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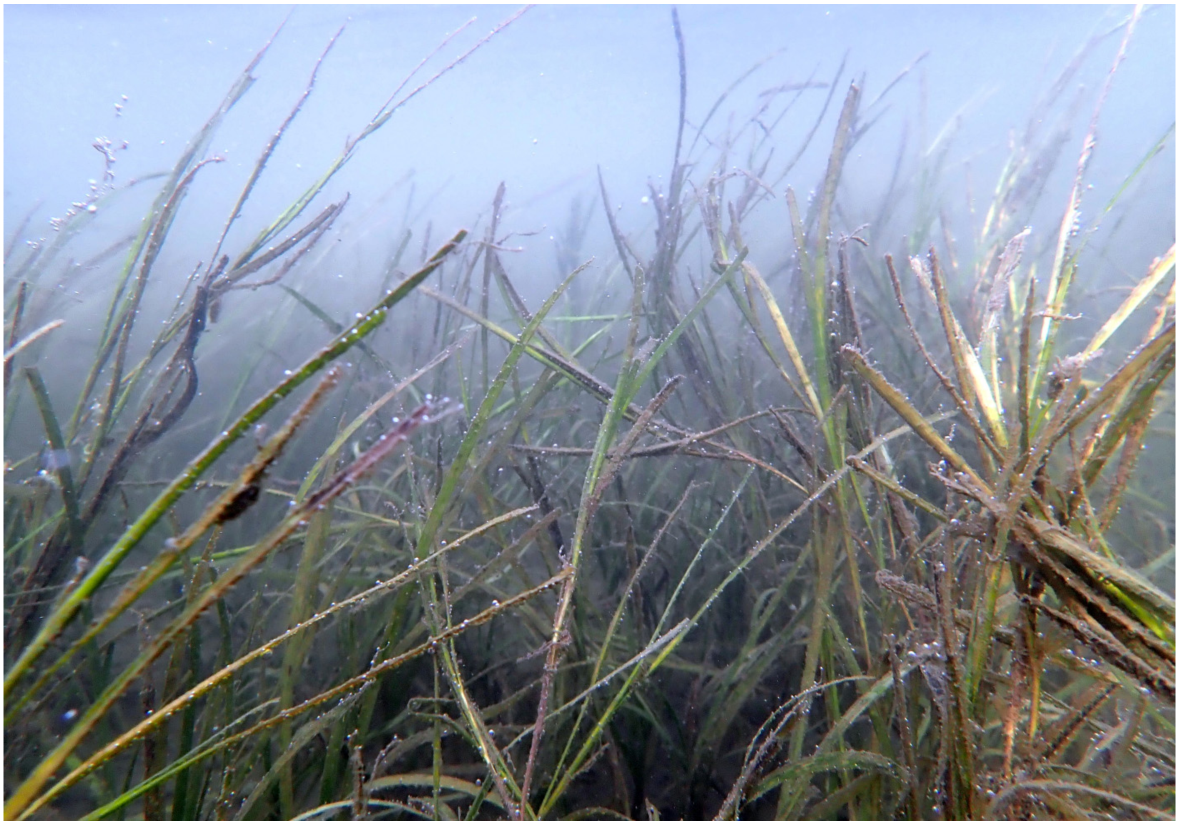
EVALUATION OF TEMPORAL AND SPATIAL CHANGES OF EELGRASS BEDS WITHIN SAN DIEGO BAY USING PERMANENTLY MONITORED TRANSECTS

July 2020



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PREFACE

As an on-going effort to monitor and facilitate management of natural resources within San Diego Bay in conjunction with commitments under the San Diego Bay Integrated Natural Resources Management Plan, the Navy has conducted recurrent biological investigations to track the status of vulnerable marine resources in the Bay. Among these is eelgrass (*Zostera marina* and *Z. pacifica*) that is present as a significant ecological resource within San Diego Bay.

Since 2007, Naval Facilities Engineering Command Southwest (NAVFAC SW) has undertaken biannual monitoring of permanently established transects at 25 locations throughout the Bay. This work was conducted through support of a NAVFAC contractor, Tierra Data Inc. (TDI) until 2017, at which point Merkel & Associates (M&A) took over the monitoring as a new NAVFAC contractor for this work. In order to maintain continuity of the historic monitoring record and ensure the integrity of the monitoring program, nearly all aspects of the analysis and reporting method and report structure have been retained throughout the program period. In some instances, additional analyses has been added along with recommendations for future program adjustments based on both the accumulated results of the present monitoring program and developing information and technological advancements drawn from similar programs being implemented elsewhere. While these recommendations are proffered, no changes have been made to the present program from that which has historically been implemented. Further, due to the inherent benefit of long-term data sets, recommendations made would not alter the nature of data presently collected on the present transects but would alter the means of data collection to make surveys more efficient and consistent with present regional monitoring methodologies applied elsewhere.

1.0 INTRODUCTION

Eelgrass is a marine flowering plant and the most widely distributed and abundant of the seagrasses in the world with a global north temperate range. Eelgrass is considered to be a foundation or habitat forming species as it provides three dimensional structure to an otherwise two dimensional soft bottom seafloor and contributes disproportionately to defining the physical, chemical, and biological character of the local ecology within and around the eelgrass beds and can also have far reaching influences beyond the eelgrass beds and even outside of the systems within which eelgrass occurs.

Eelgrass is a major source of primary production in many bay and estuary marine systems, underpinning detrital-based food webs both locally and in areas where dead leaf matter accumulates. In addition, several organisms directly graze upon eelgrass or consume epiphytes and epifauna supported by eelgrass plant structures, thus contributing to the system at multiple trophic levels (Phillips 1984, Thayer et al. 1984).

Eelgrass beds function as habitat and nursery areas for commercially and recreationally important open ocean marine fish and invertebrates, and provide critical structural environments for resident bay and estuarine species, including abundant fish and invertebrates (Hoffman 1986, Kitting 1994, Simenstad 1994). Besides providing important habitat for fish, eelgrass is considered to be an important resource supporting migratory birds during critical migration periods. Eelgrass is particularly important to waterfowl such as black brant that feed nearly exclusively on the plants and to a number of other species that make a diet of both eelgrass and the epiphytic growth that occurs on the leaves. Beyond direct habitat functions, eelgrass benefits nearshore benthos through detritus export, producing significantly greater secondary production than mudflats, marshes and sandflats (Heck et al. 1995) and supporting much greater species richness than other habitats of shallow marine embayments (Orth et al. 1984, Zieman and Zieman 1989).

As a result of the multifaceted benefits provided, vegetated shallows, including eelgrass habitats, are considered special aquatic sites under the 404(b)(1) guidelines of the Clean Water Act (40 C.F.R. § 230.43). Eelgrass is given special status as submerged aquatic beds under the Clean Water Act of 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.” In addition, pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), eelgrass is designated as a habitat area of particular concern (HAPC) within essential fish habitat (EFH) designated for various federally-managed fish species within the Pacific Coast Groundfish Fishery Management Plan (FMP) (PFMC 2008). An HAPC is a subset of EFH that is rare, particularly susceptible to human-induced degradation, especially ecologically important, and/or located in an environmentally stressed area. HAPC designations are used to provide additional focus for conservation efforts. As a result of concerns over the protection of eelgrass additional policies for eelgrass conservation and mitigation of impacts have been adopted in Calfornia in the form of the Southern California Eelgrass Mitigation Policy (SCEMP)(NMFS et al. 1991) that has been subsequently superseded by the California Eelgrass Mitigation Policy (CEMP) (NMFS 2014).

San Diego Bay has a statewide significance in the context of eelgrass resources. It ranks third behind Humboldt Bay and San Francisco Bay with respect to total eelgrass extent supporting between 10 and 15 percent of California’s eelgrass habitat during any given year and one of five systems in the state that support approximately 80 percent of all of the state’s eelgrass habitat. Due to the significance of eelgrass as a marine environmental resource, the Navy has mapped, monitored, and managed eelgrass within San Diego Bay since the 1980s.

Following on the 1988 initiation of baywide eelgrass surveys using sidescan sonar in Mission Bay to support the Mission Bay Natural Resource Management Plan, the Navy, in conjunction with the San Diego Unified Port District (Port) initiated a baywide eelgrass inventories within San Diego Bay in 1993. This program has resulted in eelgrass inventories being completed approximately every 3-4 years in 1993, 1999, 2004, 2008, 2011, 2014, 2017 (Merkel & Associates 2018). These surveys have revealed a long-term average of 1,658 acres of eelgrass in San Diego Bay with considerable variability from survey to survey. In addition, surveys completed regularly between these comprehensive surveys revealed the fact that many of the beds in San Diego Bay tend to be quite dynamic over short periods. The dynamism of San Diego Bay eelgrass beds is consistent with observations of eelgrass in many other locations (Duarte 1989, Thom 1990, Robbins and Bell 2000, Olesen and Sand-Jensen 1994).

As a result of the knowledge that short-term variability in eelgrass distribution within the bay could be quite high, the Navy implemented a more intensive eelgrass monitoring program in 2007 with the intent of tracking variability in eelgrass beds over shorter periods of time than was possible with the comprehensive baywide inventories. This was to be done using permanently positioned transects distributed through the five ecoregions of the bay that were surveyed twice annually in summer and winter seasons. These permanent transect surveys have been completed continuously from winter 2007 through the present with a single survey gap in 2010 where the summer survey was not conducted. This report summarizes the results of the summer 2019 and winter 2020 surveys.

2.0 METHODS

San Diego Bay has been characterized by ecoregions that are generally defined by bathymetric, hydrodynamic, and biological characteristics (Largier et al. 1996). These ecoregions include the Outer Bay, North Bay, North Central Bay, South Central Bay, and South Bay ecoregions (Figure 1). These ecoregions were utilized in the San Diego Bay Integrated Natural Resource Management Plan (U.S. Navy and San Diego Unified Port District 2013). To examine the regional and baywide changes in eelgrass cover over short-term periods of interseasonal and interannual temporal scales, permanent eelgrass transects were established in San Diego Bay in 2007.

The initial transect establishment was completed in 2007 by selecting transects from transect data collected in 1999/2000 and 2005 by Naval Facilities Engineering Command (NAVFAC) Southwest. Transects were selected based on historical baseline data and ability to resample the areas. Transects varied in length, energy exposure, and depth. In total, five transects were established in each of five previously identified ecoregions of the bay where NAVFAC transects suggested the presence of persistent perennial eelgrass presence. Transect distribution across ecoregions is illustrated over the baywide eelgrass frequency distribution maps derived from the on-going baywide eelgrass inventories conducted over seven survey intervals from 1993 through 2017 (Merkel & Associates 2018) (Figure 1). Biannual sampling was conducted during winter (March and April) and summer (September and October) periods.

