Morro Bay National Estuary Program

Morro Bay Eelgrass Report 2020

Morro Bay National Estuary Program
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Contents

Introduction

Seagrass beds are among the most valuable coastal habitats worldwide. They perform a wide range of important ecosystem services, including carbon sequestration, water purification, and sediment accretion and stabilization (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.

Eelgrass is a marine flowering plant with long, ribbon-like leaves that grow from an underground stem (rhizome). It is found worldwide in coastal waters. Eelgrass reproduces both sexually, via flowers and seed production, and asexually, via spreading rhizomes.

Unprecedented declines in seagrass distribution have been observed worldwide and are a growing cause for concern. The reasons for the decline are attributed to many natural and anthropogenic factors in coastal ecosystems. Natural impacts may come from 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 can 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 once supported the third largest eelgrass-dominated ecosystem in the southern California region (Bernstein et al. 2011). From 2007 to 2016 however, eelgrass in Morro Bay declined by more than 90%. This drastic decline spurred many restoration, monitoring, and research efforts. Since 2016, eelgrass has begun to re-establish in areas where it previously declined, with new signs of significant growth in 2019 and 2020.

This report summarizes all Morro Bay National Estuary Program (Estuary Program) and partners' eelgrass-related activity in 2020, including mapping efforts, restoration and detailed monitoring of new sites and existing eelgrass beds.

Morro Bay Project Area

Morro Bay is a shallow coastal lagoon located on California's Central Coast in San Luis Obispo County. Founded in 1870, the town of Morro Bay (population 10,511) is located in the northern extent of the estuary. The unincorporated community of Los Osos (population 16,533) is located on the southern shores of Morro Bay (Figure 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.

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 information, refer to the Estuary Program's Library at http://www.mbnep.org/library, under Data and Technical Reports.

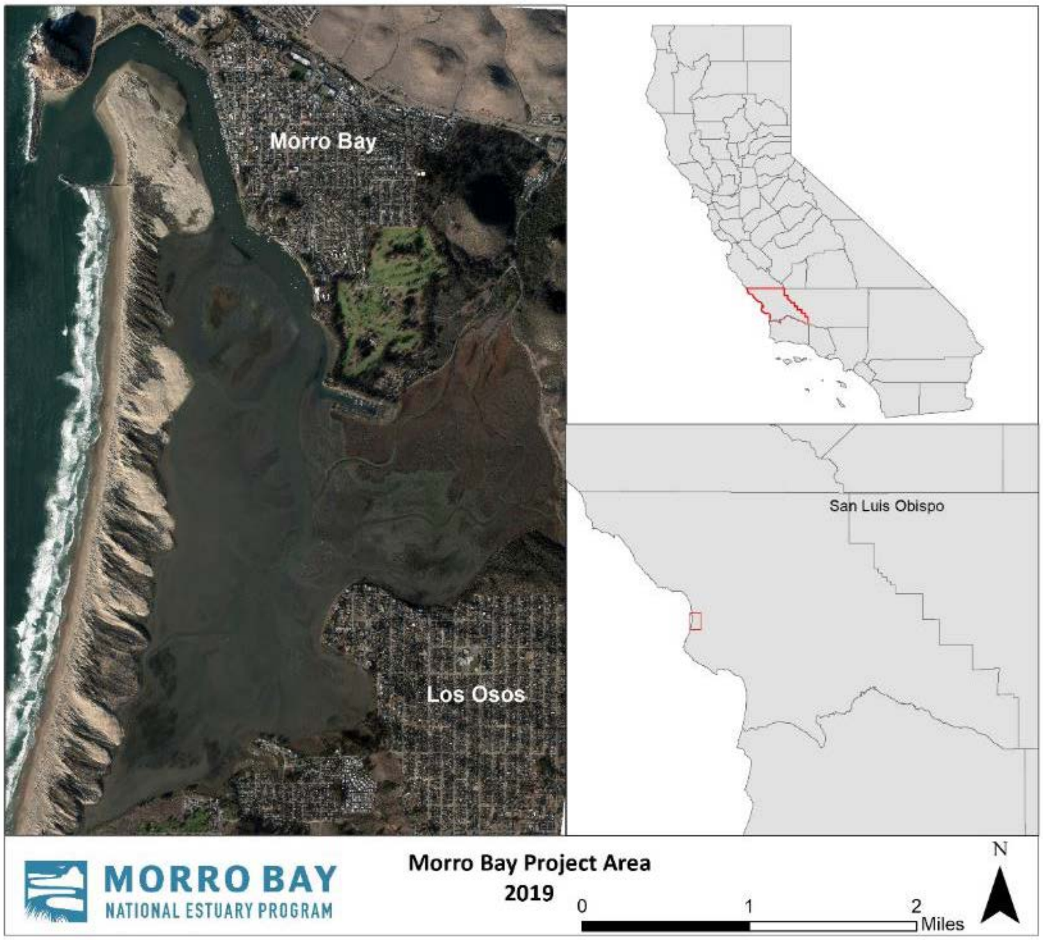

Figure 1. Morro Bay.

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 sand spit 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.

Morro Bay is a popular destination for outdoor recreation and supports a commercial fishing port and aquaculture operations. Recreational activities 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 maintained by regular dredging events (see “Dredging Operations”).

Eelgrass Distribution

Mapping Efforts

Morro Bay’s eelgrass population has been mapped for decades, but it has not always been consistent in season and method. Many of the early eelgrass acreage estimates use subjective aerial photo interpretations, and discrepancies have not been fully quantified or reconciled for datasets generated prior to 2002. In 2002 and 2003, the Estuary Program contracted true color aerial flights, which were later re-analyzed using multispectral analysis to create a map of intertidal eelgrass similar to what was completed in later years. Between 2004 and 2013, intertidal eelgrass was mapped by multispectral aerial images. Flights were typically completed during extreme low tides in November. In 2012, the flight had to be canceled due to weather conditions and was instead completed in May 2013. Merkel & Associates (M&A) surveyed the bay in July 2013 and July 2015 using sidescan sonar, a method that targets mostly subtidal eelgrass.

In 2017, a combination of sidescan sonar and unmanned aerial vehicle (UAV) imagery were seamed together to map intertidal and subtidal eelgrass bay-wide. Multispectral aerial imagery was used to create a classification of intertidal submerged aquatic vegetation, which was groundtruthed by the Estuary Program. Multispectral imaging was conducted by Ocean Imaging (OI) again in 2019 to identify eelgrass bay-wide, and quantify acreage of other exposed and submerged vegetation and substrate types. Further details from this analysis can be found in the Estuary Program's 2019 Eelgrass Report.

UAV Drone Mapping

Since 2017, California Polytechnic State University, San Luis Obispo (Cal Poly) has surveyed eelgrass in Morro Bay annually using a UAV. This method of mapping is less expensive than multispectral imaging, allowing it to be collected more frequently. For each survey, a UAV technician flies a drone over the bay at a standard height of 400 feet during a series of negative tide windows. Thousands of photos are stitched together and georeferenced to create a bay-wide map. The eelgrass is then quantified in ArcGIS, a Geographic Information System (GIS) software, by manually digitizing eelgrass beds into individual polygons.

During the fall of 2020, Cal Poly collected approximately 5,900 photos to produce a cohesive bay-wide map. The following images demonstrate the resolution of photos captured with the drone. Figure 2A shows shellfish farm infrastructure and Figure 2B shows sections of intermittent eelgrass. The dark green patches in each photo are eelgrass, and the lighter patches are algae.

Figures 2A, 3B. Resolution of photos captured with Cal Poly's UAV drone during fall of 2020. Figure 2A shows shellfish farm infrastructure, and Figure 2B shows a series of smaller patches of intertidal eelgrass.

Eelgrass Acreage Data

The following table and figure present Morro Bay's eelgrass acreage over time and the method of data collection. It is important when comparing these data to keep in mind that the mapping methodology has changed over time. Previous versions of this report are available at http://www.mbnep.org/library and include additional historical data information and sources. Note that with different mapping techniques, there can be overlap between eelgrass captured with subtidal methods and captured with intertidal methods, depending on the method and the conditions (e.g., water clarity, tide height, etc.) during the survey.

Table 1. Eelgrass acreages and mapping methods, 1960 to 2020.

