

2020 San Diego Bay Eelgrass Inventory



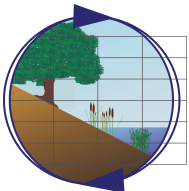
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Merkel & Associates, Inc.

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**2020 SAN DIEGO BAY
EELGRASS INVENTORY UPDATE**

Merkel & Associates, Inc.

February 2021

BACKGROUND

Eelgrass Distribution and Functions

Eelgrass is a native marine plant indigenous to the soft-bottom bays and estuaries of the northern hemisphere. The species is found from middle Baja California and the Sea of Cortez to northern Alaska along the west coast of North America and is common in healthy shallow bays and estuaries. In southern California, eelgrass is generally limited along the shoreward margin by desiccation stress at low tides and is limited along its deeper fringe by low light levels.



Eelgrass plays many roles within coastal bays and estuary ecosystems. It clarifies water through sediment trapping and stabilization and provides benefits through nutrient transformation and water oxygenation. Eelgrass serves as a primary producer in detrital based food webs and is directly fed upon by invertebrates, fish, and birds. It provides physical community structure and supports epiphytic plants and animals, which in turn are grazed upon by larval and juvenile fish, invertebrates, and birds. Eelgrass is a nursery area for commercially and recreationally important finfish and shellfish species, including fishes restricted to bays and estuaries as well as oceanic species, which enter the coastal areas to breed or spawn.

In addition to the high intrinsic values of eelgrass as a habitat, it also provides significant value as a tool for examining long-term trends in water quality improvement or deterioration. It has ideal characteristics for use in monitoring system change. Eelgrass is found at the end of the watershed within coastal bays and estuaries; and as such, monitoring the status of eelgrass resources helps to assess overall watershed management effectiveness. Eelgrass responds to persistent water quality stresses rather than short duration fluctuations. It is adapted to a wide range of tolerances and is capable of "averaging" exposure conditions including temperature, turbidity, seasonal light levels, sedimentation rates, etc., to result in either positive growth or a gradual decline. As a result, short-term variability such as can be seen with water quality testing is of relatively little consequence to eelgrass. A more biologically meaningful measure of long-term trends in environmental stressors such as elevated temperature or turbidity can be seen in the response of eelgrass to chronic exposure to the ambient environment.

Eelgrass is considered to be a habitat forming species that creates unique biological environments. Because of the importance of eelgrass, it is afforded heightened regulatory protection status. As submerged aquatic beds, eelgrass is given special status under the Clean Water Act, 1972 (as amended), Section 404(b)(1), "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Subpart E, "Potential Impacts on Special Aquatic Sites." This special status has led to mitigation efforts implemented under the California Eelgrass Mitigation Policy (CEMP, NOAA 2014).

San Diego Bay

The eelgrass resources of San Diego Bay are significant not only on a local scale, but also regionally. San Diego Bay is the largest open water bay in southern California and one of only a handful of bays in California that supports sizeable eelgrass meadows. San Diego Bay ranks third behind Humboldt Bay and slightly behind San Francisco Bay in total eelgrass habitat, supporting approximately 17 percent of all eelgrass habitat within the State of California. San Diego Bay supports approximately 50 percent of the total amount of eelgrass resources in southern California.

Table 1. San Diego Bay eelgrass contribution to the estimated California statewide eelgrass area.

System	Acreage	% Total	Source
Humboldt Bay (2009)	~4,700	30%	M&A 2017a
San Francisco Bay (2014)	2,790	18%	M&A 2014
San Diego Bay (2020)	2,598	17%	this report
Tomales Bay (2017)	1,527	10%	M&A 2017b
Mission Bay (2013)	979	6%	M&A 2013
All Other Systems	~3,000	19%	M&A 2017a
Total	~15,594	100%	

San Diego Bay is a 10,994-acre bay located between the City of San Diego to the north and east, the cities of National City, Chula Vista, and Imperial Beach to the east and south, and the City of Coronado to the south and west. The Bay represents the largest estuary in southern California. It is approximately 15.5 miles in length and contains 54 miles of shoreline. Portions of the Bay north of the Coronado Bay Bridge are narrow and deep, while most of the southern portions of the Bay are wide and shallow. Much of the northern and central Bay shoreline has been developed.

Eelgrass is predominantly a subtidal resource and as a result it is difficult to monitor and track changes in its distribution. Moreover, comparisons between various eelgrass surveys are burdened by advancements in technology and orders of magnitude advancements in precision and accuracy of mapping capabilities. Prior to the 1990's, eelgrass surveys in San Diego Bay were performed by a variety of techniques including trawl and grab sampling, diver transects, and true color and infrared aerial imagery (Lockheed 1979a, Lockheed 1979b, SDUPD 1979, SDUPD and California State Coastal Conservancy 1990). Mapping was aided by estimation of locations based on various landmarks and, on rare occasion, some controlled survey points from which relative locations were visually approximated. Small-scale eelgrass mapping was conducted primarily through the use of grabs and divers, whereas the large-scale efforts tended to rely on aerial imagery. However, aerial imagery was not consistently capable of detecting eelgrass at depth. As a result, shallow eelgrass beds were generally well mapped, but deeper eelgrass beds were often under-reported or missed entirely.

In 1988, sidescan sonar was first used to map eelgrass within the 2000-acre Mission Bay. The boat trackline was plotted using microwave navigation, and eelgrass density was determined from sonographic charts while diver transects were used to ground-truth the work effort (Merkel 1988). This approach was subsequently updated to make use of real-time differential GPS data to plot the centerline boat position as well as a CAD-based mapping effort (Merkel 1992). In 1993, the U.S. Navy applied this technology to San Diego Bay and provided the first comprehensive survey of eelgrass resources within the Bay (U.S. Navy 1994). The Navy and the San Diego Unified Port (Port)

District followed this effort with another baywide survey in 1999 using single-beam sonar methods (U.S. Navy 2000). In 2004 and 2008, Merkel & Associates carried out both eelgrass surveys and bathymetric mapping updates that included the entire San Diego Bay (Merkel & Associates 2005, 2009). In 2011, advancements in mapping technology were made with the application of interferometric sidescan sonar (ISS) to conduct the updated eelgrass mapping (Merkel & Associates 2011a). The use of ISS technology substantially improved the spatial accuracy of acoustic backscatter mapping. In 2017, baywide eelgrass surveys made use of ISS with improvements in vessel positioning and heading correction through the use of real time kinematic (RTK) GPS (Merkel & Associates 2018b). Unmanned aerial vehicles (UAVs) were used to augment the ISS survey coverage extending eelgrass mapping through shallow marsh channels and within recently restored salt evaporation ponds of South San Diego Bay. The present 2020 baywide eelgrass inventory made use the same technology as applied in 2017 and continues to provide insight into long-term trends in eelgrass habitat and environmental change within the Bay.

Baywide eelgrass surveys have been conducted for tracking ecological and water quality conditions, detecting trends derived from anthropogenic influences or climatic changes, and for natural resource and development planning. The San Diego Bay Integrated Natural Resource Management Plan establishes recurrent baywide eelgrass surveys as a monitoring priority (US Navy and Port 2013). Eelgrass survey results are presented on a baywide scale. Depths are presented in feet using mean lower low water (MLLW) as derived from composite bathymetric charts prepared as a product of 2008 surveys (Merkel & Associates 2009) (Figure 1).

SURVEY AND ANALYSIS METHODS

Interferometric Sidescan Sonar

Survey equipment used for data collection included a digital interferometric sidescan sonar system with motion sensor integration, and RTK GPS for navigation. Data were collected over the course of 19 survey days by Merkel & Associates to result in full baywide coverage. Survey density was higher within shallow environments than was employed in more open deepwater environments where eelgrass would not be expected and existing high-resolution bathymetry existed. Surveys in these areas were performed to confirm existing data sets.