Single-beam sonar surveys of permanent transects have been sampled since 2007 and provide insights into variability of eelgrass in the bay seasonally, interannually, and across ecoregions. By monitoring transects through time, it is possible to roughly assess how eelgrass varies in San Diego Bay between the completion of less frequent baywide eelgrass surveys. Data also provides insights into how eelgrass variability may influence mitigation bank resources held by the Navy or how eelgrass variability may influence eelgrass distribution patterns relative to project planning.

During this present investigation period, single-beam sonar surveys were conducted consistent with past practices for the monitoring program. Established transects defined by fixed end points, but which have been consistently monitored along slightly meandering paths were again navigated for data collection during the present survey. Because transects are not defined by straight segments, the digital trackline files for the transects were obtained from TDI and have been followed during all field surveys. For the present reporting period, transect surveys were performed in the summer of 2018 and winter of 2019, using sonar equipment. Surveys were conducted using the M&A survey vessel Ocean King I. Consistent with prior surveys, a single-beam sonar was operated along the centerlines of the established transects. The single-beam sonar was a SyQwest Hydrobox operating at 210 kilohertz (kHz) using a 6 degree transducer and a ping rate of 10 Hz. The position and heading was provided by a Hemisphere real-time kinematic (RTK) enabled global positioning system.

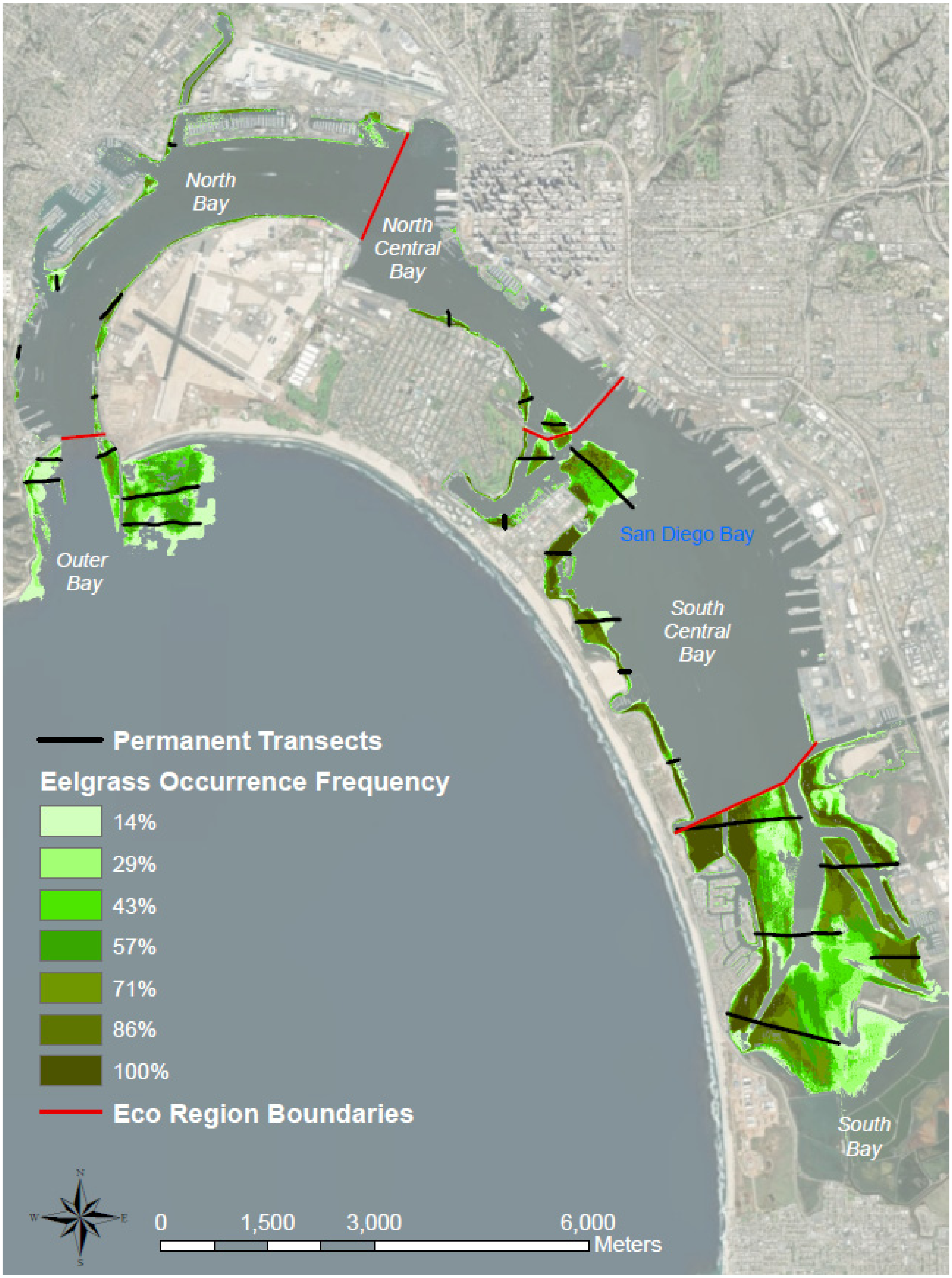

Figure 1. San Diego Bay Permanent Transect Locations Within Persistent Eelgrass Beds

Concurrent with the operation of the single-beam sonar system, the transects were surveyed with interferometric sidescan sonar (ISS) scanning out a distance of 31 meters on each of the port and starboard channels. The ISS system was a SEA SWATHplus H operating at 468 kHz and integrated with an SMC-108 motion control unit and a Valeport MiniSVS sound velocity sensor. Heading and position was provided by the same RTK GPS as used for the single-beam sonar equipment.

Previously the ISS system was used to confirm the capacity for collecting the same data as that obtained and reported on from the single-beam sonar using an ISS system that would also provide a more extensive swath view of the surrounding bottom. During the present investigation, data from the ISS system was not processed for transect coverage. Rather, the ISS system was used only to provide contextual understanding of how eelgrass had changed in the areas of the transects between the prior 2018-2019 surveys and the present 2019-2020 surveys.

The data collected from the single-beam sonar system provides a one dimensional output view of the survey area, while the ISS provides a two dimensional view of the survey area and when processed for bathymetry as well as sidescan, the ISS can provide bathymetric information for the swath as well. Bathymetric data was not processed for the present exploratory investigation as it was not needed to compare data outputs. An example of the sonograms from the single-beam sonar survey and the interferometric sonar collected simultaneously is shown in Figure 2. Given that the two survey tools yield very similar data along the centerline of the survey track, but the ISS provides additional swath based information, a recommendation is made to shift the data collection towards the swath based methodology as a means to augment the monitoring program without additional cost.

Once data were collected, sonograms were processed in Chesapeake SonarWiz 7 survey software to create geo-referenced mosaics. The data were then imported into ESRI ArcGIS®. In ArcGIS, data were clipped to the starting and ending points of the transects and the percent of eelgrass coverage was determined along the transect length and data tables for the long-term monitoring program were updated.

Analyses of data included presentation of seasonal and annual means and standard error values for baywide transect summaries as well as for individual ecoregions. For presentation of data in this report and subsequent reports, each transect is treated independently rather than calculating the baywide means as a mean of the ecoregion means.

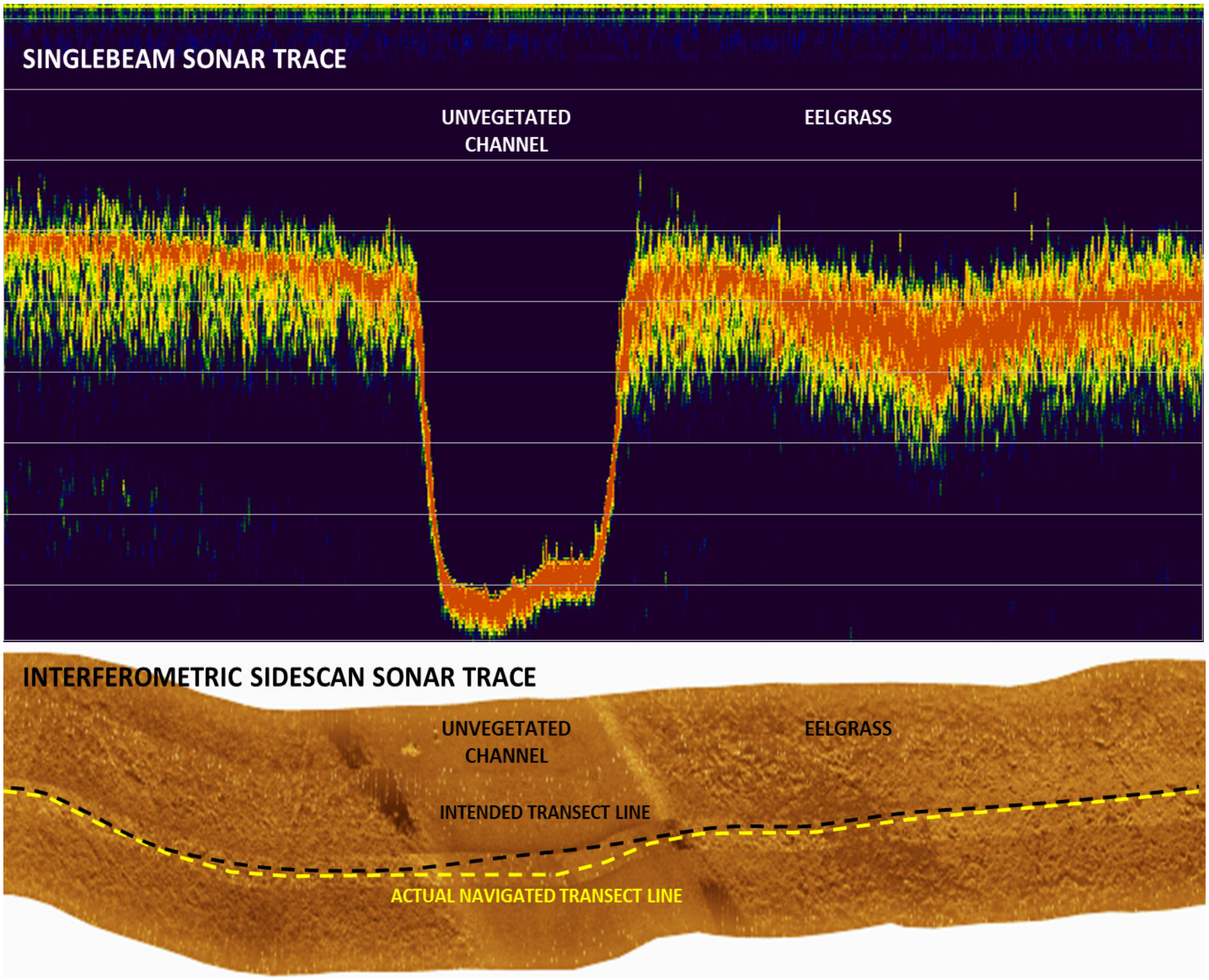

Figure 2. Sonogram of Eelgrass Transect With Defined Characteristics

3.0 SITE OVERVIEWS

Permanent transects, within each of the bay ecoregions, were selected based on existing perennial eelgrass occurrences, existing transect data, and representation of various exposures within individual ecoregions. Start and end locations of the transects are in UTM meters NAD 83 coordinates (Tables 1-5). Figures 3 through 7 present the transects on a base map of the baywide eelgrass survey frequency distribution of eelgrass from seven surveys conducted between 1993 and 2017 (Merkel & Associates 2018).