Year	Time of Year	Eelgrass Acreage	Method
1960	Unknown	335	Field surveys (Haydock)
1970	Unknown	452	Aerial photos (CA Fish & Game)
1988	Unknown	404	Aerial photos (Josselyn), reinterpreted (Chesnut)
1994	Late Sept to early Nov	435	Quadrat sampling (Chesnut)
1995	Late Sept to early Nov	260	Quadrat sampling (Chesnut)
1996	Late Sept to early Nov	165	Quadrat sampling (Chesnut)
1997	Late Sept to early Nov	98	Quadrat sampling (Chesnut)
1998	Unknown	125	Aerial photos (Tetra Tech)
2002	November 25, 2002	149	True color aerial images, reanalyzed (Estuary Program with Golden State Aerial and Ocean Imaging)
2003	November 21, 2003	167	True color aerial images, reanalyzed (Estuary Program with Golden State Aerial and Ocean Imaging)
2004	November 24, 2004	267	Multispectral aerial images (Estuary Program with Ocean Imaging)
2006	November 6, 2006	287	Multispectral aerial images (Estuary Program with Ocean Imaging)
2007	November 24, 2007	344	Multispectral aerial images (Estuary Program with Ocean Imaging)
2009	November 13, 2009	240	Multispectral aerial images (Estuary Program with Ocean Imaging)
2010	November 4, 2010	176	Multispectral aerial images (Estuary Program with Ocean Imaging)
2013	May 28, 2013 for multi-spectral imagery, July 2013 for sonar	15	Multispectral aerial images (Estuary Program with Ocean Imaging) and sonar (M&A)
2015	July 2015	13	Sonar (M&A)
2017	April 2017	14	Sonar and UAV (M&A)
2017	December 3, 2017	13	Multispectral aerial images (Estuary Program with Ocean Imaging)
2017	December 1 to 4, 2017	9	UAV (Cal Poly, Sea Grant)
2018	December 6, to 8, 20 and 21, 2018	16	UAV (Cal Poly, Sea Grant)
2019	November 26, December 11 to 13, 23 and 24, 2019, January 8, 2020	37	UAV (Cal Poly)
2019	November 24, 2019	42	Multispectral aerial images (Estuary Program with Ocean Imaging)
2020	November 14 to 16, December 14 and 15, 2020	146	UAV (Cal Poly)

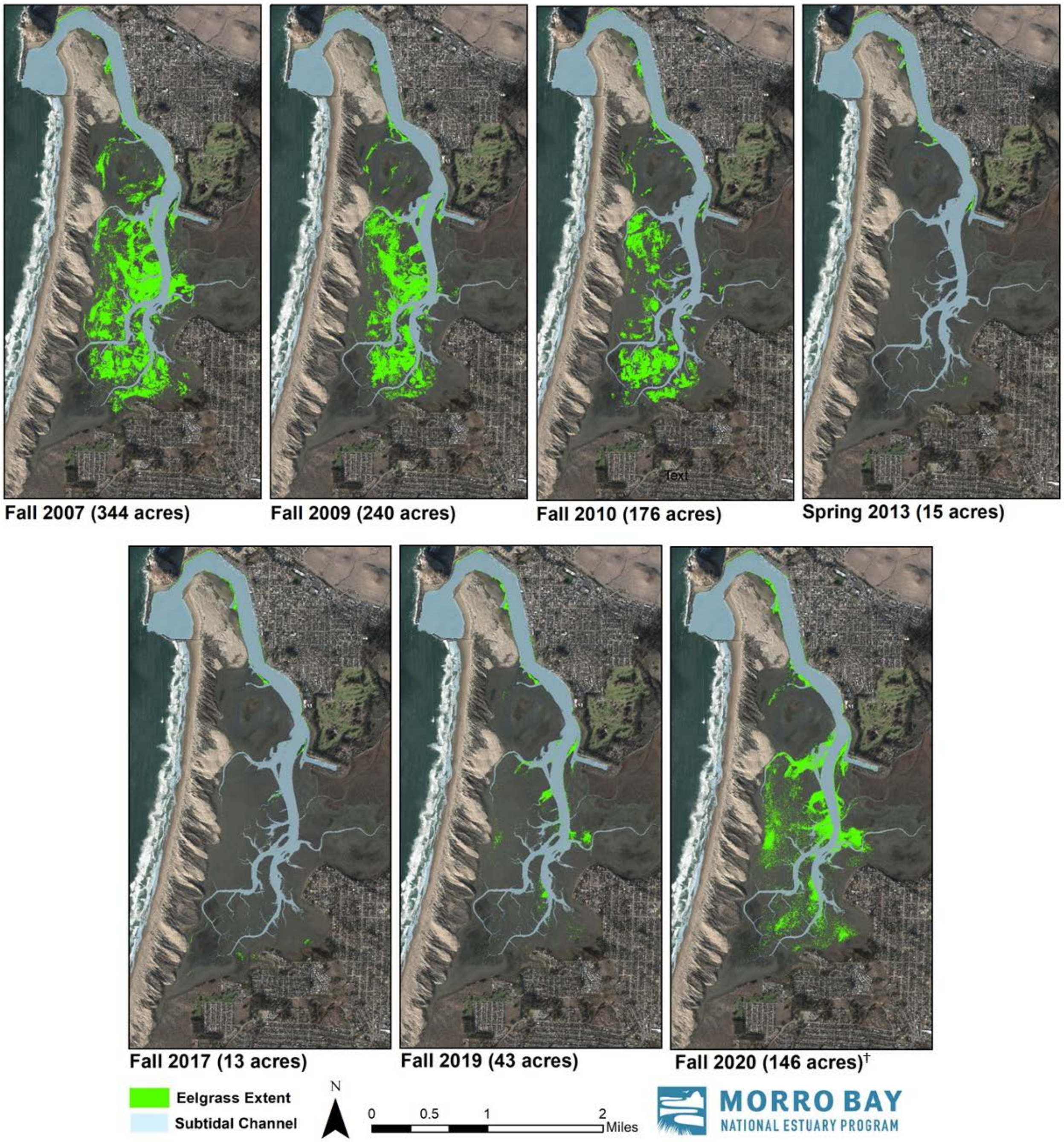

Figure 3. Changes in intertidal eelgrass density in Morro Bay from 2007 to 2020. Note that eelgrass extent from 2007 to 2019 was analyzed with multispectral imagery (Ocean Imaging), and extent from 2020 was analyzed using manual quantification of drone imagery (Cal Poly).†

† Eelgrass acreage from 2020 was analyzed using manual quantification of Cal Poly's UAV drone imagery due to the cost and labor associated with multispectral imagery analysis. Because of differences in methodology, exact acreages of eelgrass prior to 2020 are not directly comparable with the 2020 acreage, although years when both mapping methods were completed, acreage varied by only approximately 3-6 acres.

Figure 3 illustrates a time series of eelgrass extent from 2007 to 2020, with 2020 accounting for the most eelgrass coverage since the decline. While eelgrass acreage significantly declined from 2010 to 2013, mapping efforts from 2019 indicated a pivot point for the species. Many sections of patchy eelgrass present in 2017 continued to expand during 2019, combined with many newly formed eelgrass beds in the mid and back bay. During 2020, these beds continued to expand substantially, with fuller and more continuous coverage throughout the bay. Many new sections of intermittent eelgrass have also been identified in areas where they have not been seen in many years, such as on the western edge of the sand spit.

Restoration Efforts

Eelgrass restoration efforts during 2020 included intertidal and subtidal eelgrass transplanting. Intertidal transplanting was completed on foot by Estuary Program staff and volunteers during February and March 2020, and subtidal eelgrass transplanting were completed by Tenera Environmental, Inc. (Tenera) during April and May 2020. All intertidal and subtidal restoration sites are outlined in the table below. Restoration locations for 2020 are visualized spatially in relation to the 2019 eelgrass extent in Figure 4.

Table 2. Eelgrass intertidal and subtidal restoration sites completed during 2020.