Sonar

A hull mounted 468 kHz digital interferometric sidescan sonar system was used, which included SEA SWATHplus-H sonar, integrated with a Valeport miniSVP sound velocity sensor, and an SMC IMU-108 motion sensor to correct for speed of sound in water and roll, pitch, and heave of the survey vessel. The sidescan sonar data were collected with across-track swath widths of 31 m on both the port and starboard transducers. Tracklines were overlapped to provide for 100 percent seafloor coverage within the survey area (Figure 2). The acoustic wave phase difference at different sensors allows for triangulation of the position of the acoustically reflective surface.

Navigation

The navigation system used during the surveys employed an on-board dual antenna RTK GPS. The positional accuracy horizontal positioning of the survey vessel was maintained with a Hemisphere VS111 providing positional accuracy within 2 centimeters, 95 percent of the time. The secondary antenna provided heading and yaw correction. During the survey, the vessel was operated on parallel tracks with slightly overlapping sonographic records. The first trackline within each area was located 15 to 20 meters from the shoreline allowing full coverage of the Bay floor up to the

middle intertidal zone or above. Once the initial trackline had been completed, the vessel moved offshore in approximately 25-meter increments and paralleled the primary trackline (Figure 2). Maintaining a line parallel to the primary trackline was accomplished by the use of a real-time position and digital trackline map. Once sufficient shoreline buffer had been developed, straight-line swaths were employed to minimize data loss occurring in turns. High wave environments and areas with significant vessel traffic were surveyed at night to maximize the quality of acoustic records collected. Following the completion of the sonographic survey, the stored sidescan data were post-processed into a series of geo-rectified mosaic images covering all surveyed areas of San Diego Bay.

Low Altitude Photogrammetry

During extreme low tides, a UAV was flown within the south bay along pre-programmed flight patterns at 300 feet of elevation. Surveyed areas included marshland channels, restored salt ponds, and the Sweetwater River channel over marshland channels and shore margins. Photographs were collected at intervals providing 75% forward lap and 65% side lap between photographs that were collected with a 20-megapixel camera to obtain imagery with a native pixel size of 30mm. Images were processed into spatially rectified true color orthophoto mosaic images using Agisoft Metashape Professional. The registered images were then used to support heads-up digitization of eelgrass. Spectral shifts, dynamic range adjustments, and other spectral analyses tools were applied to enhance the separation of eelgrass signatures from other features such as algae in order to aid in mapping.

Ground-Truthing

Remotely operated vehicle (ROV) and drop video camera spot checks, as well as low-tide surface inspections, were used to ground-truth maps prepared using sonographic data. The distribution of ground-truthing sites was non-random and primarily focused on sites identified as having substantial discrepancies existing between the prior surveys and the present survey. Additionally, ground-truthing focused on southern portions of the Bay where warm water conditions favor the abundance of the subtropical upright bryozoan, *Zoobotryon verticillatum*. This large bryozoan returns a similar but substantially less acoustically reflective signal as eelgrass; and thus, sonographic interpretation was expected to be most questionable in these areas. The south bay region also supported limited occurrences of widgeon grass (*Ruppia maritima*), a short, densely growing, seagrass found in areas around the Chula Vista Wildlife Reserve and within the Otay River estuary which requires some initial signature verification based on the growth state of both eelgrass and widgeon grass at the time of mapping. Surfgrass (*Phyllospadix* spp.) occurs on the rocks of Zuniga Jetty, but not on soft bottom and thus is not confused with eelgrass in the mapping effort.

Other ground-truthing efforts were focused in areas of mixed rubble and soft bottom where *Sargassum muticum* can generate similar, but distinguishable acoustic signatures to those of eelgrass. Finally, ground-truthing efforts occurred around marinas, docks, and other areas where sonographic surveys were encumbered by limited open water access and where eelgrass distribution patterns are complex and frequently sharply demarcated by density changes. Although ground-truthing efforts were focused in some regions of the Bay, all portions of the Bay were ground-truthed to the level of detail required to confirm the accuracy of the sonographic data analysis.