Table 1. Outer Bay Transect Alignment and Location Information

Outer Bay			
Transect Outer Bay 1 (OB1)			
Transect OB1 is located east of Zuniga Jetty, where a persistent but variable eelgrass bed is located. The transect proceeds from west to east and is approximately 1,074 m in length.			
Start Location:	479072.77 mE 3615685.66 mN	End Location:	480125.88 mE 3615857.96 mN
Transect Outer Bay 2 (OB2)			
Transect OB2 is located offshore of OB1 within the same expansive eelgrass bed and proceeds from east to west. Transect OB2 is approximately 1,098 m in length.			
Start Location:	480154.46 mE 3615332.20 mN	End Location:	479067.00 mE 3615320.81 mN
Transect Outer Bay 3 (OB3)			
Transect OB3 is located west of Zuniga Jetty at the entrance of San Diego Bay and is 281 m in length. Transect OB3 runs from west to east, perpendicular to shore. The eelgrass bed associated with OB3 is constrained by the break wall to the east and the deep channel to the west.			
Start Location:	478704.83 mE 3616277.00 mN	End Location:	478957.21 mE 3616396.08 mN
Transect Outer Bay 4 (OB4)			
Transect OB4 is located on the northwestern boundary to the entrance of San Diego Bay and is 339 m in length. Transect OB4 is sampled from east to west.			
Start Location:	478197.28 mE 3616236.98 mN	End Location:	477860.62 mE 3616245.59 mN
Transect Outer Bay 5 (OB5)			
Transect OB5 is just offshore (south) of OB4. Transect OB5 is approximately 481 m in length and is sampled west to east.			
Start Location:	477685.00 mE 3615917.19 mN	End Location:	478164.89 mE 3615958.31 mN

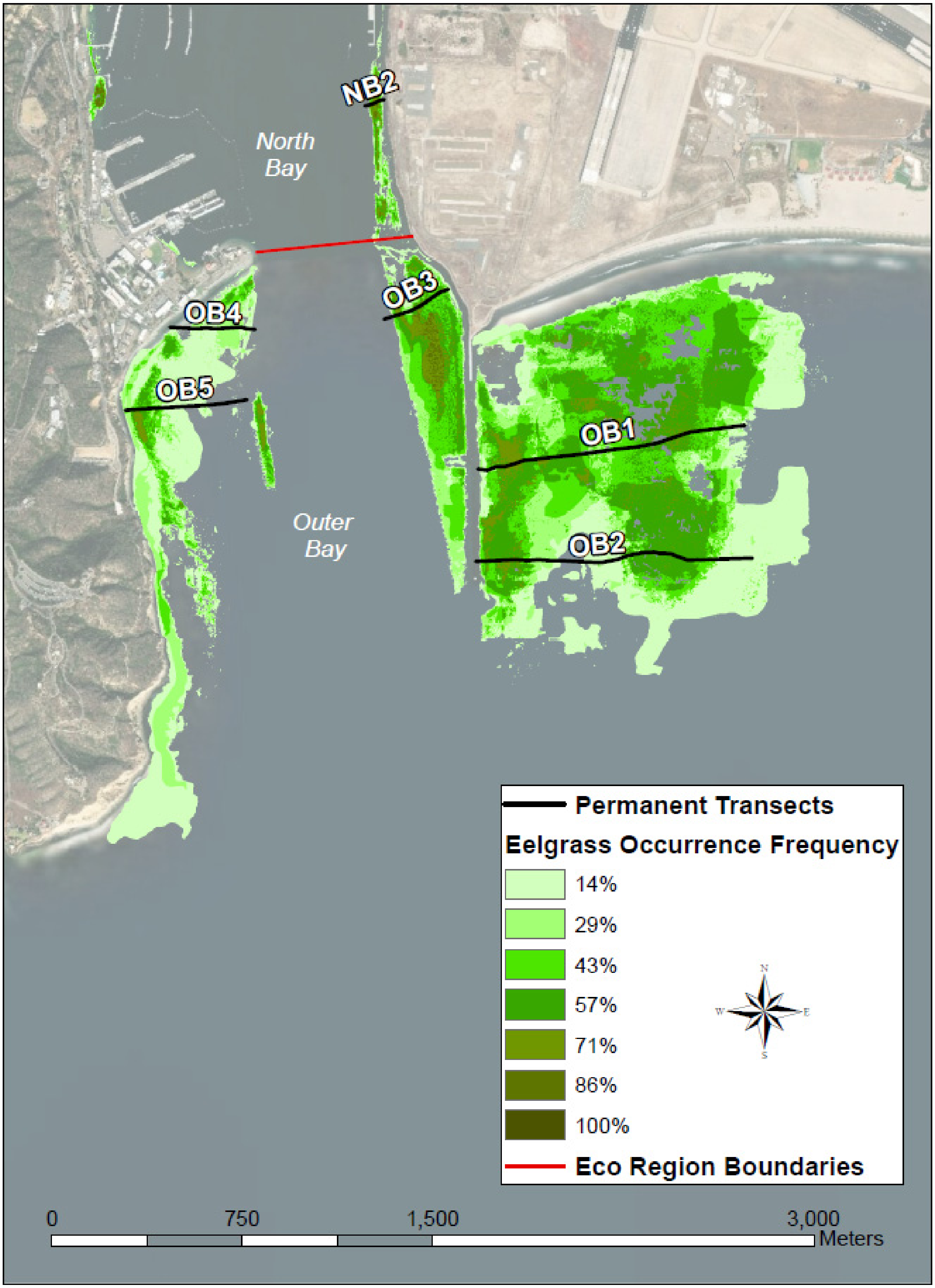

Figure 3. Outer Bay Ecoregion Eelgrass by Persistence Frequency with Permanent Transects

Table 2. North Bay Transect Alignment and Location Information

North Bay			
Transect North Bay 1 (NB1)			
Transect NB1 is located well within the bay, nearest to the jet runway on Naval Air Station North Island and across from the Shelter Island boat launch. Transect NB1 is 455 m in length and is sampled parallel to shore in a north to south direction.			
Start Location:	479043.12 mE 3618589.93 mN	End Location:	478754.04 mE 3618239.07 N
Transect North Bay 2 (NB2)			
Transect NB2 is located just inside the bay, along the eastern shoreline near the entrance of San Diego Bay. Transect NB2 is only 79 m long and is sampled in an east to west direction.			
Start Location:	478704.01 W 3617145.57 mN	End Location:	478630.46 mE 3617121.18 mN
Transect North Bay 3 (NB3)			
Transect NB3 is located on the bay's western shore, parallel to one of the few sandy beaches in this portion of the bay. Transect NB3 is 169 m in length and is sampled parallel to the shore in a south to north direction.			
Start Location:	477592.61 mE 3617687.53 mN	End Location:	477621.56 mE 3617853.31 mN
Transect North Bay 4 (NB4)			
Transect NB4 is located at the entrance of the Shelter Island yacht basin and is approximately 194 m in length. Transect NB4 is sampled in a north to south direction.			
Start Location:	478133.17 mE 3618846.88 mN	End Location:	478146.21 mE 3618653.29 mN
Transect North Bay 5 (NB5)			
Transect NB5 is located well up the western shore of North Bay, near an entrance to the Naval Training Center boat channel across from the fuel dock. Transect NB5 is 105 m in length and is situated in a west to east configuration.			
Start Location:	479710.00 mE 3620717.00 mN	End Location:	479798.03 mE 3620707.00 mN

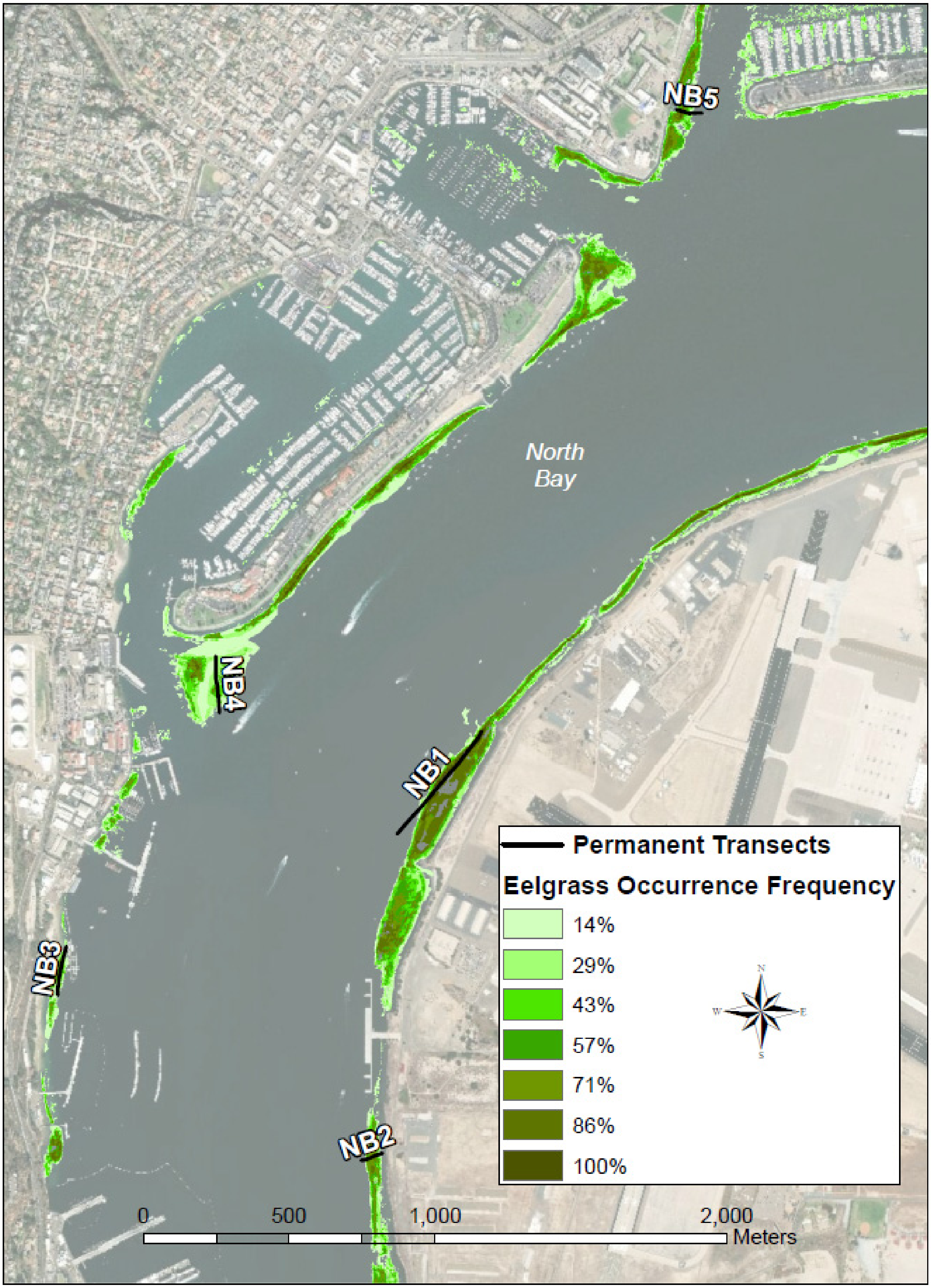

Figure 4. North Bay Ecoregion Eelgrass by Persistence Frequency with Permanent Transects