Site ID	Date Planted	Approximate Elevation	Donor Bed	Location	Planting Type
T1 Intertidal	2/22/2020	-0.4	Coleman	35.35471, -120.84984	5 one meter plots
T1 Subtidal	4/25/2020	-1.76	Coleman	35.35476, -120.84951	4 quarter meter plots, 4 rebar, 4 bamboo pieces
T4 Intertidal	3/7/2020	-0.52	Tidelands	35.34316, -120.84902	5 one meter plots
T8 Intertidal	2/19/2020	-0.4	Coleman	35.34878, -120.84767	5 one meter plots
T11 Intertidal	3/6/2020	-0.6	Tidelands	35.33926, -120.840727	5 one meter plots
T11 Subtidal	4/28/2020	-1.66	Coleman	35.33936, -120.84720	4 quarter meter plots, 4 rebar, 4 bamboo pieces
T13 Subtidal	5/9/2020	-2	Coleman	35.33824, -120.84562	4 quarter meter plots, 4 rebar, 4 bamboo pieces
T17 Intertidal	2/9/2020	0.07	N. Sandspit	35.33816, -120.85264	3 rebar/3 bamboo pieces
T18 Intertidal	2/9/2020	-0.11	N. Sandspit	35.33638, -120.85051	3 rebar/3 bamboo pieces
T19 Intertidal	2/7/2020	-0.081	N. Sandspit	35.33537, -120.85387	3 rebar/3 bamboo pieces
T20 Intertidal	2/7/2020	-0.17	N. Sandspit	35.33365, -120.85208	3 rebar/3 bamboo pieces
T21 Intertidal	2/21/2020	-0.43	Coleman	35.34525, -120.84953	6 one meter plots

Figure 4. Map of 2020 eelgrass transplanting locations with 2019 eelgrass extent in green.

Intertidal Eelgrass Transplanting

Eelgrass rhizomes were collected from three donor beds during 2020: Coleman, Tidelands, and North Sand spit. Eelgrass was harvested on foot and by hand at low tides. No more than three rhizomes per square meter were collected, per the Estuary Program's scientific collection permit from the California Department of Fish and Wildlife (CDFW). Harvesting and transplanting occurred in the spring, as previous experimental efforts have shown higher success during the spring, as opposed to the fall. Pre and post-density eelgrass counts of the donor beds were collected before and after harvesting.

Three different planting methods were used to transplant eelgrass: one-meter plots with anchoring, one-meter plots without anchoring, rebar pieces, and bamboo pieces. To transplant eelgrass within the one-meter plots, two eelgrass rhizomes were crisscrossed to form a "bundle" and secured in the sediment with a garden stake anchor. Half of the plots were transplanted without anchoring, as plantings during 2019 showed similar success rates with anchored vs. unanchored plot plantings. Bundles were spaced approximately 15 centimeters apart, for a total of 72 rhizomes in each one-meter plot. Small PVC poles were placed immediately outside of the plot corners to aid in relocating restoration sites.

Eelgrass was also planted using rebar and bamboo pieces as anchors. For the rebar pieces, 25 eelgrass rhizomes were anchored to smooth rebar with jute string. Each piece of rebar was three feet long, with one end bent into an “L” shape to hold the rebar into the sediment. The bamboo pieces were anchored similarly, with 25 rhizomes secured to a three feet bamboo shoot with jute string. Bamboo was then anchored to the sediment with garden stakes. Rebar and bamboo pieces were both planted off the main channel via kayaks at low tides. Three rebar and three bamboo pieces were planted at each of four sites, for a total of 600 rhizomes planted.

In total, the Estuary Program transplanted eelgrass at intertidal locations using 25 plots and 24 rebar pieces, across nine sites. The nine transplant sites were dispersed at various locations throughout the bay, including newly established locations as well as prior restoration sites to create larger, more stable beds.

Figure 5. Example of an intertidal restoration site (T11) along the main tidal channel with five plots planted in March 2020.

Figure 6. Example of Site T8 immediately after planting (left), approximately six months after (middle), and approximately one year after planting (right).

Figure 7. Example of Site T21 immediately after planting (left), approximately six months after (middle), and approximately one year after planting (right).

Subtidal Eelgrass Transplanting

The Estuary Program hired Tenera to complete subtidal eelgrass transplanting efforts in April and May 2020. Eelgrass was planted at three locations in the fore bay and mid-bay at three subtidal sites (T1, T11, and T13).

Eelgrass rhizomes were collected from the Coleman donor bed and harvested via scuba. Similar to the intertidal harvesting effort, eelgrass mitigation beds and areas used for long-term monitoring were avoided. Three rhizomes per square meter were collected, per the Estuary Program's scientific collection permit. Pre and post-density eelgrass counts of the donor beds were also monitored before and after harvesting.

Subtidal planting methods were similar to intertidal methods but conducted using scuba while the sites were submerged. Methods included rebar and bamboo plantings and quarter-meter plots instead of one-meter plots.

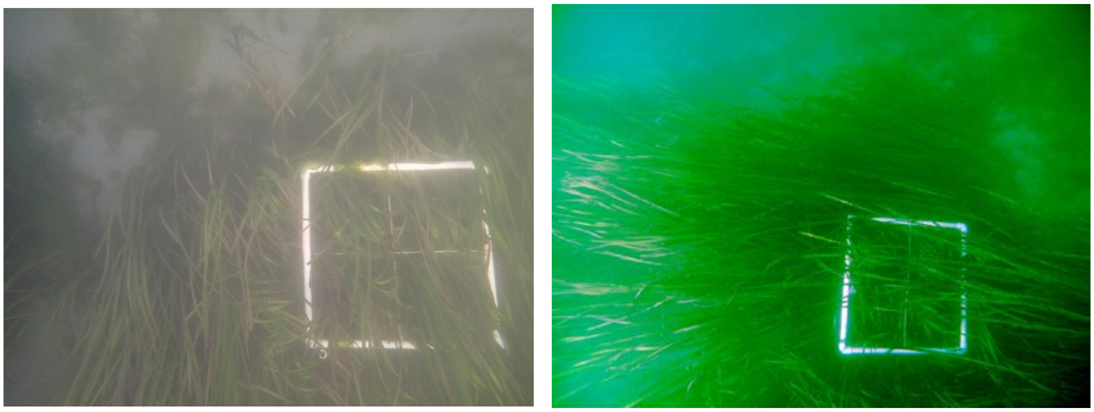

Figure 8. Example of growth outside of subtidal plots after six months at sites T1 (left) and T11 (right).

Restoration Results

Transplanted eelgrass shoots are counted at each site to track survival. The Estuary Program and Tenera have worked together to complete monitoring at one, three, six, and twelve months post-planting. Growth rates of restored eelgrass plantings have varied on a site-by-site basis, but have generally shown steady growth.

The following graphs illustrate percent survival from each site at approximately three months, six months, and one year after planting.

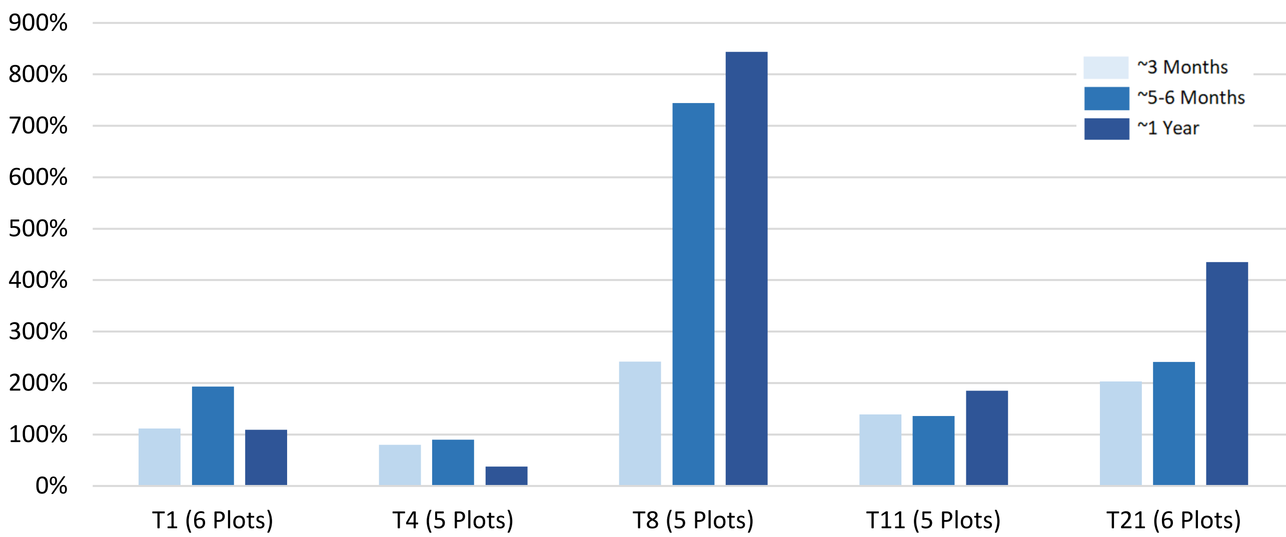

Figure 9. Average percent survival of 2020 intertidal eelgrass plots at approximately 3, 6, and 12 months after planting.