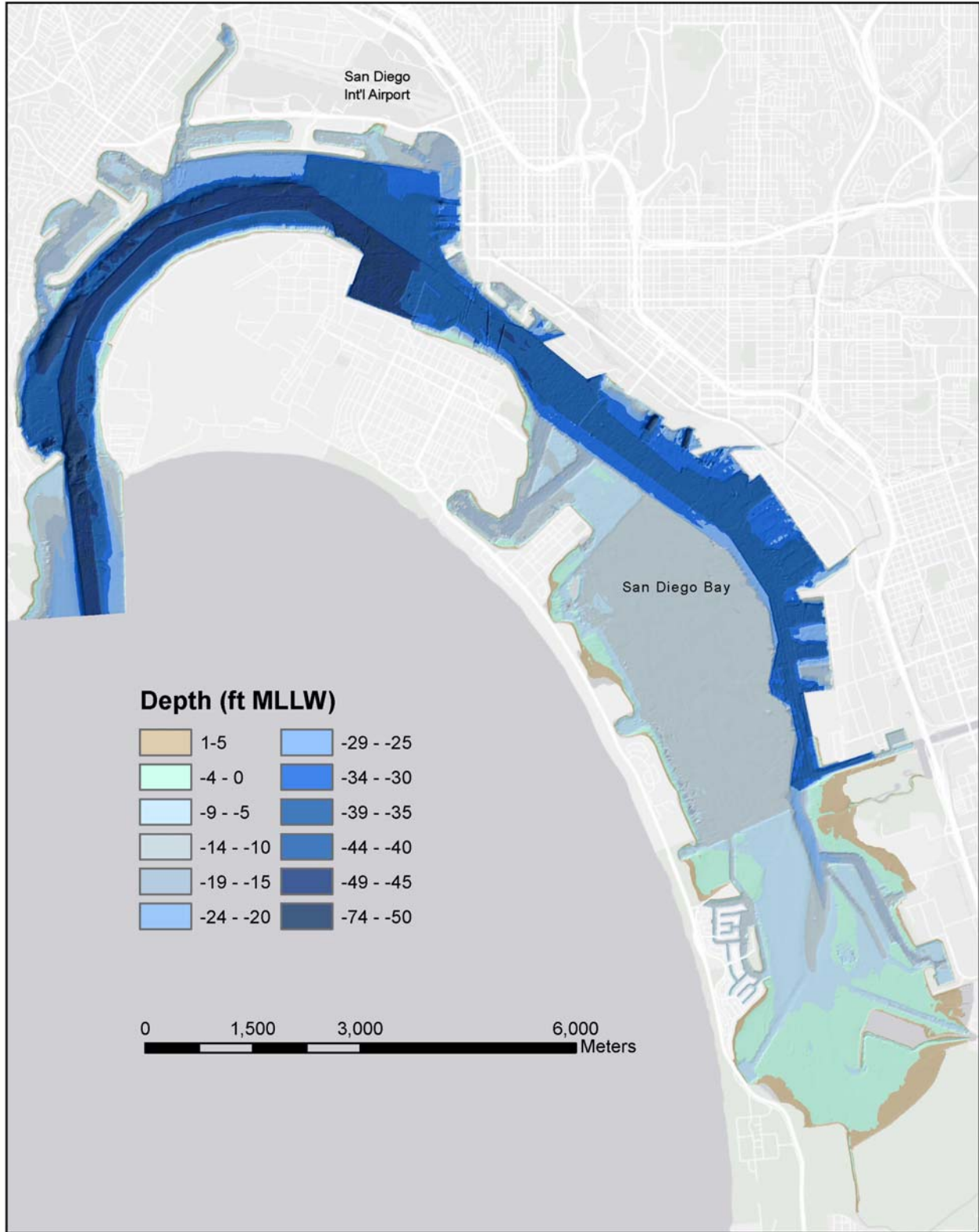


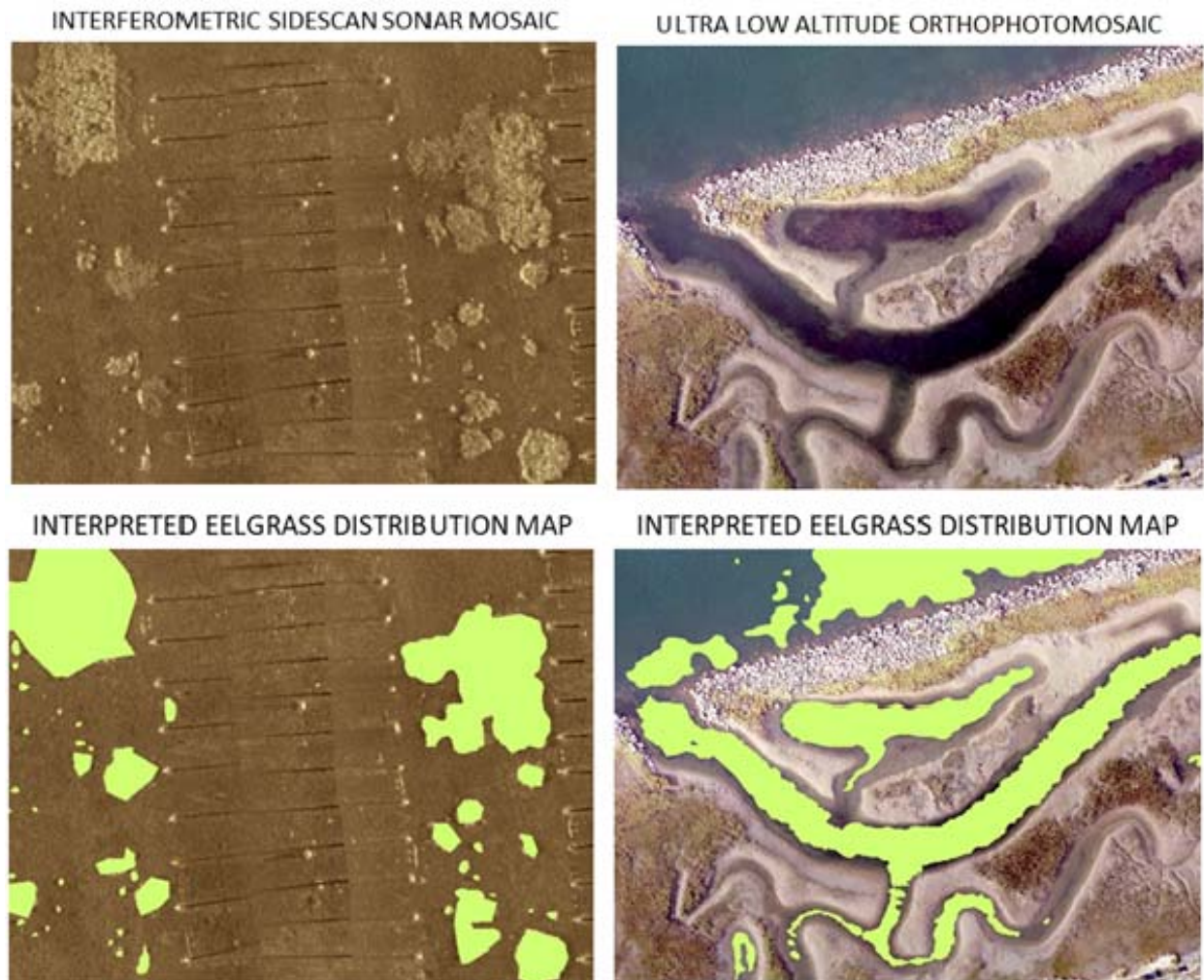
Figure 1. Composite bathymetry of San Diego Bay (Updated in 2008).



Figure 2. 2020 Eelgrass Survey Tracklines.

Eelgrass Mapping

The sonar mosaic and orthophoto mosaic images were imported into geographic information systems (GIS) software to delineate eelgrass beds through on-screen digitization of the acoustic signatures of eelgrass observed in the sonographic and photographic records. Eelgrass was manually digitized from the image sources as discrete vegetative plant patches. In the case of sonar mosaics, the individual survey swaths were mapped and then survey layers flipped to observe the bottom from differing survey angles to verify that eelgrass patches were observed. This allowed for detection of plants within the sonar nadir gap. For orthophoto mosaics, spectral shifts and dynamic range adjustments were used to separate eelgrass signatures from conflicting algae. In many cases, overlap in coverage by ISS and UAV data provided cross platform mapping verification capabilities. For purposes of mapping, the 2020 eelgrass inventory used a tight-line mapping wherein eelgrass features were individually mapped as opposed to mapping eelgrass by cover classes. The mapped eelgrass patches were then merged into a single shape-file reflecting the 2020 eelgrass distribution.



Examples of interpreted mosaic files from interferometric sidescan sonar surveys and UAV ultra-low altitude orthophotography covering shallow marsh channels and other vessel inaccessible portions of the survey area.

RESULTS

Information presented in this report has been prepared for use in digital format and large-scale presentation format for the Navy and Port District. Reduced versions of graphics are incorporated in this document for completeness of interpretation.

Eelgrass

The 2020 eelgrass distribution within San Diego Bay extended over a total bottom area of 2,597.9 acres (Figure 3). The distribution of eelgrass follows the general patterns of distribution noted in prior surveys. The greatest extent of eelgrass is found within the shallow southern ecoregion of the Bay with more extensive eelgrass also being found on the shallower fringes of the western Bay shorelines where gradual soft shorelines are more prominent (Figure 1). Other smaller beds occur scattered throughout the more developed regions of the Bay where shallows allow for adequate light levels to support eelgrass habitat. Eelgrass beds also exist at the mouth of San Diego Bay within the shallows outside of Ballast Point and along Zuniga Jetty on North Island.

DISCUSSION

The 2020 survey year was notable for extensive eelgrass expansion beyond the prior maximum extent of eelgrass recorded during the seven prior surveys extending over nearly three decades (Figure 4). The extent of eelgrass present exceeded the next highest year, 2004, by 25 percent. Notable expansions in eelgrass observed in 2020 were below the deeper margins of previous bed distributions extending into the concave deeper trough of the south bay ecoregion and within the outer channels of the Coronado Cays. In the south-central bay ecoregion eelgrass has extended to the bottom of the 3-foot vertical step that defines the boundary between the south and south-central bay ecoregions and onto the flatter dredged bay floor at -10 to -12 feet MLLW around the Naval Amphibious Base where eelgrass has also expanded into deeper waters, and on the deeper floors of Fiddler's Cove and Crown Cove. In the north-central ecoregion, expansion beyond the prior recorded maximum extent is principally found in the deeper waters of the Tuna Basin and Marriott Marina basins. In the north bay ecoregion the pattern of eelgrass expansion into deeper waters was also observed with greater eelgrass at depth being observed at the Harbor Island West and East Basins, and within America's Cup Harbor.

Other, more minor, eelgrass expansion beyond prior maximum recorded distribution has been related to habitat restoration projects including eelgrass expansion at the eastern end of the BAE Systems Pier 1 North Dry Dock eelgrass restoration within the decommissioned South Bay Power Plant cooling water intake channel, within the South Bay Salt Works Ponds 10 and 11 tidal channels developed as a part of wetland restoration completed by the USFWS, and at Smuggler's Cove constructed and planted by the Navy in 2020.