Table 3. North Central Bay Transect Alignment and Location Information

North Central Bay			
Transect North Central 1 (NC1)			
Transect NC1 is located on the northern of the City of Coronado, just east of the aircraft carrier turning basin across from the convention center. Transect NC1 is 212 m in length and is sampled in a north to south direction.			
Start Location:	483617.87 mE 3618349.80 mN	End Location:	483639.38 mE 3618141.46 mN
Transect North Central 2 (NC2)			
Transect NC2 is located on the southwestern shore of the City of Coronado, just north of the Coronado Bridge and inshore of the yacht moorings. Transect NC2 is 204 m in length and is sampled in a west to east direction.			
Start Location:	484615.58 mE 3617049.38 mN	End Location:	484807.56 mE 3617118.50 mN
Transect North Central 3 (NC3)			
Transect NC3 is located southeast of NC2, outside the yacht moorings and is 314 m in length. Transect NC3 is sampled in a west to east direction.			
Start Location:	484948.58 mE 3616758.15 mN	End Location:	485260.09 mE 3616743.92 mN
Transect North Central 4 (NC4)			
Transect NC4 is located south of NC3, on the south side of the Coronado Bridge, just offshore of the golf course on North Island. Transect NC4 is 484 m in length and is sampled in an east to west direction.			
Start Location:	485096.94 mE 3616261.04 mN	End Location:	484613.27 mE 3616253.50 mN
Transect North Central 5 (NC5)			
Transect NC5 is located in Glorietta Bay, perpendicular to the beach, just south of the boat launch. Transect NC5 is 152 m in length and is sampled in a south to north direction.			
Start Location:	484414.92 mE 3615277.78 mN	End Location:	484416.28 mE 3615429.67 mN

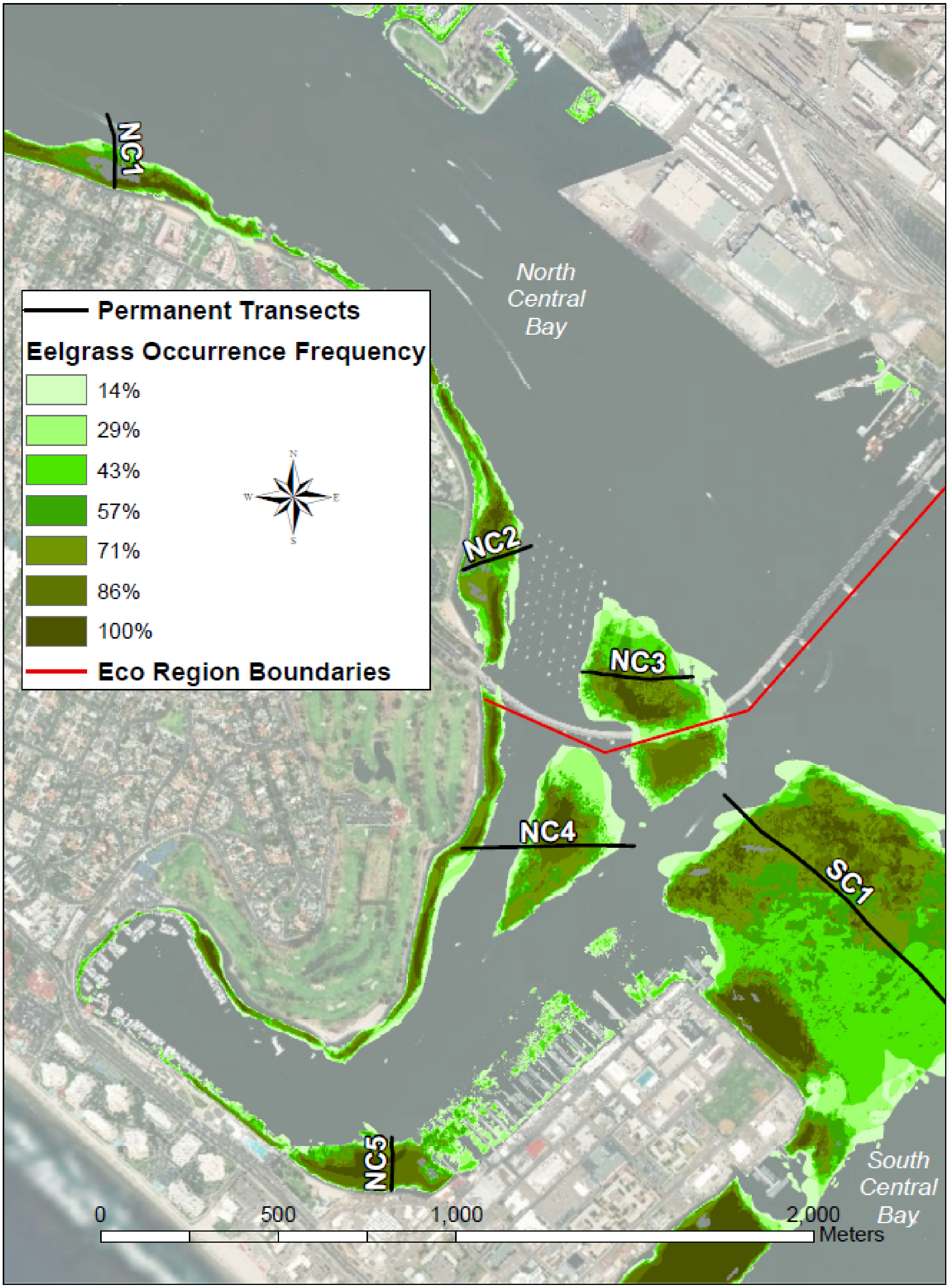

Figure 5. North Central Bay Eelgrass by Persistence Frequency with Permanent Transects

Table 4. South Central Bay Transect Alignment and Location Information

South Central Bay			
Transect South Central 1 (SC1)			
Transect SC1 is located on the south side of the Coronado Bridge, offshore of the Naval Amphibious Base. Transect SC1 is 1,225 m in length and is sampled in a north to south direction.			
Start Location:	485348.57 mE 3616406.52 mN	End Location:	486221.97 mE 3615551.29 mN
Transect South Central 2 (SC2)			
Transect SC2 is located southwest of SC1 and inshore of Homeport Island. Transect SC2 is 353 m in length and is sampled in a west to east direction. This eelgrass bed has been well studied by the USFWS and National Oceanic and Atmospheric Administration, and serves as a long-term monitoring location.			
Start Location:	484988.77 mE 3614913.87 mN	End Location:	485340.45 mE 3614908.16 mN
Transect South Central 3 (SC3)			
Transect SC3 is located south of SC2, adjacent to the California least tern colonies at North/South Delta. Transect SC3 is 621 m in length and is sampled in an east to west direction.			
Start Location:	486033.26 mE 3613973.45 mN	End Location:	485414.10 mE 3613935.40 mN
Transect South Central 4 (SC4)			
Transect SC4 is located just south of SC3 at the head of the South Delta California least tern area and north of Fiddler's Cove Marina. Transect SC4 is 132 m in length and is sampled in an east to west direction.			
Start Location:	486168.21 mE 3613230.09 mN	End Location:	486036.00 mE 3613227.23 mN
Transect South Central 5 (SC5)			
Transect SC5 is located on the eastern shore, just south of Fiddler's Cove Marina. Transect SC5 is 167m in length and is sampled in an east to west direction.			
Start Location:	486858.50 mE 3611983.59 mN	End Location:	486697.90 mE 3611936.88 mN