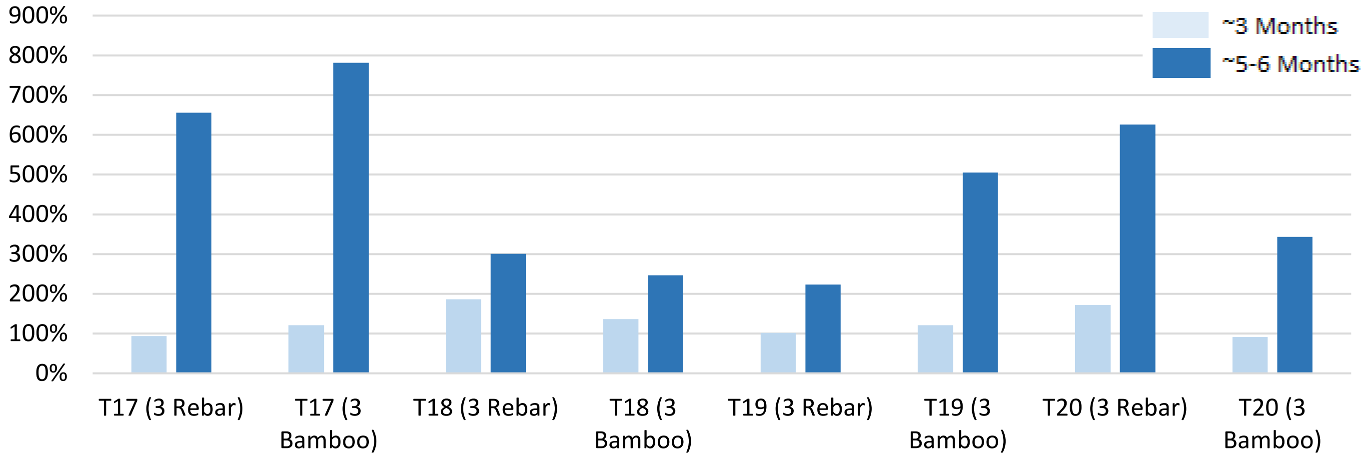

Figure 10. Average percent survival of 2020 intertidal eelgrass rebar and bamboo plantings at approximately 3 and 6 months after planting.

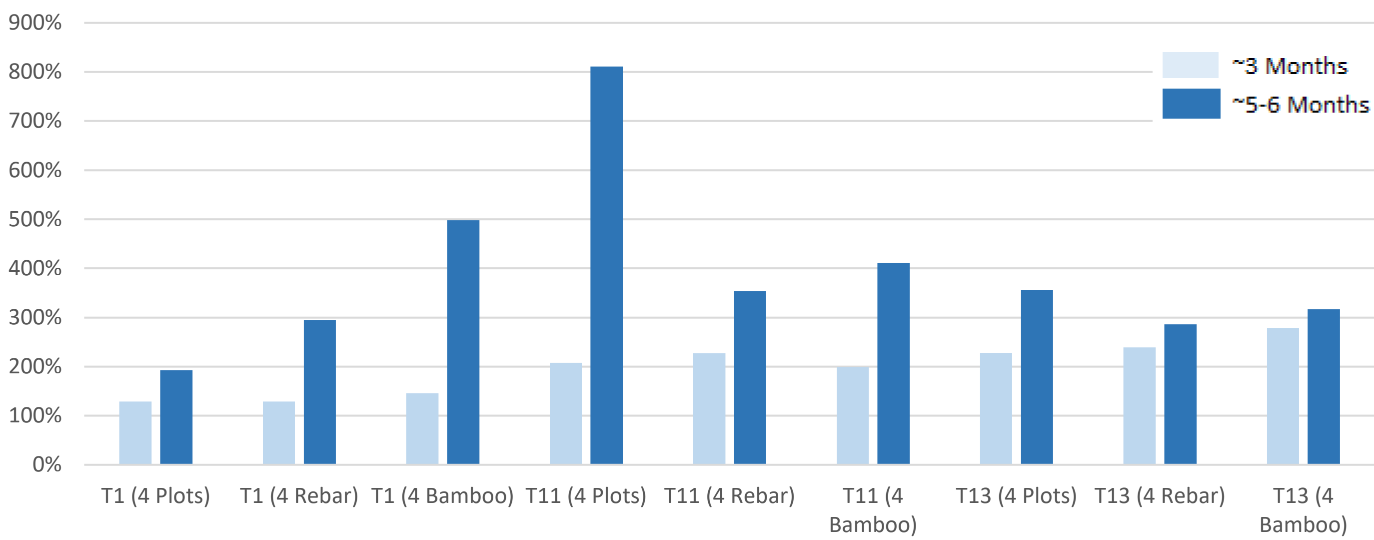

Figure 11: Average percent survival of 2020 subtidal eelgrass plantings at approximately 3 and 6 months after planting.

Table 3. Eelgrass expansion at subtidal sites approximately one year after planting.

Site ID	Three Months Post-Planting	Six Months Post-Planting	1 Year Post-Planting
	Average Survival Rate	Average Survival Rate	Observations
T1 (4 Plots)	129%	193%	Eelgrass grew into one large bed, 18.2 by 6.4 meters.
T1 (4 Rebar)	129%	295%	
T1 (4 Bamboo)	146%	498%	
T11 (4 Plots)	208%	811%	Site markers could not be found. Eelgrass bed nearest GPS site location was 33 x 6 meters.
T11 (4 Rebar)	227%	354%	
T11 (4 Bamboo)	199%	411%	
T13 (4 Plots)	228%	357%	Eelgrass has grew into two beds, 14 x 4 meters and 6 x 2 meters.
T13 (4 Rebar)	239%	286%	
T13 (4 Bamboo)	279%	317%	

Other Monitoring Efforts

In addition to monitoring the restoration plots, there have been several supplementary monitoring efforts to track eelgrass changes throughout the bay. The Estuary Program established permanent transects beginning in 2005 to measure average shoot density at sites located throughout the bay. California Sea Grant and Cal Poly established bed condition monitoring beginning in late 2015 to measure average density and overall condition of remaining eelgrass. Cal Poly and California Sea Grant established permanent plots in 2018, which the Estuary Program monitored in 2018 and 2019.

Permanent Transects

History

Permanent transects were established to track changes in eelgrass shoot density throughout Morro Bay. There are currently six permanent transects, some having been established as far back as 2005. Four transects (Coleman, Reference, Chorro, Pasadena) were monitored annually from 2006 to 2010. No data were collected in 2011 due to staffing logistics. In November 2012, a fifth transect was established near the State Park Marina. Some sites were not surveyed due to poor weather or tide conditions from 2012 to 2016. In December 2017, a new transect was established on the eastern side of the channel at Tidelands Park, called “Embarcadero”. The transect now called “Reference” was originally named “Tidelands” but has since been renamed to avoid confusion.

Figure 12. The six current permanent transect monitoring locations: Coleman, Embarcadero, Reference (previously named Tidelands), Marina, Chorro, and Pasadena.

Methods

Monitoring was conducted during extreme low tides (-0.4 feet and below) during the late fall, as this period provides the best tidal windows for accessing sites. 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 a 50 meter transect. A 0.5 meter x 0.5 meter quadrat was used to take measurements at points along the tape. Percent coverage of eelgrass, macroalgae (predominantly *Gracilaria* and *Ulva*), and bare substrate were measured. If eelgrass was present, shoots were counted to determine density.

While there are six permanent transect locations, some sites have more than one transect. If an eelgrass bed was fairly wide, additional transects were established that run parallel to each other to measure eelgrass at various 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.