Throughout the Bay, eelgrass is observed to be restricted to the shallower portions of the baywide depth range (Figure 5). Eelgrass grows most extensively in waters ranging from approximately +1 to -8 feet MLLW, with the greatest percentage of available substrate being occupied between -2 feet and -4 feet MLLW. Some notable deviations from this typical range are seen in areas on higher mudflats and at the toe of riprap slopes, where wave scour, boat propeller scars, and activities of rays have created small perched pools that can support eelgrass habitat above the +1 foot MLLW elevation that typically defines the upper elevation of eelgrass in San Diego Bay. In addition, deepwater eelgrass beds are found at the mouth of the Bay outside of Ballast Point where clear water and sandy sediments supports the broad-leaved Pacific eelgrass (*Zostera pacifica*). At the



Figure 3. Eelgrass spatial distribution for San Diego Bay 2020 baywide survey

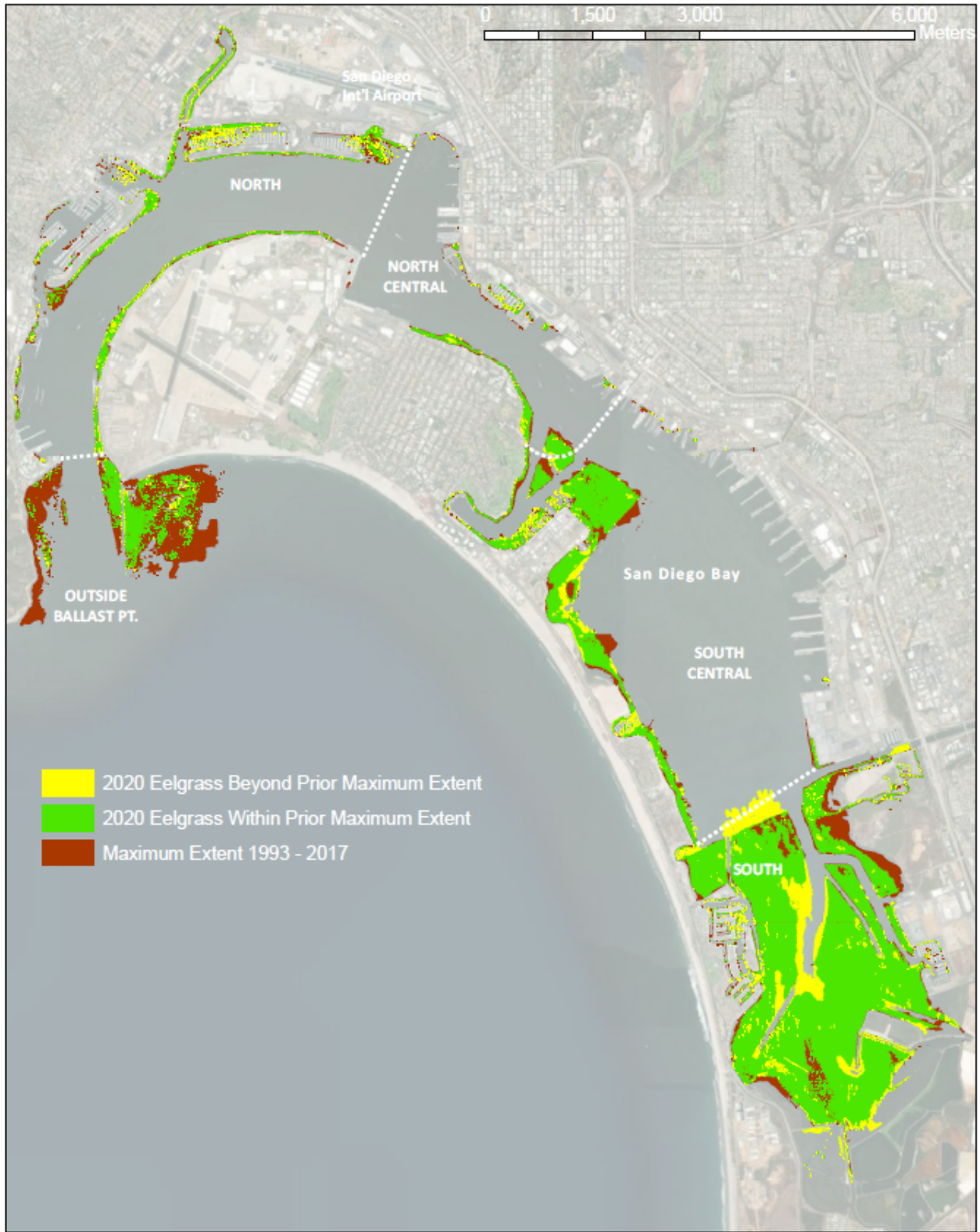


Figure 4. 2020 eelgrass relative to prior maximum extent eelgrass distribution (1993-2017).

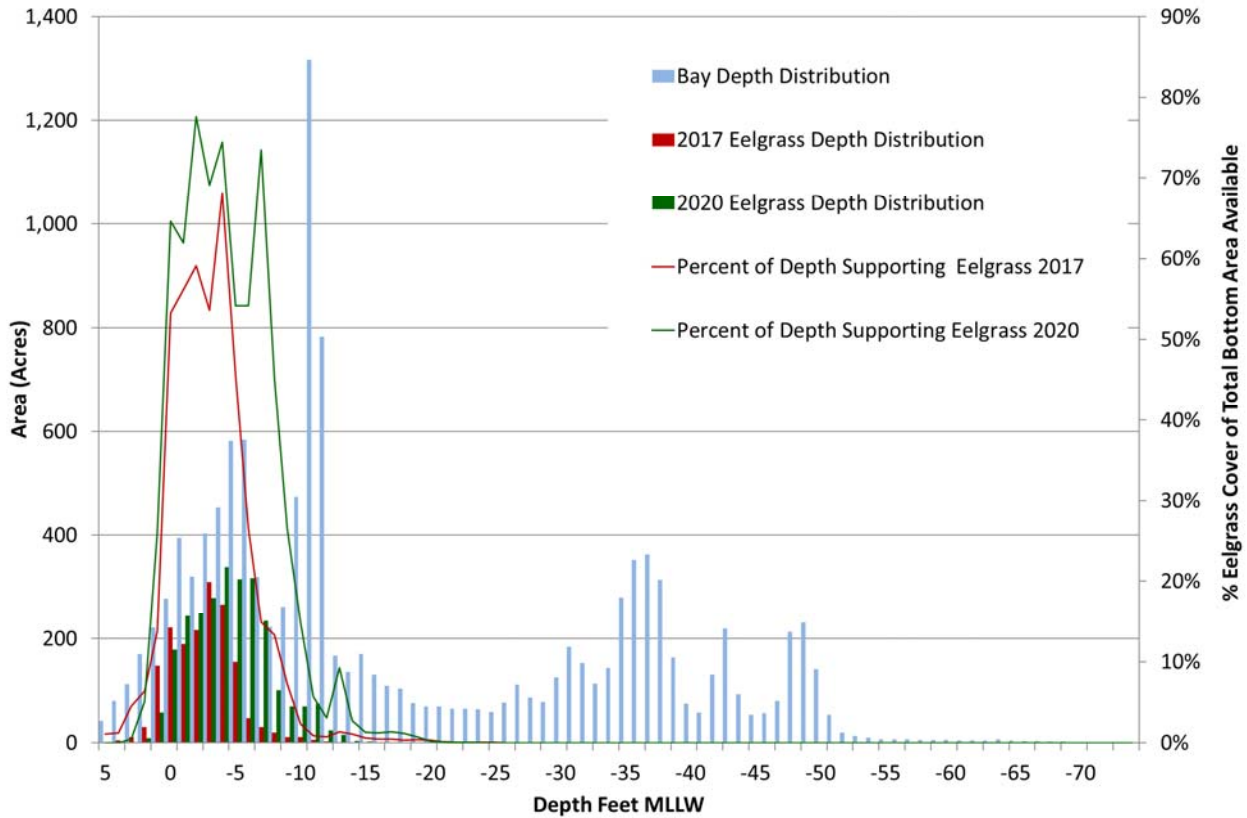


Figure 5. San Diego Bay depth distribution by percentage of total area.

mouth of San Diego Bay, these beds rarely extend to depths in excess of -21 feet MLLW but are generally restricted to depths in excess of -12 feet MLLW. A very small amount of eelgrass also regularly has occurred in deeper waters within the eastern portion of the central bay where clear water often occurs around the commercial piers that are exposed to flows from the deep navigation channel. The deeper distribution of eelgrass observed in 2020 is particularly interesting in that expansion has entered into depth ranges of the bay that have historically not supported significant eelgrass. To explore this further, eelgrass depth distribution has been plotted on the most recent composite bathymetric data compiled from a number of primary and secondary sources in 2008 (Figure 3, Merkel & Associates 2009). It is recognized that the 2008 composite bathymetry is now substantially out of date and needs to be refreshed; however, it provides a reasonably good tool for exploring changes in eelgrass distribution across the bay’s bathymetric range. Plotting the 2017 and 2020 data on the depth distribution for the entire bay reveals that the general expansion of eelgrass in 2020 is skewed towards deeper waters (Figure 5). Further, when the area of eelgrass is divided by the area of available bay bottom within each depth bin, the percent occupancy of the bay bottom by depth can be determined. From this, it can be seen that the expansion of eelgrass at the deeper depths is entering into a bathymetric range between -10 to -12 feet MLLW. This depth range constitutes 21 percent of the total bay area with the cumulative area of bay falling within this depth zone being nearly 2,600 acres, dwarfing the areal extent of any other three-foot depth band represented in the bay (Figure 5). This is of tremendous importance in that there is considerable potential for eelgrass expansion in this depth range whereas there is limited potential for expansion within the shallower core of the eelgrass distribution range.