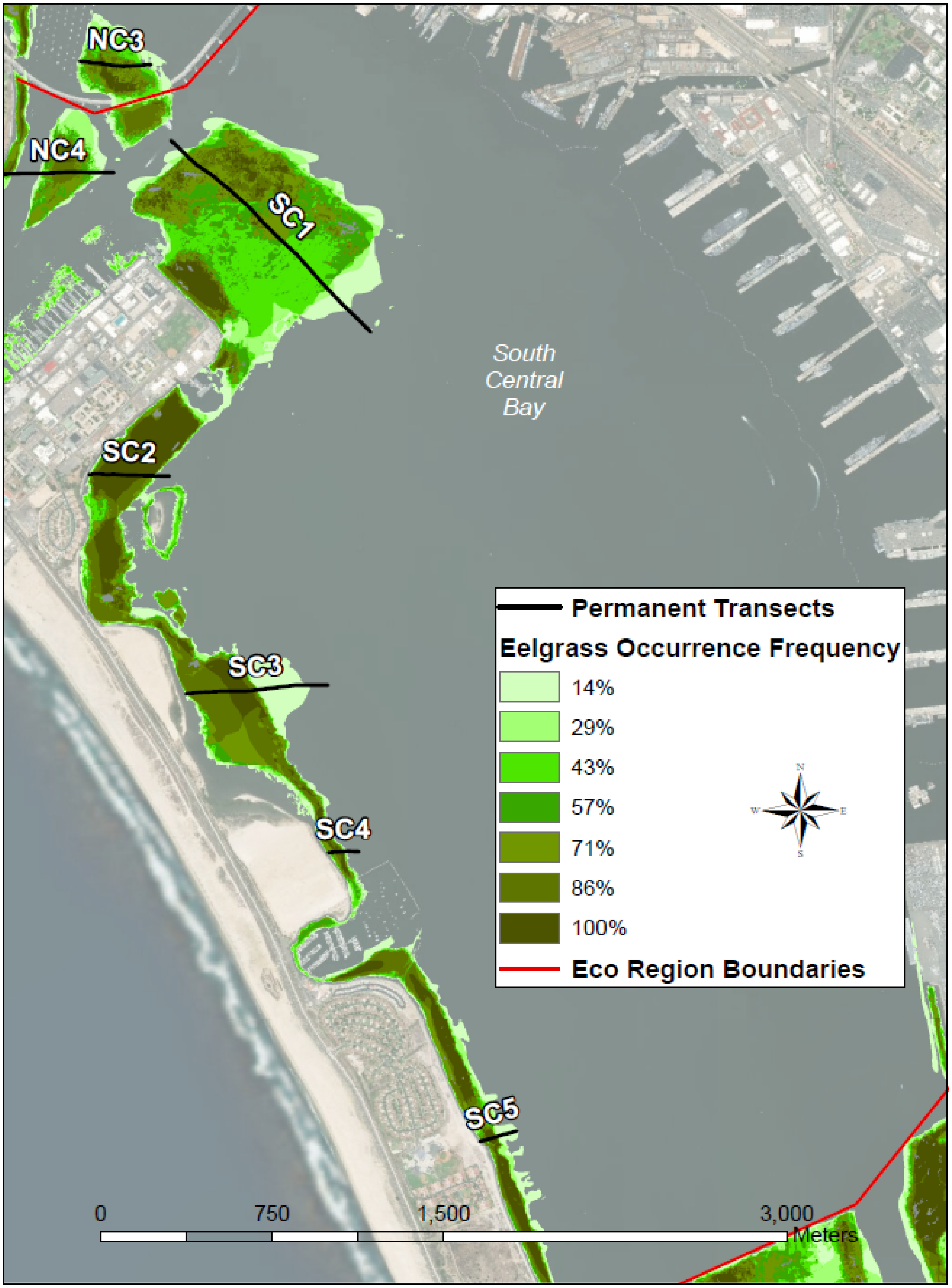

Figure 6. South Central Bay Eelgrass by Persistence Frequency with Permanent Transects

Table 5. South Bay Transect Alignment and Location Information

South Bay			
Transect South Bay 1 (SB1)			
Transect SB1 is located on the western shore south of SC5, near the Silver Strand State Beach bayside facility. Transect SC1 is 1,749 m in length and is sampled in a west to east direction.			
Start Location:	486833.63 mE 3610996.46 mN	End Location:	488574.09 mE 3611161.79 mN
Transect South Bay 2 (SB2)			
Transect SB2 is located on the eastern shore across the bay and south from SB1. Transect SB2 originates in shallow waters near the commercial boat yard, is 1,100 m in length, and is sampled in an east to west direction. Transect SB2 crosses two channels and terminates at the main channel in the center of South Bay.			
Start Location:	489931.56 mE 3610508.26 mN	End Location:	488835.50 mE 3610477.71 mN
Transect South Bay 3 (SB3)			
Transect SB3 is located on the western shore, near the south entrance to Coronado Cays. Transect SB3 is perpendicular to shore, is 1,203 m in length, and is sampled from west to east. This transect crosses two channels; the second is the main channel in the center of South Bay.			
Start Location:	487929.63 mE 3609515.15 mN	End Location:	489127.91 mE 3609520.96 mN
Transect South Bay 4 (SB4)			
Transect SB4 is located just south of the entrance to the Chula Vista Marina, aligned perpendicular to shore. Transect SB4 is 677 m in length and is sampled in a west to east direction.			
Start Location:	490227.92 mE 3609183.78 mN	End Location:	489552.07 mE 3609170.16 mN
Transect South Bay 5 (SB5)			
Transect SB5 is located in the southern-most portion of the bay near Emory Cove. Transect SB5 is 1,634 m in length, is almost perpendicular to shore, and is sampled in an east to west direction.			
Start Location:	489107.11 mE 3607953.72 mN	End Location:	487531.07 mE 3608384.96 mN

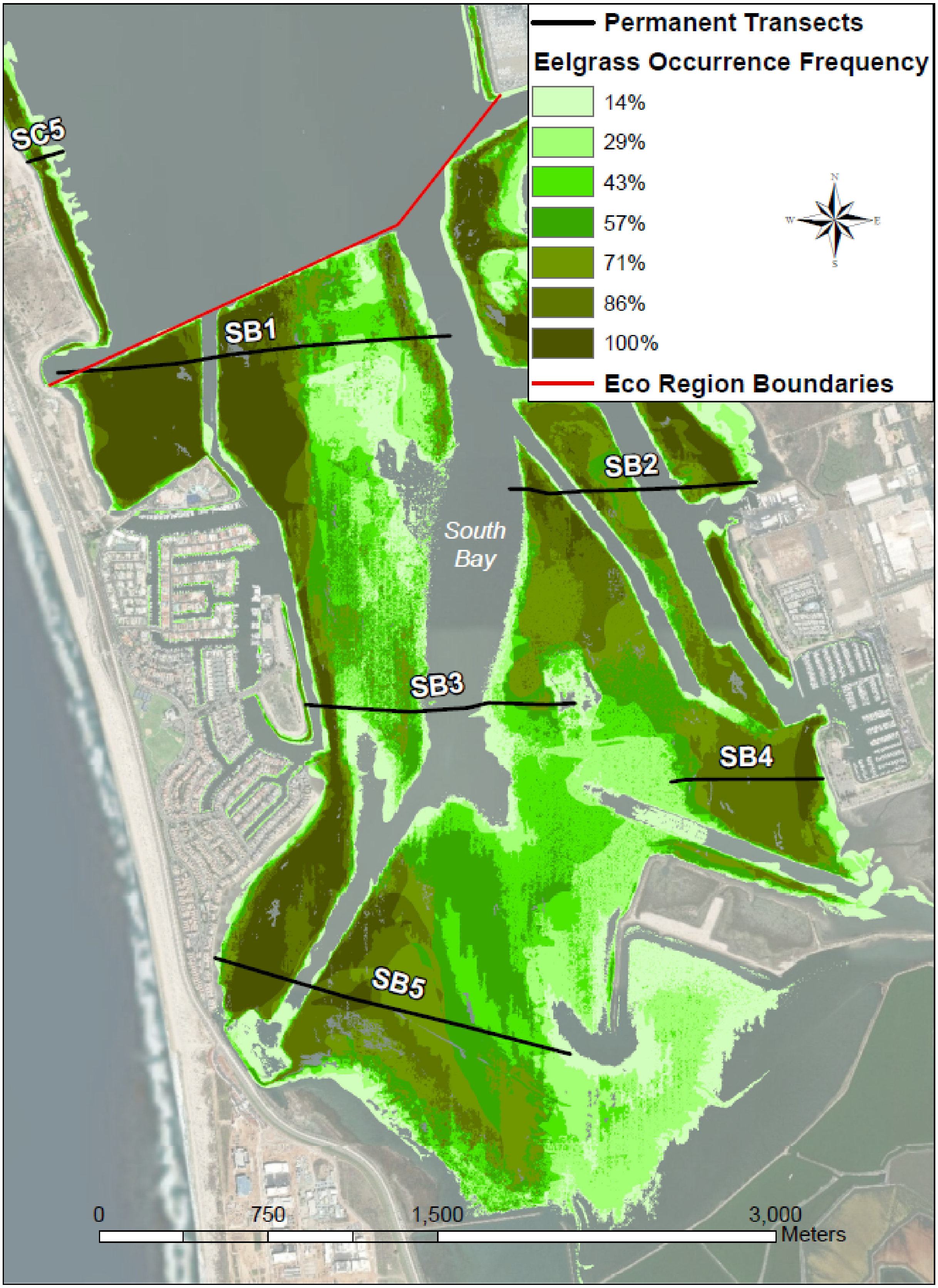

Figure 7. South Bay Ecoregion Eelgrass by Persistence Frequency with Permanent Transects

4.0 RESULTS AND DISCUSSION

4.1 MEAN EELGRASS PERCENT COVER

The percentage of eelgrass cover on transects was examined by season, year, and ecoregion to analyze temporal and spatial variation in eelgrass coverage. Data collected during the summer 2019 and winter 2020 sampling periods were integrated with results previously reported for the years 2007 through winter 2019 (Merkel & Associates 2019), and data were evaluated as a continuous monitoring record. Figure 8 presents the winter (2007-2020) and summer (2008-2019) means of all transects along with the standard error for the sampling intervals. Annual winter increases in percent cover continued through 2014 for four straight year reaching 49.08% cover. This was followed by a small drop in coverage for winter 2015 to 48.24%. The drop in coverage for winter 2015 was followed by an increase in the winter of 2016 to 49.15% prior to again exhibiting a decline in 2017 to 46.98%, followed by a partial recovery to 48.07% in 2018. In 2019, a new high for the life of the monitoring event was reached, when the percent cover increased to 52.91%. That high was exceeded in 2020 with the mean baywide transect coverage of 54.43%. This increasing coverage trend tracks with a recent cooling trend in the ocean water over the past two years.

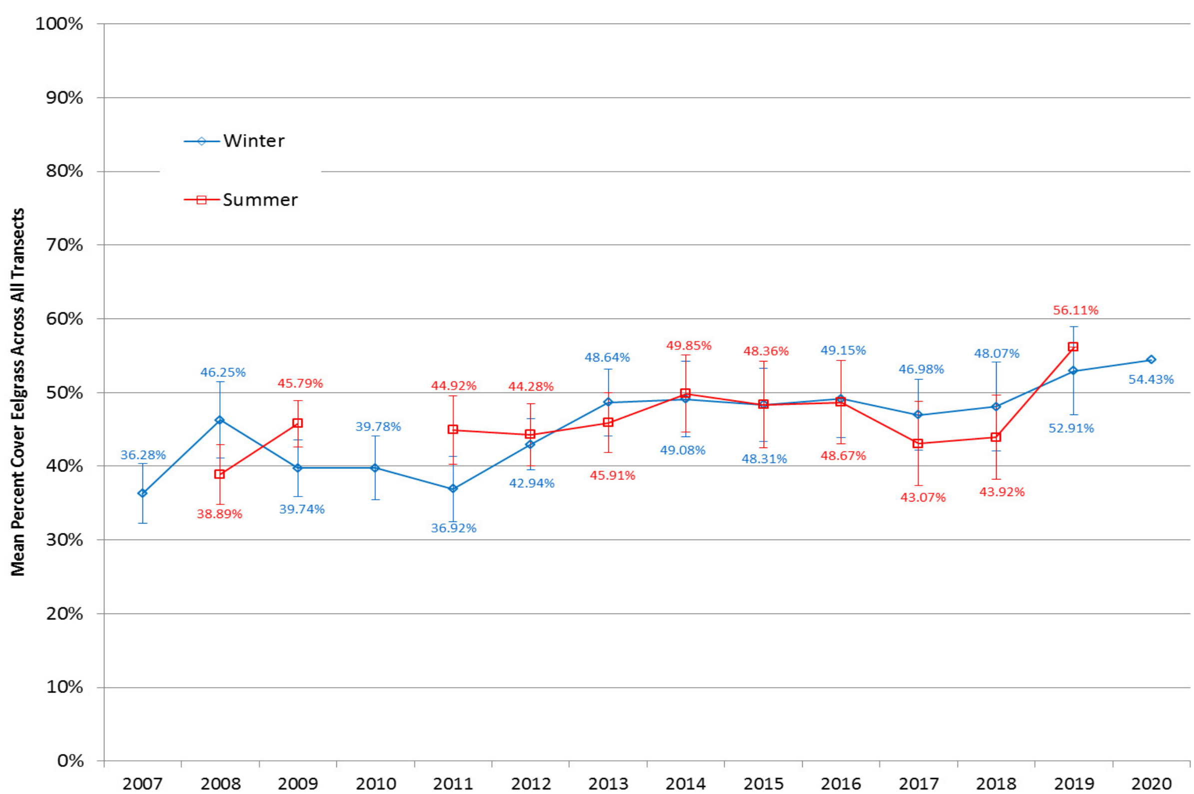

Figure 8. Mean Percent Cover of Eelgrass of all Transects Averaged by Five Ecoregions in San Diego Bay. Winter Data were collected in March/April each year, summer data were collected in September/October each year. Error Bars Represent the Standard Error from the Annual/Seasonal Means.