Initially, the effort included an eelgrass biomass measurement. From 2005 to 2012, eelgrass 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

Average shoot density for each site is summarized in Figure 13.

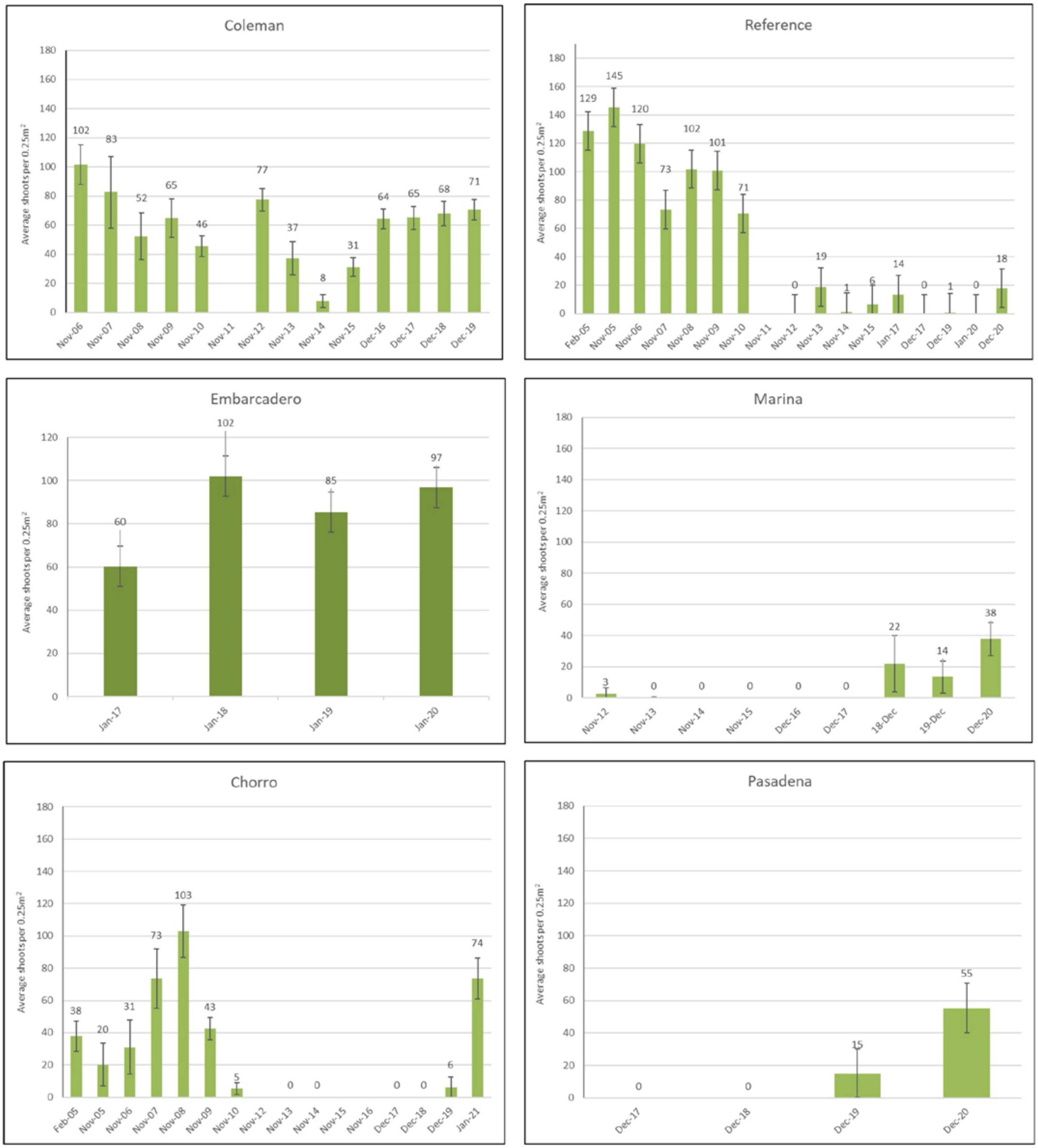

Figure 13. Average shoot density counts per year at six sites. Shoots were counted within a 0.5m x 0.5m quadrat. Error bars represent the 95% confidence interval.

While average shoot densities have declined since this monitoring began in the early 2000s, eelgrass does seem to be rebounding at a handful of sites, although not all to the extent of pre-decline levels. During 2020, average densities at both the Coleman and Chorro transects reflect pre-decline levels. Although densities at Coleman have remained stable since 2016, average shoot counts at the Chorro transect increased dramatically in 2020. The average shoot density at the Chorro transect rose from only 6 shoots per 0.5m x 0.5m quadrat in 2019 to 74 shoots per quadrat in 2020.

While the newer Embarcadero transect (established in 2017) has no historic data to compare to, the site has continuously been the densest of all six sites from 2018 to 2020. Although the Marina transect also has limited historic data for comparison, it had the highest recorded shoot density during 2020, at nearly 38 shoots per quadrat.

Permanent Transect Photos and Observations

Photos monitoring documents site conditions, although they have not been taken every year.

Coleman Transect

Eelgrass shoot density remained relatively stable at this transect from 2016 to 2019, with a slight density increase during 2020. This is documented in the photos below, although photos for 2019 are not available.

Figure 14. Coleman Transect, 2016 to 2020.

Reference Transect

Between 2017 and 2019, the Reference transect (previously known as Tidelands) had no eelgrass present on the transect itself. During 2019, new small patches of eelgrass were developing near the transect, and during 2020, many new patches of eelgrass had emerged. This eelgrass has grown at notably higher elevations than other sites, forming small, patchy eelgrass islands as seen in the photo below. Density counts from 2020 resemble that of 2013, but not of pre-decline levels.

Figure 15. Reference Transect (previously "Tidelands"), 2017 to 2020.

Embarcadero Transect

This transect was established in 2017 on the eastern side of the channel at Tidelands Park at the south end of the dock. Since then, the eelgrass bed has remained mostly continuous with a high shoot density and low density of epiphytes. During 2018, 2019, and 2020, the Embarcadero transect had the highest shoot density of all the sites. This site has been a harvest site for restoration efforts for multiple years, although there is no indication of impairment to the overall health of the bed.

Figure 16. Embarcadero Transect, 2017 to 2020.

Marina Transect

Prior to 2018, little to no eelgrass was present along this transect. During 2018 and 2019, patchy eelgrass began developing along all three transects as well as in the surrounding area. In 2020, much of the patchy eelgrass has developed into one continuous bed, as seen in the photo below. Shoot density at the Marina transect during 2020 was the highest recorded since the site' was established in 2012.

Figure 17. Marina Transect, 2017 to 2020.

Chorro Transect

Of all the sites surveyed in 2020, the Chorro transect saw the most substantial shoot density increase. In 2018, no eelgrass was found, and during 2019, only one patch of eelgrass was found along the transect. During 2020, the shoot density reflected that of the Coleman transect, with an average shoot count of nearly 74 shoots per quadrat, up from an average of nearly 6 shoots per quadrat (see Figure 13).

Figure 18. Chorro Transect, 2017 to 2020.

Pasadena Transect

The Pasadena transect also showed substantial change during 2020, with nearly triple the amount of eelgrass from the previous year. It appears that small patches of eelgrass have spread into one continuous eelgrass bed, with healthy blades and low epiphytic cover. Note that data prior to 2017 is no longer included in the graphs, due to uncertainty around the location of the transects.