If the 2020 deeper water eelgrass was to persist and expand within the same depth ranges over the long-term the bay would have the capacity for near doubling of the present eelgrass habitat. However, this condition is not expected to persist. Normal variability in water clarity renders eelgrass at these depths inherently unstable from year to year, and sea level rise will continue to reduce potential for eelgrass persistence at deeper depths. To evaluate how much of an anomaly the present 2020 eelgrass distribution represents, the depth distribution of prior baywide eelgrass inventories has been plotted along with the mean and standard deviation of all surveys (Figure 6). This plot shows relatively consistent upper and lower eelgrass extents and a more variable eelgrass area within the core of the depth range. It also shows the 2020 deep water depth extension as an anomaly well outside of the norm compared to other inventory years and the overall historic mean. However, it is notable in the graph, coded by year to follow the light spectrum, that there has been a relatively consistent trend of increasing eelgrass expansion within the core of the depth distribution range (0 to -5 feet MLLW).

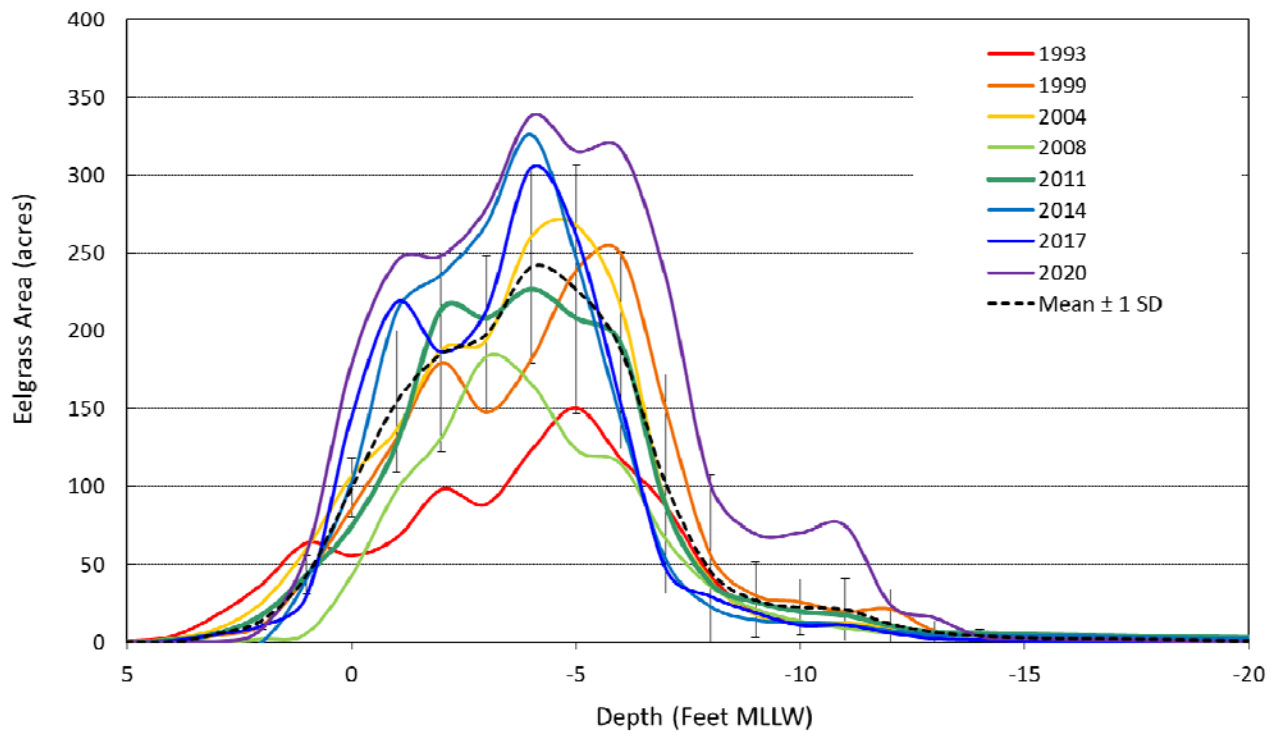


Figure 6. Eelgrass area distribution by depth and baywide survey year.

In addition to the trend of increasing coverage of eelgrass within the core of the depth distribution, there has also been an overall long-term trend of increasing eelgrass extent within the bay over the past three decades (Figure 7, Table 2). This pattern has been strongly driven by a trend of increasing eelgrass area within the south bay ecoregion with the other ecoregions playing lesser and mixed roles with respect to the eelgrass extent in the bay. Eelgrass is not evenly distributed across the ecoregions and neither is the capacity for expansion and contraction with the beds. For the most part, eelgrass in the north bay and north central bay ecoregions is restricted to fringing eelgrass beds along the margins of deep harbor areas with limited expansion potential, while the south bay, south central, and outside Ballast Point ecoregions have greater capacity for eelgrass expansion with slight sustained increases in water clarity.

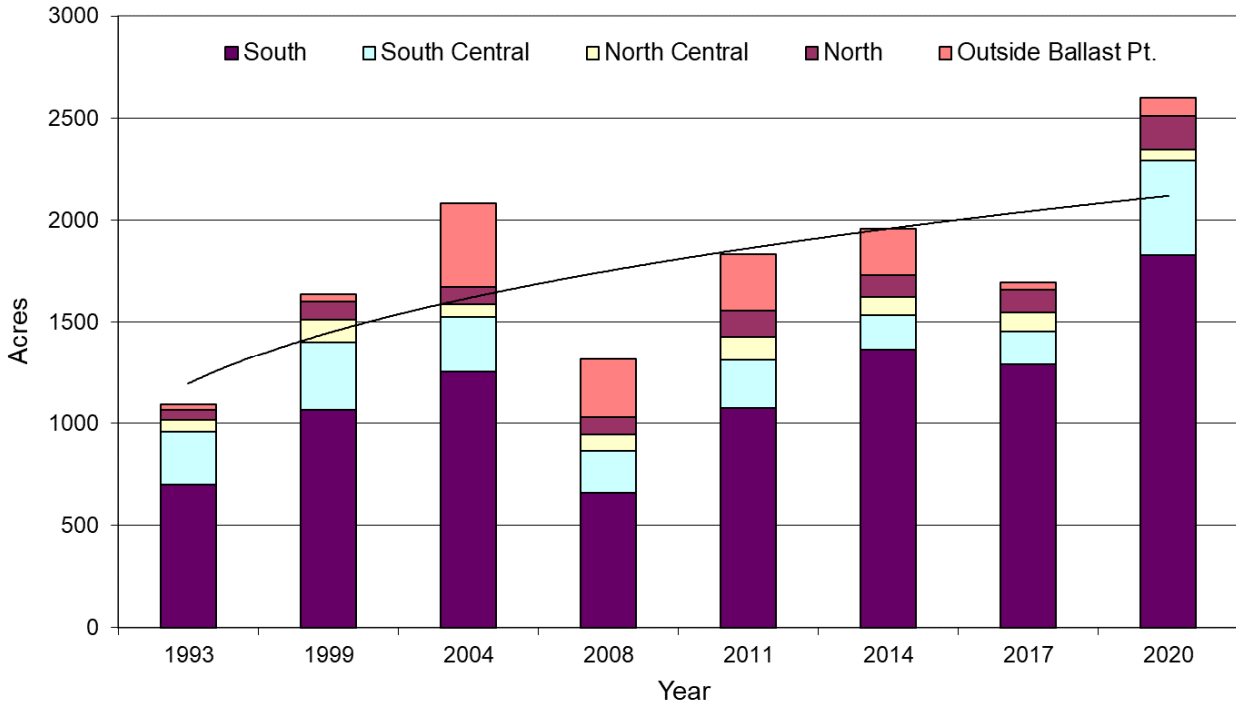


Figure 7. Eelgrass area distribution by ecoregion and baywide survey year.