The summer conditions generally tracked closely with winter conditions in later years of the monitoring period, with earlier years showing a greater deviation between winter and summer eelgrass coverage along transect lines. Annual summer increases in percent cover continued through 2014 for the third straight year reaching 49.85% cover, its highest recorded level since the surveys began. However, eelgrass declined slightly between 2014 and 2015 to 48.36%, remaining relatively consistent from 2015 to 2016 when it had a mean cover of 48.67%. In 2017, summer eelgrass declined to a coverage of 43.07%, the lowest coverage level recorded since 2008. In summer 2018, the mean baywide eelgrass coverage along the transects began a slight rise to 43.92% and then increased considerably in 2019 to 56.11%, a new high for the life of the monitoring event.

4.2 Estimating Baywide Eelgrass Area from Transect Coverage

In 1993 eelgrass baywide was quantified as 1091.4 acres; however, surveys were not conducted east of Zuniga Jetty and thus the area of the bay was not equivalent to the subsequent baywide surveys. Therefore this survey has been omitted from the long term record presented in Figure 9. From 1999 to 2017 six additional baywide eelgrass surveys were completed with the total acreage of eelgrass varying between a low of 1,319.1 acres in 2008 to a high of 2,083.7 in 2004 (Merkel & Associates 2018). The distribution of eelgrass across ecoregions is highly skewed towards the South Bay ecoregion which chronically supports more eelgrass than all other ecoregions combined. The baywide surveys reveal relatively consistent extent of eelgrass within the North, North Central, and South Central ecoregions with the most variable eelgrass areas being the Outer Bay and the South Bay ecoregions (Figure 9).

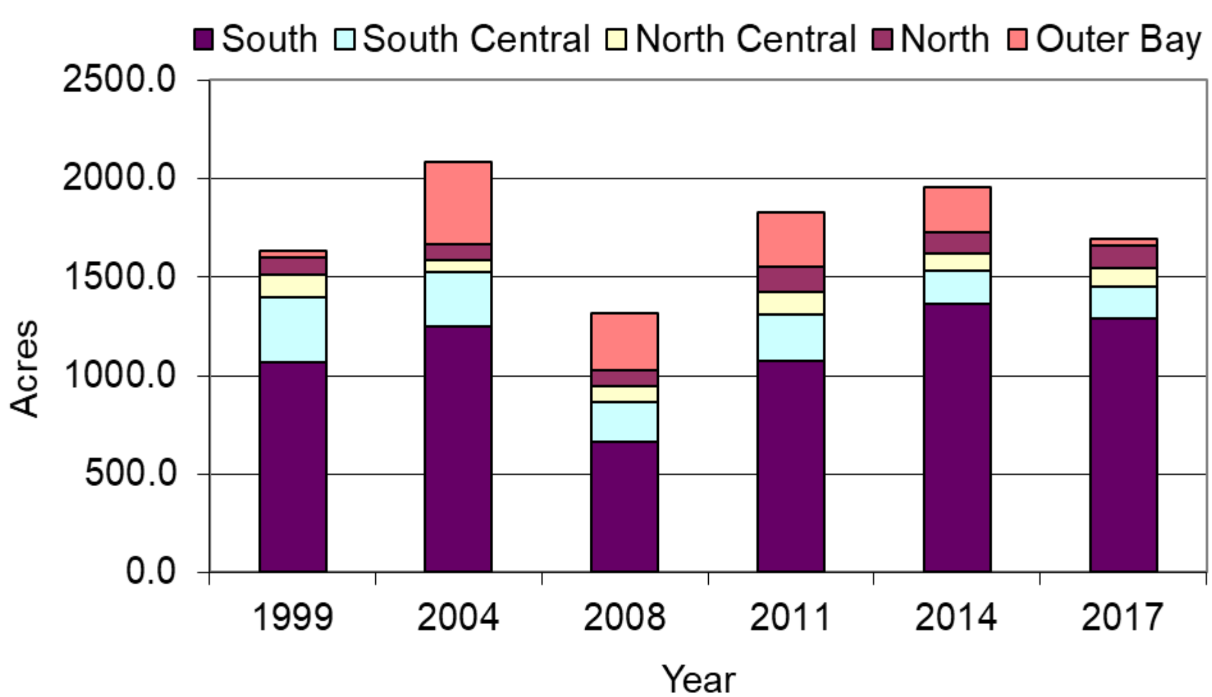

Figure 9. San Diego Bay Eelgrass Distribution from Regional Bay-wide Surveys

Trends in average percent cover of eelgrass resources documented during annual surveys were examined relative to eelgrass coverage derived from baywide comprehensive surveys. This was done by scaling the summer mean percentage of eelgrass cover on transects for each of the baywide survey seasons against the cover in 2014, a baywide survey year. Summer was selected since the baywide surveys are performed in the summer to fall when peak eelgrass cover is generally present. The ratio of eelgrass cover on transects during the baywide survey year was then multiplied by the acreage of eelgrass determined to be present in San Diego Bay through the 2014 baywide survey in order to estimate predicted variance between transect based scaling and comprehensive eelgrass surveys. Table 6 presents the differences between transect scaled estimates of eelgrass extent and the surveyed extent of eelgrass. Note that a zero difference occurs for 2014 since the estimator for the analysis is based on the 2014 surveys and thus the there is no difference in transect cover for 2014.

Table 6. San Diego Bay Average Percent Cover for All Years and Seasons Compared to Acres from Bay-wide Surveys

Average Percent Cover for All Transects														
Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Winter (% Cover)	36.28%	46.25%	39.74%	39.78%	36.92%	42.94%	48.64%	49.08%	48.31%	49.15%	46.98%	48.07%	52.91%	54.43%
Summer (% Cover)	ND	38.89%	45.79%	ND	44.92%	44.28%	45.91%	49.85%	48.36%	48.67%	43.07%	43.92%	56.11%	ND
Eelgrass Area from Baywide Suveys (Acres)		1319.1			1830.4			1955.7			1692.7			
Predicted Eelgrass from Transects (Acres)		1525.6			1762.4			1955.7			1689.9			
Calculated Error (% from 2014 based ratio)		15.7%			-3.7%			0.0%			-0.2%			

As was discussed in the prior monitoring report (Merkel & Associates 2019), the estimates in eelgrass within San Diego Bay derived from the transects appear to parallel the baywide survey inventories fairly well for two years, 2011 (-3.7% difference between transect estimates and measured coverage) and 2017 (-0.2% difference between transect estimates and measured coverage). However, for 2008, there is a gross disparity between the measured extent of eelgrass and the transect estimated extent of eelgrass in the bay (15.7% difference between the transect estimator and baywide survey results). This is not surprising considering how the transects are distributed and used in the present analysis. Because of the disproportionate distribution of eelgrass in the bay and the disproportionate distribution of transects across eelgrass, overall baywide conclusions based on scaling beyond the transects should be cautiously interpreted.

In other regional monitoring programs, this issue is addressed by blocking of transect sampling to specific eelgrass bed segments within the system such that the conclusions are interpreted for more limited and discrete bed segments that are well represented by the transects sampled (Merkel & Associates 2008, Bernstein et al. 2011). This provides a more robust overall method of scaling the results of the transect sampling to broader conclusions about how eelgrass is likely to be fairing baywide because eelgrass beds of a similar nature are scaled only to transects anticipated to exhibit the same characteristics and the broader bed segments. It is believed that the present transect surveys could be used to support a regional monitoring program structure making use of bed segment scaling to benchmark years in order to provide annualized estimates of eelgrass within San Diego Bay, including potential historic estimates. This is further discussed in the recommendations section of this report.

4.3 Seasonal Variability in Eelgrass Coverage by Ecoregion

During the summer 2019 and winter 2020 surveys, eelgrass coverage within ecoregions has generally been similar with greater mean coverage in winter than summer for all ecoregions except for the outer bay transects which have been greatly depressed in overall cover for several years. The trend of higher average winter transect coverage than summer coverage is notable and has been repeated over the past two years. Overall, eelgrass mean percent cover differences between summer and winter surveys of individual ecoregions were not significantly different (Figure 10). The South Bay ecoregion transects supported the highest mean cover for both summer and winter surveys and the lowest mean percent cover was observed for the Outer Bay transects, following suite with the prior year (Figure 10). The relatively minor interseasonal difference in eelgrass coverage suggests relative persistence in eelgrass beds during the 2019-2020 year within the inner bay ecoregions of the South Central Bay and South Bay.