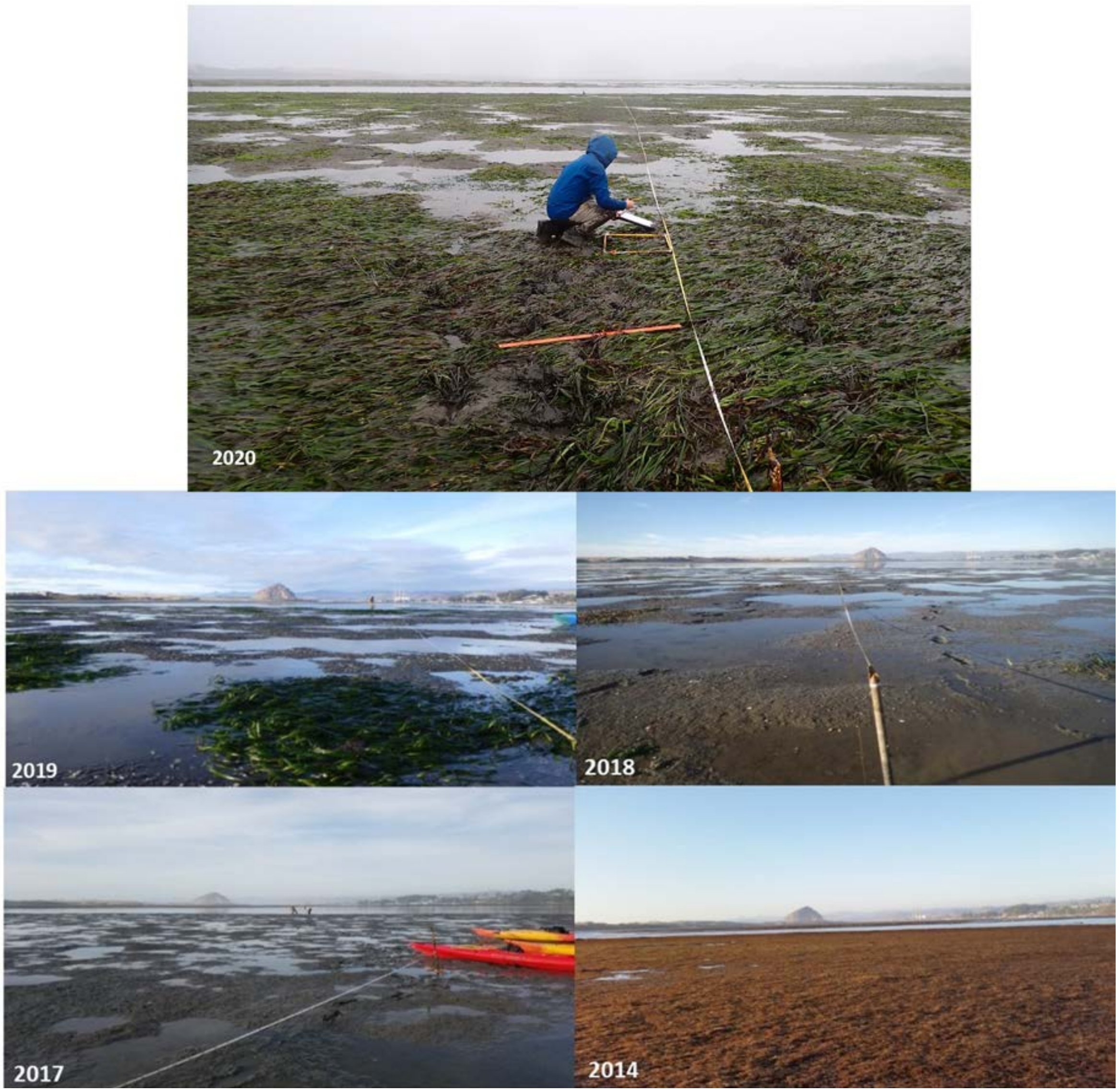

Figure 19. Pasadena Transect, 2014 to 2020.

Permanent transects were initially established to track eelgrass density amongst a range of sites. While density data at permanent sites can provide insight to the patchiness or continuousness of eelgrass at a particular location, it is not always the most optimal method of monitoring eelgrass health. For example, there are often instances of eelgrass near the site (even within just a few meters), but because it was not on the transect, it is not captured in the data collection. Most transects are also not permanently marked, or are difficult to permanently mark, which makes it a challenge to return to the exact location each year. Due to challenges with this methodology, a different method of monitoring was needed to more fully capture the health of existing eelgrass. The Estuary Program collaborated with Cal Poly and Sea Grant to develop a new monitoring protocol called Bed Condition Monitoring. However, permanent transect monitoring has and will continue, as it is the longest running eelgrass dataset for Morro Bay. This dataset helps to document pre and post-decline conditions.

Bed Condition Monitoring

Bed condition monitoring was established as a joint effort between Dr. Jennifer O'Leary of California Sea Grant and the Estuary Program in late 2015. This method measures eelgrass conditions in terms of density, blade length, evidence of necrotic tissue, and competition with algae and other organisms.

Monitoring occurs at five significant beds in Morro Bay along a 150-meter, seven-quadrat survey. Both intertidal and subtidal eelgrass are surveyed, as much of the intertidal eelgrass was lost in the decline from 2009 to 2016. Monitoring has occurred twice per year since 2015, once in late fall and again in the spring. Due to the lack of adequately low tides during daylight hours during the fall, the fall monitoring was halted and monitoring only occurs in the spring.

Figure 20. Bed condition monitoring sites at Coleman Beach, North Sand spit, Reference Bed, and Windy Cove.

The Estuary Program conducted spring 2020 monitoring at Coleman Beach, Reference Bed, and Windy Cove sites. North Sand spit was a site monitored from 2015 to 2017 but was not monitored in 2019 nor 2020 due to lack of adequate low tides. The Estuary Program continues to conduct this monitoring each spring, with analysis to be conducted by Dr. O'Leary. The data analysis for this monitoring is not yet complete, although analysis is ongoing.

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 important harbor 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 feet.

ACOE began their annual dredging in Morro Bay on May 10, 2020 and the project was completed on June 2, 2020. During active dredging, ACOE contracted Merkel & Associates (M&A) to conduct weekly water sampling efforts upstream and downstream of the dredge footprint as well as at the disposal location. Water quality parameters included dissolved oxygen, light transmittance, turbidity, pH, temperature, and salinity. Action levels for all parameters were defined as a 20 percent or greater change between upstream and downstream locations, and dissolved oxygen levels were maintained at a minimum of 5 mg/L. In addition, two 1-liter water samples were collected at all sampling locations once during the cycle. These samples were then analyzed for Total Suspended Solids (TSS) and Total Chlordane.

According to a post-project report, no water quality exceedances were encountered during dredging activities. Adequate dissolved oxygen was maintained throughout the project, ranging between 6.9 mg/L to 9.4 mg/L. TSS values ranged from 27.2 mg/L to 48.4 mg/L, which falls within typical non-rainy season values for Morro Bay. Chlordane was not detected at any station during sampling. (M&A, 2020)

Embarcadero Projects

Eelgrass grows intermittently along the Morro Bay Embarcadero, and impacts to eelgrass must be considered before any construction may occur. Surveys to monitor eelgrass changes have typically been completed by Tenera Environmental, Inc. using scuba divers and/or sonar before, during, and after construction projects. Between summer of 2019 and 2020, two surveys were conducted to support construction projects on the Embarcadero. The conclusions of the surveys were as follows:

- A pre-construction survey completed for the reinforcement of three pile foundations at a wharf near 495 Embarcadero in Morro Bay. This was the second survey completed by Tenera with an initial survey completed in 2017. No impacts to eelgrass were anticipated from either of the two planning surveys, as no eelgrass was immediately adjacent to any of the planned pile work.
- A 30-day post-construction survey for a project to extend an over-water public walkway. Because the completed work differed from the original plan, the purpose of this survey was to determine if the final in-water construction could negatively affected eelgrass or potential habitat for eelgrass. The survey classified this location as rocky riprap, which is unsuitable for eelgrass colonization. Thus, no eelgrass was considered to be affected by the augmented construction plan.

Partnerships

The Estuary Program is continuing their partnership with Cal Poly and Cuesta College to support eelgrass research efforts. The effort also involves CDFW, NOAA and U.S. Fish and Wildlife Service (USFWS) partners. These partnerships promote sharing of data and expert opinions to help guide eelgrass activity.

Research Efforts

Various research efforts are underway related to Morro Bay eelgrass. They are briefly summarized, including an estimate of when results will be available.

Fish Biodiversity

Dr. Jennifer O'Leary completed a paper in June 2020 (published in early 2021) assessing the effects of estuary-wide seagrass loss on fish populations. Surveys were conducted in Morro Bay during the pre and post-eelgrass decline to assess fish biodiversity and biomass. The pre-decline surveys were conducted in 2006 and 2007, and post-decline surveys were completed in 2016 and 2017 at seven sites (Figure 21) using trawls and beach seines.