Table 2. San Diego Bay eelgrass area distribution by ecoregion and survey year.

<i>Eco-Region</i>	1993	1999	2004	2008	2011	2014	2017	2020	Mean
Outside Ballast Pt.	26.1	35.6	413.8	286.0	276.4	226.2	33.6	89.6	173.4
North	50.0	87.8	83.4	85.4	126.7	106.5	110.9	162.9	101.7
North Central	56.2	109.6	61.7	78.2	117.1	90.2	95.1	54.1	82.8
South Central	261.8	335.5	273.0	204.4	234.9	167.6	166.1	463.3	263.3
South	697.3	1065.1	1251.7	660.8	1075.2	1365.2	1287.1	1827.9	1153.8
TOTAL	1091.4	1633.7	2083.7	1314.8	1830.4	1955.7	1692.8	2597.9	1775.1

Despite recent periods of high variability of eelgrass, the long-term trend has been for increasing eelgrass coverage in San Diego Bay. The upward trend has a lot to do with the 2020 increase of over 900 acres of eelgrass from the 2017 eelgrass coverage. This reflects a 53.5 percent increase and is the single largest change in eelgrass coverage recorded over the monitoring program.

Over the past three decades of baywide inventories, there have been a number of large events that have shaped eelgrass distribution and coverage patterns. Several but not all of these have been captured in the baywide eelgrass inventory program. Most notable in Figure 7 is the substantial loss of eelgrass between 2004 and 2008. This loss appeared to be related to a combination of a 2005 El Nino Southern Oscillation (ENSO) event and a biologically mediated decline given the pattern of losses occurring in expansive high-density beds rather than in isolated less dense beds and the pattern of subsequent recovery. Similar anomalous declines in the region’s eelgrass beds were also observed in other systems such as Mission Bay (Merkel & Associates 2008a). Between

2014 and 2017, a significant decline in eelgrass was noted as a result of two potentially unrelated or possibly synergistic stressors that led to major declines. The first was a strong and persistent marine heat wave that led to record setting temperature during a strong 2015/2016 ENSO event and increased thermal stress on plants. The second is considerable wave impact damage to areas of eelgrass beds outside of Ballast Point. It is not known whether thermal stress and weakening of the integrity of the eelgrass beds made them more susceptible to storm damage, or whether the storm damage would have removed beds outside of the bay, irrespective of the condition of these beds prior to the big wave south swell storms. What is not as evident in the data is the fact that eelgrass in 1999 was significantly depressed from conditions in 1996 due to the effects of the 1997-1998 ENSO event that resulted in loss of hundreds of acres of eelgrass in the central portion of the south bay ecoregion (Merkel & Associates 2000).

The 2011 regional survey suggested that prior declines observed in the 2008 survey were reversing with expansion of eelgrass being observed during the survey. The 2014 survey provided evidence of continued recovery. However, the 2017 survey revealed a subsequent decline in eelgrass with the majority of the decline occurring in shallower portions of the bay. The decline was a notable reduction in upper margins of eelgrass beds. The pattern of declines reported in 2017 has been completely reversed in the 2020 baywide survey.

Changes in eelgrass extent within San Diego Bay are generally believed to be transitory responses to prevailing environmental conditions prior to the surveys and potentially extending through the survey period. However, over longer periods of repeated survey intervals, a robust picture of the system norm dilutes inter-survey variability. Depending upon the nature and scale of stressors that act on eelgrass, both the areas of the bed and the extent of bed gains and losses vary. To begin to illuminate the robust and less stable patterns of eelgrass distribution, a frequency distribution map has been prepared (Figure 8). This map presents the spatially explicit eelgrass persistence patterns within the bay as percentage of the times during baseline surveys that an area supported eelgrass. The frequency of eelgrass presence is derived by dividing the number of times eelgrass was present at a particular raster location by the total number of baywide surveys conducted. As the number of surveys increases, the stability and variance in the map can be quantified. In the future, running averages over multiple survey years will allow separation of trends from interannual variability.

While the recent baywide surveys would suggest an overall long-term gradual increasing trend in habitat area within San Diego Bay (Figure 7), the real picture is more complicated. A closer review reveals that increases in eelgrass are driven by the net of gains and losses within differing ecoregions of the Bay. Eelgrass habitat is marked by seasonal and inter-annual variability such that on a fine scale, gains and losses of eelgrass habitat occur throughout the Bay, and it is appropriate to consider the distribution of eelgrass in a more probabilistic sense (Merkel & Associates 2000). Thus, various portions of the Bay have a higher or lower probability of supporting eelgrass habitat at any given time. When evaluating the eelgrass frequency results (Figure 8), it is evident that some areas within the Bay had highly consistent presence of eelgrass, while other areas supported eelgrass only during one or two of the survey years. In some cases, the eelgrass frequency map indicates the presence of eelgrass within areas that are no longer suited to support eelgrass due to development that has occurred since the first surveys were conducted nearly three decades ago.

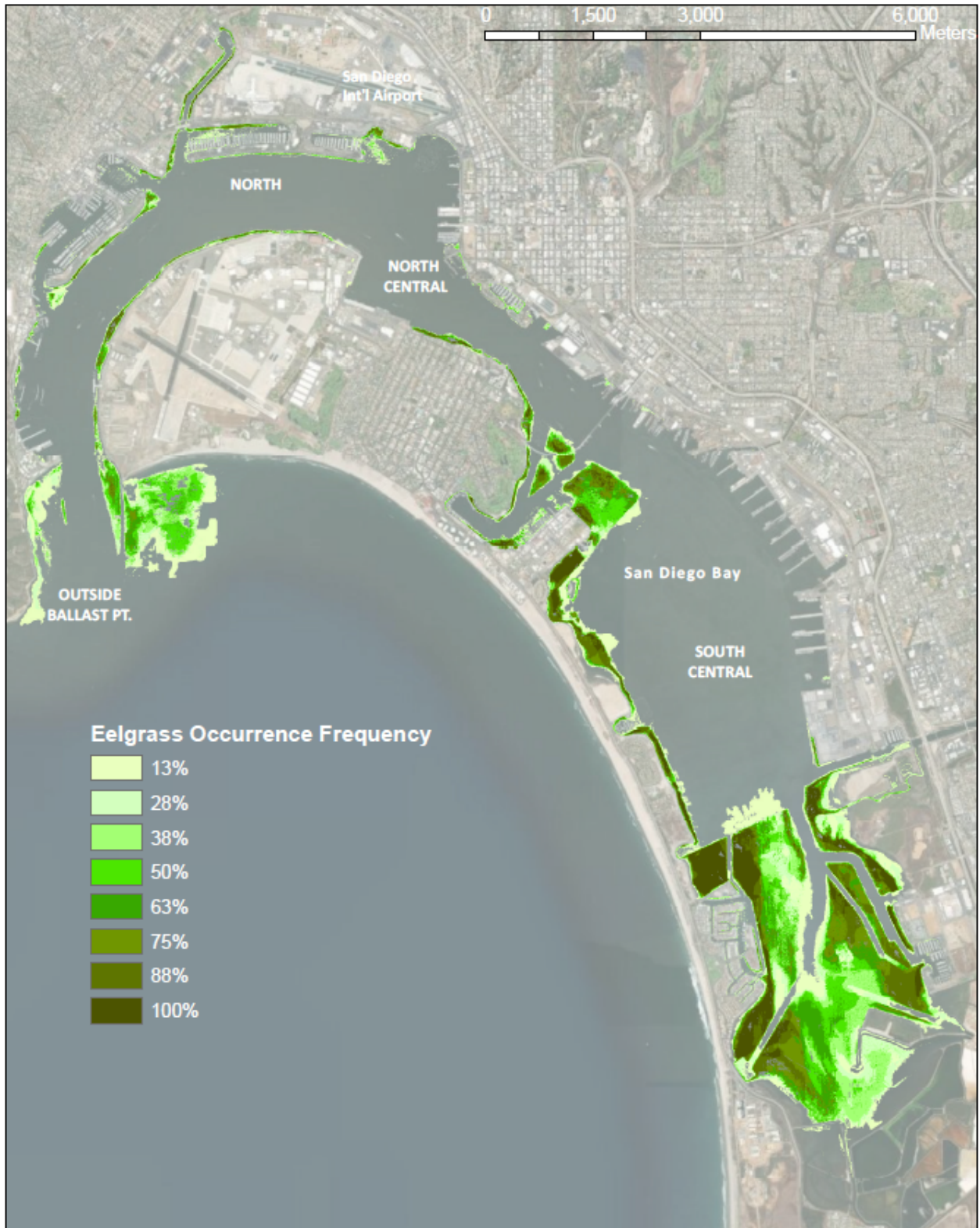


Figure 8. Eelgrass occurrence frequency for the baywide eelgrass (1993-2020).