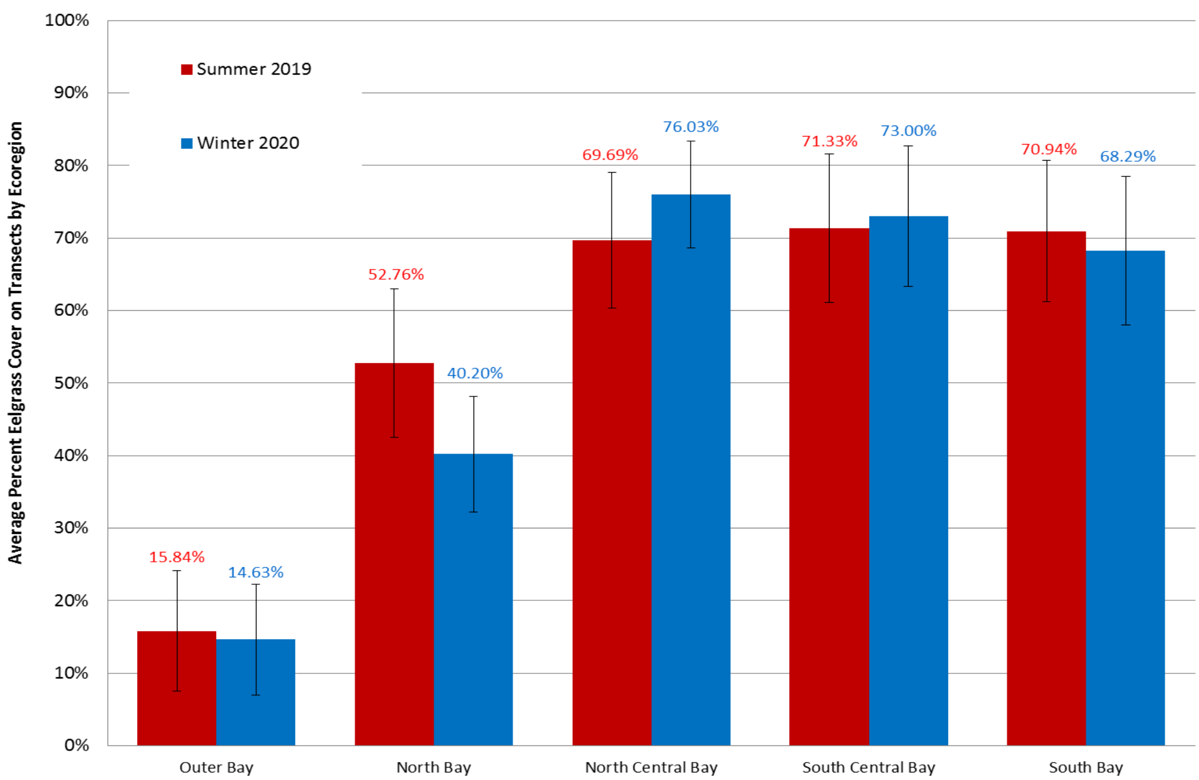

Figure 10. Average Percent Cover of Eelgrass in San Diego Bay Ecoregions. Data represent the means and standard error of five transects within each ecoregion by season. Winter sampling (2007-2020) and Summer sampling (2008-2009, 2011-2019).

4.4 Ecoregion Temporal and Spatial Trends

4.4.1 Temporal Trends

The average percent cover of all individual transects surveyed in the winter of 2020 was 54.43% (Table 7). There was a substantial increase in transect cover between the 2019 surveys and the 2020 surveys. Fifteen of the 25 surveyed transects showed higher values for winter surveys conducted in 2020 than in 2019, while one was unchanged, and nine transects showed a reduction in eelgrass coverage (Table 7). The average transect cover baywide was above the long-term mean coverage for all transects over the 14-year monitoring period.

The average percent cover of all individual transects surveyed in the summer of 2019 was 56.11% (Table 8). There was a substantial increase in transect cover between the 2018 surveys and the 2019 survey. Nineteen transects showed eelgrass coverage gains, two showed no change, and the remaining four showed a reduction in eelgrass coverage between 2018 and 2019. The average transect cover baywide was above the long-term mean coverage for all transects over the 14-year monitoring period.

As with the interpretation of transects to evaluate baywide eelgrass dynamics, evaluation of the changes in eelgrass coverage across transects should be viewed with caution due to the equivalent treatment of non-equivalent transects in the monitoring program. Because of highly variable lengths and capacity for eelgrass variability along the transects due to bathymetric gradients and substrate constraints on some of the transects, the transect variability is limited along some transects and less constrained along others. As a result, the temporal variability of eelgrass is best evaluated on a transect by transect basis rather than by ecoregion or baywide. When examined on a transect by transect basis, it is easy to see some substantial changes in eelgrass have occurred in different parts of the bay. Between winters of 2018 and 2019 eelgrass coverage along SC5 rose by 40.05% while coverage on NB3 fell by 20.34%. This range of fluctuation is hard to interpret without careful consideration of the individual transect characteristics. Further each transect exhibits an independence that argues against consideration of transects as replicates for broader ecoregion characterization. For instance in the North Central ecoregion, transect NC3 rose by 34.50% while all other transects in this ecoregion fell between 2.53% and 8.60%.

The Outer Bay has suffered substantial declines on transects OB4 and OB5 which represent beds to the west of the San Diego Bay entrance channel south of Ballast Point. The eelgrass in this area declined precipitously commencing about 2011 first near Ballast Point and expanding seaward in 2012. These beds have not recovered since the initial declines. Notably these beds were predominated but not exclusively comprised of Pacific eelgrass and hosted a lesser extent of common eelgrass. The noted declines in these outer beds has persisted through 2020.

As with using transects to estimate the overall eelgrass within the bay, the present monitoring program could benefit from assignment of eelgrass bed segments to transects that would best represent the surrounding beds. Under such an approach, the ecoregion beds would be grouped with representative transects such that short steep gradient transects are not used to represent eelgrass across long-flat gradient bottom elsewhere in the ecoregion. This would reduce the variance between transect cover and that of represented beds. It would also better illuminate the likely area across which the variability in beds is occurring based on the transect measurements.

Table 7. Winter San Diego Bay Permanent Eelgrass Transects (2007-2020) Percent Cover and Standard Deviations by Transect. High Cover (green) and Low Cover (red) are shown for individual years.

Region	Site	Percent Cover by Year														2007-2020	
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average	StDev
Outer Bay	OB1	16.12%	76.23%	55.56%	65.20%	22.30%	49.00%	62.34%	43.53%	40.86%	38.30%	38.97%	21.81%	17.94%	20.27%	40.60%	19.36%
	OB2	49.35%	74.43%	17.05%	22.93%	20.45%	27.38%	52.15%	33.75%	40.32%	49.00%	46.03%	7.38%	7.69%	9.69%	32.69%	20.03%
	OB3	31.41%	51.90%	39.69%	60.13%	56.10%	62.98%	60.17%	71.58%	58.26%	61.65%	30.84%	22.54%	26.84%	41.71%	48.27%	15.74%
	OB4	16.42%	34.05%	30.51%	17.82%	9.73%	**8.53%**	**10.11%**	10.08%	8.94%	9.03%	5.66%	**0.00%**	**0.00%**	1.17%	11.58%	10.26%
	OB5	20.38%	35.95%	34.18%	26.95%	18.18%	13.45%	20.80%	13.85%	**2.00%**	**2.47%**	**2.93%**	**0.00%**	**0.00%**	**0.32%**	13.68%	12.83%
North Bay	NB1	**86.99%**	80.81%	72.85%	**88.00%**	72.36%	68.54%	72.73%	70.75%	72.64%	73.79%	73.43%	56.49%	64.05%	63.72%	72.65%	8.53%
	NB2	33.76%	24.64%	68.06%	33.24%	15.55%	45.35%	45.50%	52.51%	50.34%	62.29%	66.67%	80.23%	73.61%	40.31%	49.43%	19.09%
	NB3	24.57%	43.88%	32.12%	52.67%	59.33%	52.21%	56.95%	72.25%	50.83%	48.67%	64.89%	72.56%	52.22%	44.22%	51.96%	13.49%
	NB4	13.64%	8.68%	13.71%	12.99%	4.56%	11.89%	16.09%	**4.88%**	12.20%	12.50%	17.65%	14.26%	14.20%	13.79%	12.22%	3.77%
	NB5	24.33%	41.56%	47.24%	42.94%	35.88%	47.11%	42.86%	No Data	No Data	No Data	No Data	39.66%	49.20%	38.98%	40.98%	7.16%
North Central Bay	NC1	**7.95%**	11.91%	37.57%	12.53%	19.31%	35.75%	13.63%	12.36%	11.45%	25.66%	24.70%	22.39%	13.79%	53.02%	21.57%	12.86%
	NC2	31.84%	71.80%	25.41%	30.27%	43.62%	52.65%	41.28%	56.12%	55.50%	56.56%	63.85%	77.01%	74.48%	82.09%	54.46%	18.20%
	NC3	38.53%	73.07%	34.02%	68.36%	65.72%	58.09%	56.97%	43.51%	58.80%	43.81%	47.67%	48.49%	82.99%	91.45%	57.96%	16.87%
	NC4	64.00%	52.27%	37.17%	43.85%	53.08%	54.72%	54.44%	51.46%	44.54%	41.28%	48.66%	58.54%	55.95%	65.03%	51.79%	8.11%
	NC5	58.19%	78.91%	76.83%	53.67%	47.85%	**72.26%**	**88.61%**	75.48%	82.95%	94.62%	88.60%	81.96%	78.34%	88.58%	76.20%	13.99%
South Central Bay	SC1	13.36%	67.49%	31.25%	51.61%	43.73%	38.32%	13.94%	7.56%	28.55%	10.58%	17.72%	27.47%	45.57%	59.64%	32.63%	19.08%
	SC2	62.43%	**85.86%**	**77.05%**	60.52%	65.28%	54.85%	82.70%	76.60%	73.36%	79.78%	75.33%	83.43%	**100.00%**	**100.00%**	76.94%	13.43%
	SC3	39.47%	No Data	40.62%	43.72%	40.23%	34.18%	44.40%	46.39%	46.26%	49.09%	48.81%	52.70%	53.39%	53.68%	45.61%	5.96%
	SC4	31.52%	58.82%	54.30%	No Data	33.80%	33.50%	48.00%	56.30%	58.96%	43.68%	56.36%	61.98%	66.45%	92.86%	53.58%	16.49%
	SC5	13.18%	14.96%	26.09%	11.69%	15.00%	30.90%	29.32%	39.04%	41.43%	38.95%	35.29%	9.29%	49.34%	58.83%	29.52%	15.29%
South Bay	SB1	46.89%	23.28%	29.55%	33.59%	17.08%	41.16%	52.92%	41.98%	47.56%	45.90%	46.44%	60.64%	69.80%	83.06%	45.70%	17.59%
	SB2	27.65%	18.72%	20.80%	14.01%	30.85%	49.66%	50.24%	60.04%	60.00%	60.00%	61.20%	66.50%	70.51%	60.93%	46.51%	19.73%
	SB3	33.42%	**3.17%**	**3.12%**	**4.92%**	**0.35%**	21.75%	37.13%	55.48%	32.23%	43.58%	34.20%	65.26%	72.62%	38.55%	31.84%	23.24%
	SB4	63.23%	26.54%	41.32%	54.45%	**76.91%**	46.37%	84.07%	**94.50%**	**100.00%**	**100.00%**	**90.95%**	**100.00%**	**100.00%**	98.02%	76.88%	25.67%
	SB5	58.37%	51.04%	47.34%	48.58%	55.84%	62.97%	78.65%	87.94%	81.55%	88.43%	40.65%	71.13%	83.75%	60.89%	65.51%	16.26%
Baywide		**36.28%**	**46.25%**	**39.74%**	**39.78%**	**36.92%**	**42.94%**	**48.64%**	**49.08%**	**48.31%**	**49.15%**	**46.98%**	**48.07%**	**52.91%**	**54.43%**	**45.66%**	**24.66%**

Table 8. Summer San Diego Bay Permanent Eelgrass Transects (2008-2019) Percent Cover Averages and Standard Deviations by Transect. High cover (green) and Low Cover (red) are shown for individual years.