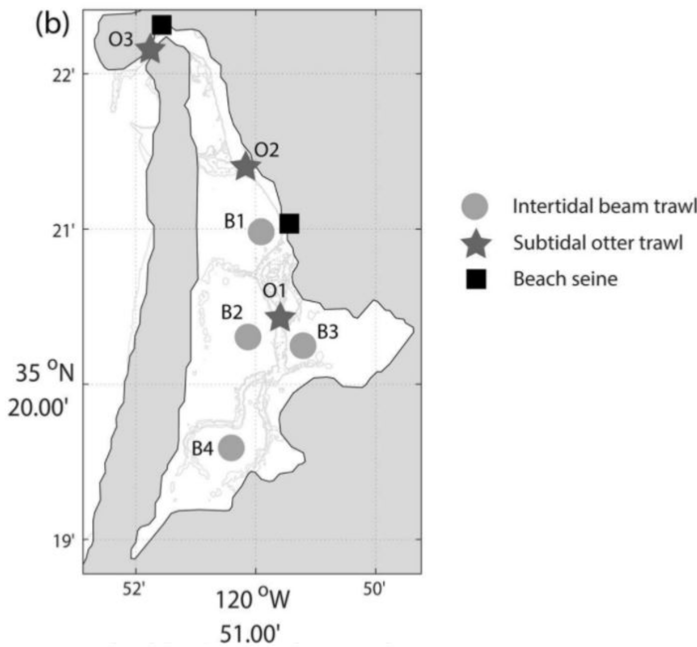

Figure 21. Map of approximate trawl and beach seine locations in Morro Bay (O'Leary et. al, 2021).

The study found that the loss of eelgrass did not result in fewer fish or a reduction in overall fish biomass. Instead, findings indicated an overall change in species composition, with post-decline diversity dominated by flatfish and sculpins and an overall reduction of pipefish and perch species. These results support further evidence that the relative abundance of habitat-specialist species like the bay pipefish predicts whether habitat loss is a major contributor to overall fish abundance. The paper suggests that further research is needed to fully understand how changes in fish communities affect trophic dynamics and ecosystem function (O'Leary et. al, 2021).

Water Quality Monitoring

Dr. Ryan Walter from Cal Poly's Physics Department continues to maintain and run a water quality instrument package at the mouth of the bay and a weather station in the back bay. Funding for these stations are provided by the Central and Northern California Ocean Observing System (CeNCOOS) and the Estuary Program. A realtime data stream is available here: https://www.cencoos.org/data/shore/morro. Additionally, Dr. Walter maintains temperature sensors at the mouth of the bay and back of the bay.

Dr. Emily Bockmon of Cal Poly's Chemistry Department oversaw the deployment of two autonomous pH sensors in 2020, placed at the bay mouth T-Pier and back bay stations. These pH sensors began collecting data in March and continued through the end of the year. Data is collected every five minutes and streamed directly to the web. Data can be viewed and downloaded here: https://data.cencoos.org/#metadata/100050/station. Due to COVID-19 safety restrictions and lack of access to a laboratory, data calibration, processing, and quality control of this data is still underway.
In addition, Dr. Bockmon and her students completed carbonate chemistry sampling at six shallow, shoreline locations throughout the bay. Sampling was done on five different occasions between January and October 2020. Two sampling dates in September and October were performed concurrently with Morro Bay community scientists Brom Webb and Richard Sadowski, who measure carbon dioxide concentrations in the atmosphere. With these measurements, Bockmon's team was able to compare air and seawater values to estimate whether the estuary is acting as a sink or a source of carbon. This collaboration is planned to continue through June 2021.

Eelgrass Wasting Disease Research

Students and faculty from Cuesta College have been studying the occurrence of the slime mold *Labyrinthula spp.* on eelgrass (*Zostera marina*) in Morro Bay since 2018. This project is studying whether *Labyrinthula spp.* slime mold is present throughout the estuary and if it occurs on both healthy and necrotic plants.

Eelgrass blade sampling was completed in Morro Bay in July 2020 by Cuesta College students, under the guidance of Cuesta College professors Dr. Laurie McConnico and Dr. Silvio Favoreto. Approximately 20 to 25 individual blades were collected from the mouth, mid-bay and back bay. Students processed and cultured fragments of each blade to examine for the presence of *Labyrinthula spp*. over a span of two weeks. A separate portion of each eelgrass blade was dried and preserved for subsequent sequencing and DNA quantification. Due to the COVID-19 pandemic, DNA quantification (qPCR) has been postponed until students can return to the on-campus laboratory.

In addition to studying *Labyrinthula spp.*, Dr. McConnico and Dr. Favoreto's students also compared the health of eelgrass samples using a non-invasive, quantitative, image-based analysis called Excess Green Index (EGI). The method is based on RGB deconstruction and analysis of high definition images obtained from cultured blade fragments. These samples will help to correlate microbial load to the overall health of the eelgrass sample.

Although data analysis for this project is still underway, the past three years of data indicate that the slime mold *Labyrinthula spp.* is present during the summer at all three locations in the Morro Bay estuary. Preliminary results show the highest occurrences of *Labyrinthula spp.* at the mouth and in the back of the bay, with lower occurrences in the mid-bay. *Labyrinthula spp.* has also been present on both visibly healthy (green) and necrotic (dark and damaged) plants at all three sites. The occurrence of the slime mold throughout the bay and on both healthy and necrotic plants may indicate that the slime mold occurs as an opportunist in the estuary instead of a causal agent of wasting disease, as has been proposed in other regions such as Washington state.

Further sampling and analysis is expected to take place during 2021. Once completed, results from 2018 to 2021 will be compared and used to assess interannual variation of *Labyrinthula spp.* These long-term data sets will be critical to better understanding the role *Labyrinthula spp*. plays, or has played, in the declines of eelgrass within the Morro Bay estuary.

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. Although shifts in climate are thought to be altering migratory behavior, the brant populations are likely impacted by the eelgrass decline.

John Roser, a local biologist, has been counting brant in Morro Bay for nearly 25 years. Roser estimates brant numbers by using a seasonal use-day estimate. This is calculated by counting brant one day during the middle of each month that brant occupy Morro Bay (typically November to 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. Figure 22 illustrates brant numbers in Morro Bay over the past 20 years.

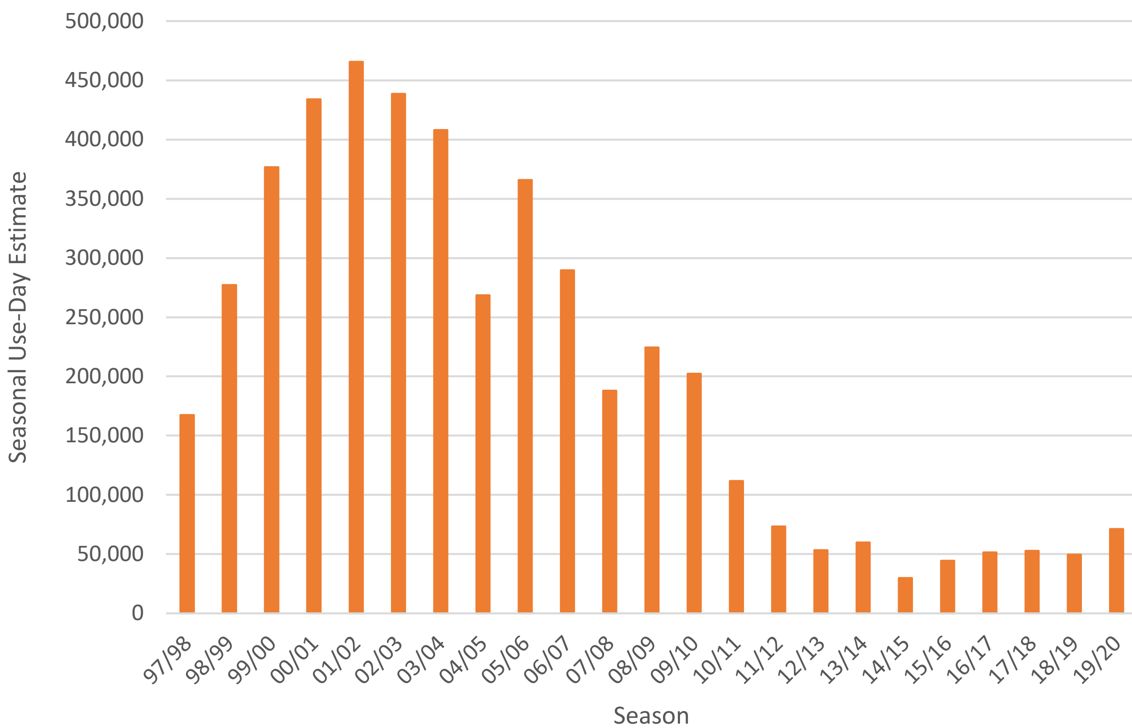

Figure 22. Brant seasonal use-day estimates in Morro Bay from 1997 to 2020 (data adapted from Roser 2020).