From a resource management standpoint, it is appropriate to consider that areas that lack eelgrass during a particular survey period may support eelgrass at other times. Further, it is also reasonable to acknowledge that not all eelgrass beds provide the same consistency in habitat values and thereby ecological function through time. As such, planning efforts should consider both spatial and temporal characteristics of the resource when evaluating benefits or detriments that may occur as a result of land-use and habitat management decisions. Substantially more complicated is the need to consider effects of actions located outside of eelgrass beds on parameters that influence eelgrass habitat development or sustainability. These may include alterations to circulation patterns, or nutrient and sediment loading of the Bay.

The ability of eelgrass to weather short-term stressful environmental conditions has been demonstrated on a number of occasions through natural and experimental restriction of resource availability. However, prolonged stresses such as consistent light limitation will result in a decline in eelgrass habitat. Within most sub-tropical and temperate environments, desiccation stresses limit the upper edge of eelgrass growth, and light requirements needed to balance respiration and fuel metabolism (photo-compensation depth) set the lower limits of eelgrass growth in soft-bottom bays. This trend holds true in San Diego Bay; and as a result, a distinct topographic, but seasonably variable boundary typically defines the upper limit for eelgrass between 0.0 and +1.0 feet MLLW. A less distinct lower limit is defined by differences in depth and light penetration. The addition of potential biologically limiting factors on bed distributions creates a new complication to the standard model for eelgrass distribution patterns in San Diego Bay.

The differing survey methods used prior to 1993 prevent in-depth comparisons of longer-term trends in San Diego Bay eelgrass abundance. However, on a decadal scale, eelgrass does appear to have historically expanded in its range in the Bay when compared to the best estimates that can be made from prior historic surveys and ancillary historic photographs and data. Eelgrass expansion within the Bay is likely the result of improved water quality and restoration efforts. Raw-sewage and industrial-waste discharges into the Bay have been significantly reduced since the 1970s (SDUPD and California State Coastal Conservancy 1990, USFWS 1998). The improved water quality has resulted in lower total particulate matter that would otherwise decrease light availability for eelgrass. Additionally, stresses related to nutrient enrichment leading to plankton and macroalgal blooms have declined with reductions in waste discharges.

The long-term monitoring program for eelgrass in San Diego Bay has begun to provide a view of eelgrass not as snapshots in time, but rather as a persistent, however, dynamic resource. To make full use of this monitoring program as a tool in assessing environmental trends, it is critical that it be continued into the future. In addition to the full bay surveys that are conducted on an approximately 3-5 year cycle, the Navy and Port also complete more frequent semiannual surveys of indicator transects. In order to optimize the value of the transect surveys as a supplement to the less frequent full-bay surveys, the transect monitoring and methodology is being adjusted and coupled with defined bay segments that can be used to monitor eelgrass changes during intervening years and allowing for development of estimators of overall eelgrass presence and eelgrass extent by bay segment during intervening years between comprehensive baywide surveys. Such a program has been modeled after a similar effort that has been developed and tested for two years in San Francisco Bay and which has now been applied for management purposes in the past several years (Merkel & Associates 2008b, 2011b, 2013, 201a). This supports the broader efforts to implement regional eelgrass monitoring for the Southern California Bight (Bernstein et al. 2011).

A pilot investigation of this type of monitoring was undertaken in San Diego Bay, among several other systems in southern California, in 2016 by NOAA NMFS in support of the development of a southern California eelgrass monitoring program (Merkel & Associates 2017c). The 2016 monitoring conducted by NMFS in San Diego Bay estimated 1,847.74 acres of eelgrass existed in 2016, while the 2017 survey revealed 9 percent less eelgrass presence. In reviewing the data from the two surveys, it is believed this decline observed between years was real and not an artifact of the subsampling methodologies. Present efforts to advance the utility of the annual transect sampling are making use of this prior pilot and the existing baywide survey data.

USE OF THESE EELGRASS MAPS

Poster versions of the eelgrass inventory maps are provided in Appendix 1. Because of the level of error inherent in regional mapping, these data should only be used as a general measure of the health of the system over time and as a planning tool. Eelgrass data reflect a particular period in time and are anticipated to be seasonally and stochastically dynamic. Information cannot be extrapolated for impact assessment purposes or site-specific uses. While maps are generally accurate with respect to location of eelgrass, it is clear that eelgrass within San Diego Bay is dynamic. For this reason, it is essential that these maps not be over applied to situations for which they are not suited.

Eelgrass maps and bathymetric data are for planning and resource management purposes only and are not to be used for project specific analyses or navigation purposes. The authors make no representation regarding the accuracy of these maps for navigation applications.

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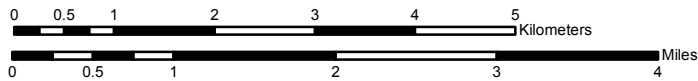
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APPENDIX 1. 2020 EELGRASS DISTRIBUTION



Notes:

