again in fall 2017.

Restoration

Experimental restoration efforts will be conducted beginning in spring 2017 with Cal Poly and the Estuary Program, as part of Erin Aiello's master's thesis work. The initial planting will compare eelgrass success at two distinct sites in the bay and will be monitored to assess whether a second summer experimental transplant should occur. An experimental seed-bag effort will also be conducted.

Other monitoring

Bed condition monitoring will continue in spring and fall of 2017 with Cal Poly, California Sea Grant, and the Estuary Program. A new monitoring strategy of permanent plots will also be implemented. Several 1 m x 1 m plots in eelgrass will be marked at different sites throughout the bay and monitored to track conditions of specific patches of eelgrass through time.

Additional Activity

Another round of dredging will take place in Morro Bay in 2017. Cal Poly and California Sea Grant research projects will continue to collect data to further our understanding of the shifting eelgrass and its consequences. Sediment loading and transport is thought to play a central role in eelgrass health, and proposals to further study this technical area have been created.

Discussion

Eelgrass (*Zostera marina*) plays a vital role in the health of the Morro Bay ecosystem. While the Morro Bay eelgrass population has fluctuated in the past, the last decade has seen a drastic loss of about 97%. The exact cause of the decline is unclear, as eelgrass is sensitive to a suite of factors, all of which may have complex interactions. The natural factors that may have negatively impacted eelgrass include water depth, salinity, wave velocity, increased turbidity due to sediment or phytoplankton blooms, pathogens, and grazing. Human activity also potentially negatively impacts the eelgrass environment through dredging, propeller scarring, shading, introducing invasive species, and non-point source loading of nutrients, herbicides and sediment.

The drastic decline of eelgrass in Morro Bay has driven many recent restoration and research efforts. Subtidal eelgrass was mapped in 2015 and, in addition to observations of intertidal eelgrass beds, showed a stabilization of eelgrass at a very low acreage. Three large-scale transplants were completed during the summers of 2012, 2013, and 2014 but did not lead to a persistent eelgrass presence in the mid-bay. Detailed monitoring of the eelgrass beds has continued to track changes to eelgrass beds.

In 2016, new small patches of eelgrass were observed popping up around the bay, particularly in the mid- and back-bay. The patches ranged in sizes from just one plant to larger than one meter square areas. It is unclear whether these new eelgrass patches are natural recruits from seeds or from an established system of underground rhizomes.

In 2017, numerous projects will continue to investigate many facets of eelgrass. There will be a spring and fall mapping effort to get a better sense of both intertidal and subtidal eelgrass. There will be experimental restoration efforts that will be closely monitored, plus additional monitoring activity to continue to track changes in eelgrass. Many research projects will continue to strive toward understanding the factors that led to the decline – and now possible recovery– of eelgrass.

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Appendix A: 2014 Transplant Method

The method used by M&A to complete the 2014 transplant effort is similar to what had been done for those in 2012-2013 (Merkel & Associates 2014).

Collection: Harvesting was performed by SCUBA divers moving through the donor bed and hand-collecting surface and near surface rhizomes, taking plants from a variety of depths and locations within the bed to maximize genetic diversity. Rhizomes were worked free from the sediment, preserving as much root material as possible. Care was taken to collect no more than ten percent of the bed material and no more than three shoots per square meter.

This harvesting method was chosen as it has been shown to minimize donor bed impact and result in no loss of bed area and rapid recovery of eelgrass shoot density. Collecting bare-root units is the method usually used in large-scale restoration efforts, as they have been shown to readily expand and colonize bare substrate. Unlike sediment plug extractions, bare-root units can be prepared without extensive damage to the donor bed or sediment disturbance.

Eelgrass was collected from the bed along the State Park Marina entrance channel and the bed across from Tidelands park on the west side of the bay, rather than the bed at Coleman Beach as in the 2012 to 2013 transplant efforts.

Preparation: "Planting units" were prepared by bundling four to six shoots together and attaching a biodegradable, paper and cotton anchor. Planting units were held in in-bay storage nets until they were planted. The units were generally prepared the same day as harvesting and then planted by SCUBA divers the same day or the day following initial harvest. All planting units prepared were inspected and counted by M&A staff before they were deployed.

Planting: As in the previous 2012 and 2013 transplants, the planting plots were laid out as linear arrays 66 meters in length and 3 meters wide, with 200 planting units in each plot. Two person dive crews planted each of the plots, planting the anchors parallel to the sediment about 15 cm below the sediment surface, and the root/rhizome bundle about 3-5 cm below the sediment surface. Units were planted 1 m apart within the plot. A total of 8,949 planting units were transplanted into 45 plot locations within the central portion of Morro Bay, approximately 2.2 acres of total planting area.

Appendix B: Test Seed Bag Deployment Method

The Estuary Program was planning a seed bag restoration effort for fall 2015 and, while it never occurred due to delays with the permit, they tested the buoy seed bag deployment technique (see pg 11). The method of their seed bag test follows.

The test seed bag design was an oyster bag attached by rope to a buoy on one side and a cinder block on the other. Oyster bags were cut in half and secured by zip ties. Six of these designs were set out around the bay and, after three weeks, four remained intact. One bag was not re-located and one bag lost its buoy. Of the intact bags, many had moved significantly from the original deployment location and *Gracilaria* build up was substantial.

For the future, if this method is used, ample rope should be tied to the bag, buoys should not be Styrofoam, heavier cinder blocks/anchor should be used, and *Gracilaria* build-up on the rope should be regularly removed. Bags should be deployed while sediment is exposed so the anchor can be buried.

Figure 16. The test seed-bag design: cinder block, attached to oyster bag, attached to a buoy.

Figure 15. Seed bag unit one week after deployment. Note how far it moved from its original location and the *Gracilaria* build-up.

Appendix C: Permanent Transect Site Photos and Observations

Photos were taken to document site conditions. Site photos from several years and general observations are provided.

Coleman Transect:

In 2013, it was noted that the eelgrass appeared to be wilted and not as robust as in past surveys. The 2016 density counts show a significant density increase, the highest density observed since 2012.


Nov 4, 2010


Nov 1, 2013


Dec 14, 2016

Tidelands Transect:

In 2013, it was noted that due to the shape of the bed, the transect went through a bare area, which decreased the average density counts. However, density was high throughout the bed. In 2016, it was noted that the visibility was poor, but density counts were roughly equal to those from 2013.


Nov 6, 2010


Nov 16, 2013

Marina Transect:
Since being established in 2012, there has been minimal eelgrass observed. In 2016, none of the quadrats measured along the transect held eelgrass, but there were two patches of eelgrass on/near the transect (at 8 m and near 47 m). In the general area, there were 31 patches of eelgrass that ranged in size from 0.25 m x 0.25 m to 1 m x 1 m. The survey area had numerous depressions in the mud, likely from bat rays.

Pasadena Transect:
Eelgrass was present in 2010, but no eelgrass was found in 2012 to 2014. In 2013, mature healthy subtidal eelgrass was noticed near the transect. No data for 2015 to 2016

Chorro Transect:
In 2010, eelgrass densities saw a drastic decline from the previous few years. No eelgrass, intertidal or subtidal, was observed in the area from 2013 to 2014. No data for 2015 to 2016.