Several Cal Poly students have also studied brant foraging behavior over the past few years. In 2018, Cal Poly graduate student Dakota Osborne began studying the impacts of brant grazing on eelgrass. He installed eelgrass enclosure cages, which are open cages that the brant will not enter, thus preventing them from feeding on eelgrass. He has installed these cages in eelgrass beds and has been recording measurements to determine brant grazing effects in caged area as compared to uncaged areas. Results from this research are expected in 2021.

Upcoming Projects

Tidal Prism Analysis

A topobathymetric digital elevation model (DEM) of Morro Bay was completed in 2019, in partnership with NOAA's Office for Coastal Management. The survey combined swath acoustic bathymetry and Light Detection and Ranging (LiDAR) data to create a comprehensive topographic-bathymetric map. Data from the 2019 topobathymetric survey will be used for tidal prism calculations. The analysis will be compared to historic tidal prism volumes to assess bay circulation and hydrodynamics. The analysis is expected to be available in 2021.

For more information on the 2019 topobathymetric survey, refer to the Estuary Program's 2019 Sediment Report, available at www.mbnep.org/library under Data and Technical Reports.

Drone Mapping

The Estuary Program will partner with Cal Poly for a bay-wide UAV drone survey and mapping effort during fall 2021. This work involves the drone flight as well as the manual quantification of eelgrass coverage in GIS.

Restoration and Monitoring

Restoration and survival monitoring will be conducted in 2021, as well as permanent transect and bed condition monitoring. Funding has also been secured to complete an additional two-year permanent plot study to assess yearly trends in eelgrass during 2021 and 2022. This study was developed by Dr. O'Leary and last conducted during 2018 and 2019.

Additional Research Activity

Dr. Ryan Walter of Cal Poly will continue to maintain and run the water quality instrument package at the mouth of the bay and in the back bay throughout 2022. Dr. Bockmon of Cal Poly will also continue to oversee the operation of the autonomous pH sensors at the mouth and back bay locations. Her team also intends to collect monthly shoreline carbonate chemistry samples and nutrient samples, including new locations where the creeks meet the bay. Drs. Bockmon and Walter will also conduct a short-term ocean acidification experiment in July 2021 inside and outside of eelgrass patches using moored instrument arrays.

Additional research efforts by Cal Poly, Cuesta College, and others will continue to collect data to further our understanding of suitable conditions for eelgrass in the bay. Eelgrass health is thought to be impacted by sediment loading and transport, and proposals have been created to further study this technical area.

Conclusions

Eelgrass plays a vital role in the health of the Morro Bay ecosystem. While the Morro Bay eelgrass population has fluctuated in the past, there was a drastic loss of eelgrass in the early 2010's. The 2017 map showed encouraging signs of eelgrass returning in the mid and back bay and in areas where it has not been seen for several years. The mapping efforts for 2019 and 2020 tracked a rebound of eelgrass acreage to the highest levels since 2010. Estuary Program's monitoring related to permanent transects, bed condition, bay-wide mapping, and restoration all indicate a substantial rebound of eelgrass in 2020.

Anecdotally, it appears a portion of Morro Bay eelgrass is ephemeral, coming and going with the seasons rather than forming permanent beds. This seasonal growth was documented in fieldwork in late 2016 as well as in the mapping efforts of 2017 and 2019. Observations in 2018 and 2019 support the conclusion that some of these small eelgrass patches are ephemeral, as their locations shift from year to year. Other patches seem to be perennial and have been growing and expanding in 2020, including the 2018 and 2019 transplant plots. Further seasonal monitoring over a larger scale is needed to better understand the portion of eelgrass patches that are ephemeral versus present year-round.

In 2021, more projects will continue to investigate the many facets of eelgrass, including permanent plots, permanent transects, bed condition monitoring, bay-wide mapping, and restoration. Additionally, a partnership with Cal Poly and funding from Restore America's Estuaries will support monitoring, research, and restoration efforts through the end of 2022. USFWS funding will also support restoration efforts. The Estuary Program and its many partners will continue to strive to understand conditions in the bay that impact eelgrass survival and identify actions to support a sustainable eelgrass population in Morro Bay.

References

Bernstein B, Merkel K, Chesney B, Sutula M. 2011. Recommendations for a Southern California Regional Eelgrass Monitoring Program. Technical Report 639. Prepared for the National Marine Fisheries Service. Southern California Coastal Water Research Project. Costa Mesa, CA

Chesnut J. 1999. Eelgrass Habitat in Morro Bay. Morro Bay National Estuary Program.

Cuesta College. Nov 2019. Role of *Labyrinthula spp.* in the development of eelgrass wasting disease in the Morro Bay Estuary. Final Community Project Report, Project Number 7219RF. Prepared for the Morro Bay National Estuary Program.

Cuesta College. 2021. 2020 *Labyrinthula spp.* Summary. Prepared for the Morro Bay National Estuary Program.

Harenčár J.G., G. Lutgen, Z. Taylor, N. Saarman, J.M. Yost. 2017. How population decline can impact population genetics: A case study of eelgrass (*Zostera marina*) in Morro Bay. Estuaries and Coasts. Accepted with revision.

Hauxwell J, Cebrian J, Valiela I. 2003. Eelgrass (*Zostera marina)* loss in temperate estuaries: relationship to land-derived nitrogen loads and effect of light limitation imposed by algae. Marine Ecology Progress Series 247, 59-73.

Kitajima A. Jan 2016. Morro Bay National Estuary Program's Data Summary Report 2015. Morro Bay National Estuary Program.

Merkel & Associates. Sept 2014. Re: Morro Bay Eelgrass Recovery Program 2014 Eelgrass Transplant Report. Prepared for the Morro Bay National Estuary Program. M&A #12-090-05.

Merkel & Associates. Sept 2015. 2015 Monitoring Report, Morro Bay Eelgrass Recovery Program. Prepared for the Morro Bay National Estuary Program.

Merkel & Associates. June 2020. Re: Morro Bay FY 2020 Federal Maintenance Dredging, Final Water Quality Monitoring Summary Report. Prepared for the U.S. Army Corps of Engineers. M&A #05-024-42.

Morro Bay National Estuary Program. July 2017. Morro Bay Eelgrass Report 2014-2016.

Morro Bay National Estuary Program. April 2019. Morro Bay Eelgrass Report 2018.

Morro Bay National Estuary Program. February 2021. Morro Bay Eelgrass Report 2019.

Nordlund L.M., Koch E.W., Barbier E.B., Creed J.C. 2017. Seagrass ecosystem services and their variability across genera and geographical regions. PLOS ONE 12(1): e0169942. https://doi.org/10.1371/journal.pone.0169942

Ocean Imaging. November 2020. 2019 Morro Bay Submerged Aquatic Vegetation (SAV) Mapping in Morro Bay Utilizing Multispectral Imagery - Final Report (Revision 4). Prepared for the Morro Bay National Estuary Program.

O'Leary, J.K., Goodman, M.C., Walter, R.K. et al. March 2021. Effects of Estuary-Wide Seagrass Loss on Fish Populations. Estuaries and Coasts. https://doi.org/10.1007/s12237-021-00917-2

Ralph PJ, Durako MJ, Enriquez S, Collier CJ, Doblin MA. 2007. Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology 350, 176-193.

Roser J. April 2019. Brant Counts for Morro Bay, California, 2018 - 2020 Season. *Unpublished.*

Tenera Environmental. October 2020. Eelgrass 30-Day Post-Construction Survey, Document ESLO2020-31.1.

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