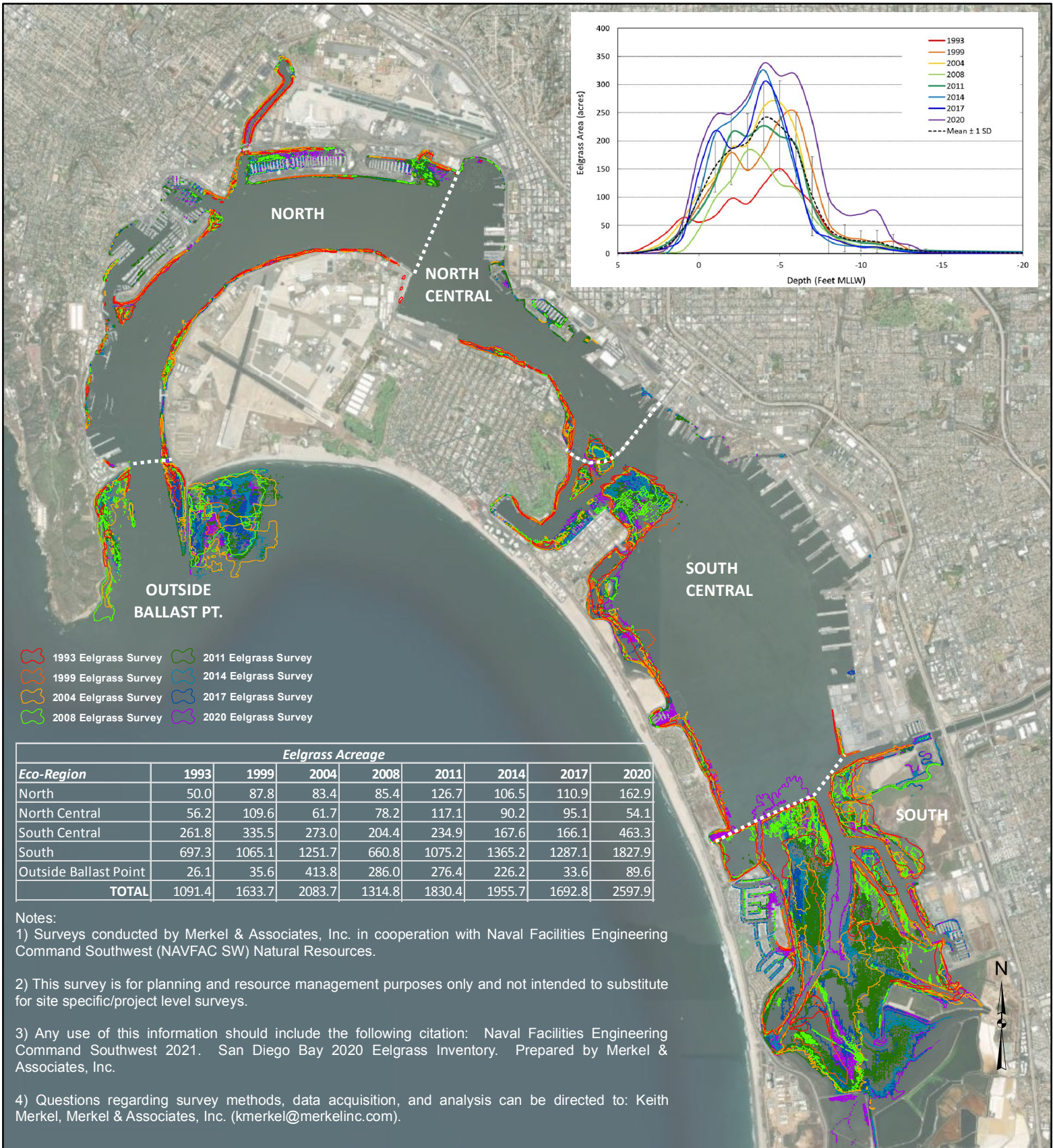
- 1) Surveys conducted by Merkel & Associates, Inc. in cooperation with Naval Facilities Engineering Command Southwest (NAVFAC SW) Natural Resources.
- 2) This survey is for planning and resource management purposes only and not intended to substitute for site specific/project level surveys.
- 3) Any use of this information should include the following citation: Naval Facilities Engineering Command Southwest 2021. San Diego Bay 2020 Eelgrass Inventory. Prepared by Merkel & Associates, Inc.
- 4) Questions regarding survey methods, data acquisition, and analysis can be directed to: Keith Merkel, Merkel & Associates, Inc. (kmerkel@merkelinc.com).



SAN DIEGO BAY

2020 EELGRASS INVENTORY

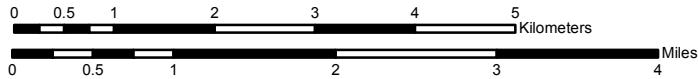
APPENDIX 2. 1993-2020 EELGRASS DISTRIBUTION MAP



- 1993 Eelgrass Survey
- 1999 Eelgrass Survey
- 2004 Eelgrass Survey
- 2008 Eelgrass Survey
- 2011 Eelgrass Survey
- 2014 Eelgrass Survey
- 2017 Eelgrass Survey
- 2020 Eelgrass Survey

Eco-Region	Eelgrass Acreage							
	1993	1999	2004	2008	2011	2014	2017	2020
North	50.0	87.8	83.4	85.4	126.7	106.5	110.9	162.9
North Central	56.2	109.6	61.7	78.2	117.1	90.2	95.1	54.1
South Central	261.8	335.5	273.0	204.4	234.9	167.6	166.1	463.3
South	697.3	1065.1	1251.7	660.8	1075.2	1365.2	1287.1	1827.9
Outside Ballast Point	26.1	35.6	413.8	286.0	276.4	226.2	33.6	89.6
TOTAL	1091.4	1633.7	2083.7	1314.8	1830.4	1955.7	1692.8	2597.9

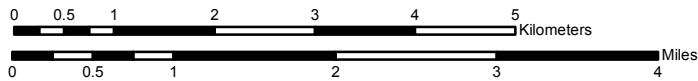
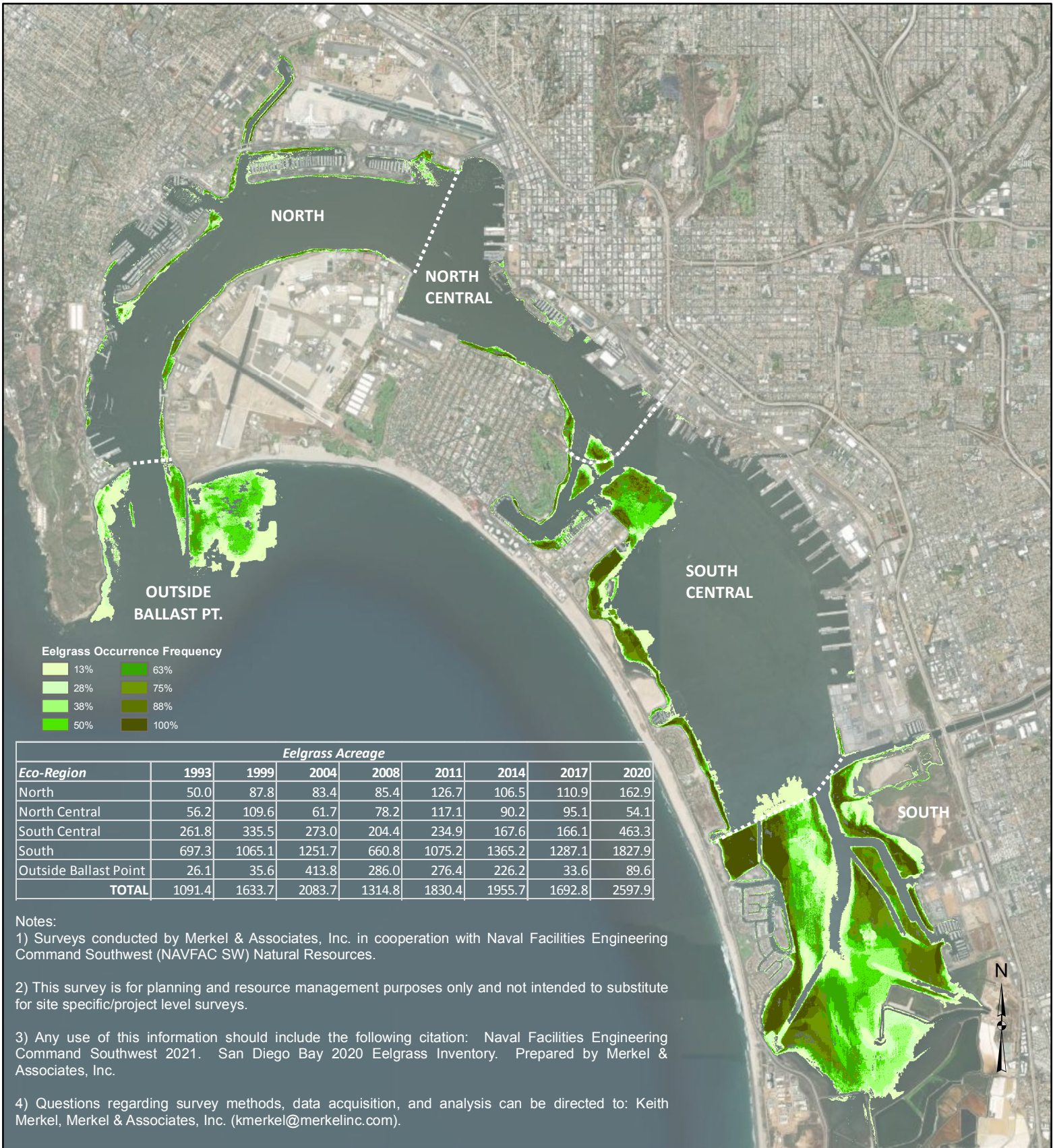
- Notes:
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 - 4) Questions regarding survey methods, data acquisition, and analysis can be directed to: Keith Merkel, Merkel & Associates, Inc. (kmerkel@merkelinc.com).



SAN DIEGO BAY

2020 EELGRASS INVENTORY

APPENDIX 3. EELGRASS FREQUENCY MAP 1993-2020



SAN DIEGO BAY

2020 EELGRASS INVENTORY