Region	Site	Percent Cover by Year												2008-2019	
		2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*Average*	*St Dev*
Outer Bay	OB1	47.33%	72.46%	No Data	43.11%	45.49%	50.58%	31.11%	25.90%	15.73%	29.29%	26.18%	26.32%	37.59%	16.38%
	OB2	12.33%	44.38%	No Data	26.78%	38.71%	45.54%	35.34%	17.67%	14.22%	5.72%	7.22%	8.75%	23.33%	15.32%
	OB3	43.86%	59.85%	No Data	57.35%	71.12%	52.89%	66.86%	59.25%	29.57%	22.54%	24.27%	43.23%	48.25%	17.74%
	OB4	22.53%	27.22%	No Data	**3.00%**	7.27%	13.54%	**3.59%**	8.07%	11.26%	**0.00%**	**0.00%**	**0.00%**	9.65%	9.24%
	OB5	27.50%	53.85%	No Data	44.63%	17.84%	23.28%	16.40%	**0.00%**	**3.51%**	**0.00%**	**0.00%**	0.88%	17.08%	19.13%
North Bay	NB1	56.99%	No Data	No Data	85.21%	73.82%	74.86%	68.98%	68.68%	63.26%	64.99%	65.19%	64.93%	68.69%	8.12%
	NB2	48.09%	53.27%	No Data	34.89%	37.33%	53.75%	45.88%	60.26%	50.00%	65.89%	70.54%	73.26%	53.92%	11.42%
	NB3	25.96%	55.34%	No Data	65.76%	63.44%	56.07%	62.50%	85.73%	58.14%	68.59%	62.35%	46.57%	59.13%	14.87%
	NB4	6.80%	**11.66%**	No Data	11.46%	**6.81%**	**8.57%**	8.36%	7.56%	No Data	7.21%	7.21%	15.67%	8.40%	1.89%
	NB5	32.05%	35.94%	No Data	56.42%	48.93%	53.33%	No Data	No Data	No Data	16.27%	27.46%	63.39%	38.63%	14.80%
North Central Bay	NC1	29.29%	41.30%	No Data	44.33%	25.23%	18.87%	13.66%	17.94%	20.19%	10.34%	16.09%	35.06%	24.75%	11.43%
	NC2	26.77%	28.36%	No Data	49.90%	24.46%	36.33%	40.58%	75.23%	66.79%	43.58%	32.69%	78.21%	45.72%	17.09%
	NC3	22.73%	55.16%	No Data	72.80%	65.97%	53.42%	70.23%	72.70%	41.97%	64.04%	41.50%	82.51%	58.46%	16.50%
	NC4	51.58%	53.11%	No Data	59.98%	60.56%	49.75%	47.68%	41.03%	31.31%	40.77%	25.33%	65.28%	47.85%	11.55%
	NC5	**88.24%**	No Data	No Data	**89.41%**	72.86%	**86.00%**	88.28%	83.82%	93.14%	86.46%	86.97%	87.37%	86.26%	5.60%
South Central Bay	SC1	50.87%	41.86%	No Data	40.83%	44.67%	34.72%	23.33%	8.79%	10.91%	19.66%	22.94%	48.30%	31.53%	14.71%
	SC2	82.57%	**79.17%**	No Data	79.74%	**79.12%**	80.00%	76.63%	82.11%	84.22%	80.59%	75.86%	**100.00%**	81.82%	2.57%
	SC3	46.30%	61.63%	No Data	28.01%	53.19%	45.04%	50.10%	46.69%	53.38%	30.91%	52.70%	64.77%	48.43%	10.32%
	SC4	41.73%	47.97%	No Data	22.25%	52.51%	34.10%	52.94%	48.87%	63.96%	45.16%	51.40%	90.55%	50.13%	11.45%
	SC5	21.26%	34.07%	No Data	15.04%	27.96%	30.74%	45.29%	41.35%	43.27%	36.45%	26.05%	53.01%	34.04%	9.84%
South Bay	SB1	41.11%	45.18%	No Data	33.41%	33.73%	42.13%	50.64%	37.34%	50.23%	45.95%	63.29%	82.21%	47.75%	9.03%
	SB2	32.11%	26.62%	No Data	43.14%	32.03%	47.11%	71.52%	65.10%	66.34%	62.43%	69.63%	69.85%	53.26%	17.38%
	SB3	**6.45%**	No Data	No Data	16.30%	15.27%	23.36%	39.97%	26.85%	56.45%	69.77%	69.51%	42.57%	36.65%	24.06%
	SB4	49.46%	42.15%	No Data	36.91%	53.39%	61.79%	**98.09%**	**95.15%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	76.09%	27.12%
	SB5	58.26%	36.90%	No Data	62.39%	55.28%	71.86%	88.41%	84.63%	91.55%	60.24%	73.67%	60.09%	67.57%	17.03%
Baywide		**38.89%**	**45.79%**	**No Data**	**44.92%**	**44.28%**	**45.91%**	**49.85%**	**48.36%**	**48.67%**	**43.07%**	**43.92%**	**56.11%**	**45.46%**	**23.83%**

4.4.2 Spatial Trends

As discussed previously, the general differences in cumulative ecoregion mean percent cover is typically limited between seasons except where winter dormancy occurs (Figure 10). This is not indicative of eelgrass turion (shoot) density. Typically winter turion density is generally highly depressed from that observed during the actively growing periods of summer months, even though the extent of beds may remain fairly consistent between seasons with eelgrass actually expanding shoreward to higher elevations during winter months due to relaxation of desiccation stress.

Notwithstanding the similarity between winter and summer seasons, when viewing eelgrass trends in mean transect coverage by ecoregion on a seasonal basis, it is notable to explore trends. In the case of winter eelgrass coverage, there has generally been a long-term increase in eelgrass coverage within the in-bay ecoregions concurrent with a pronounced decline in eelgrass coverage within the Outer Bay ecoregion over time (Figure 11). The South Bay and South Central Bay ecoregions have made substantive increases due mostly to seedling recruitment in deep water along some of the transects and subsequent survival of these seedlings over subsequent winter months. Based on where these gains have occurred, it would not be surprising to see similar steep declines in coverage in future years as the seedling derived plants die out. The South Bay and Outer Bay ecoregion have been the most variable of the ecoregions.

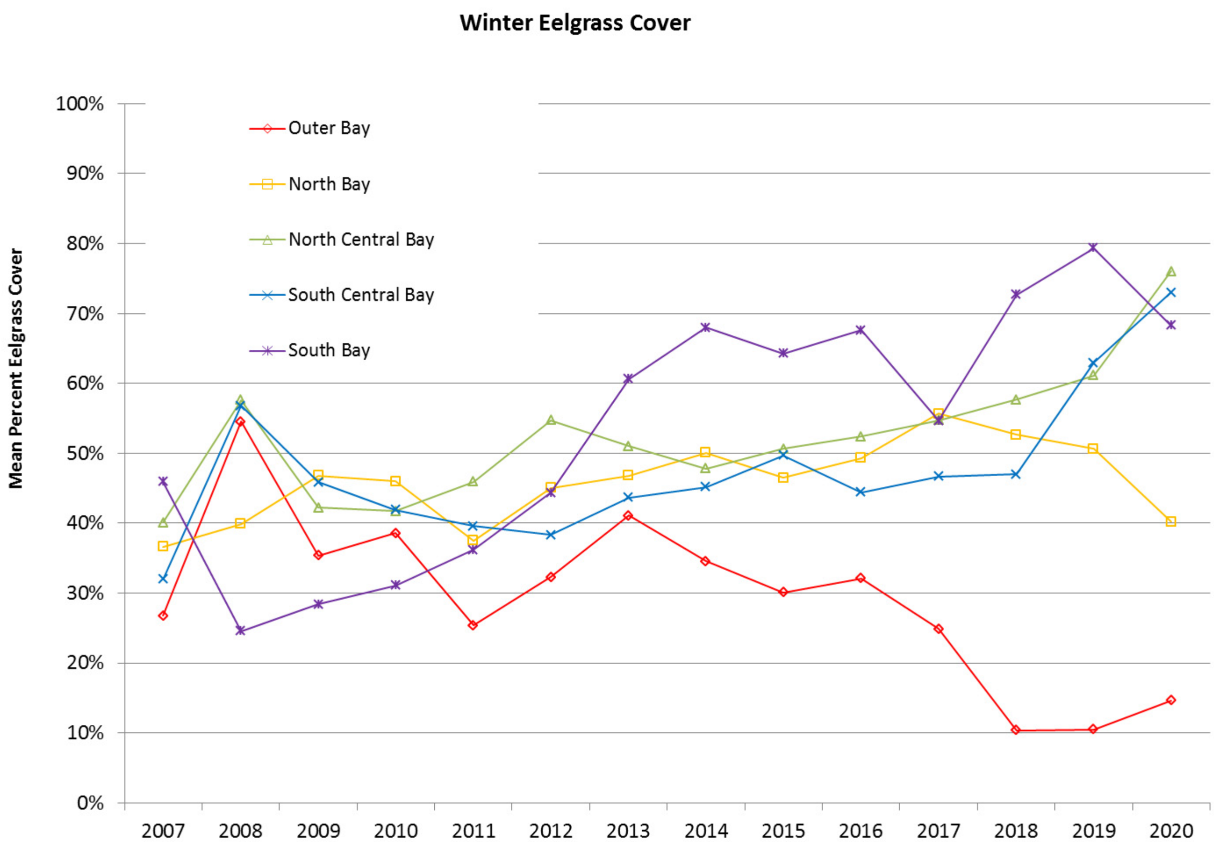

Figure 11. Mean Annual Percent Eelgrass Cover in Winter within Five Ecoregions of San Diego Bay

Annual average percent cover of eelgrass for summer surveys generally tracked with that seen in the winter surveys across all ecoregions (Figure 12). As with the winter surveys, the Outer Bay eelgrass has shown a significant decline in eelgrass since the initiation of monitoring while the in-bay transects have revealed relative stability over time with a notable increase in eelgrass coverage in South Bay ecoregion transects as discussed previously.

In 2018, three of five ecoregion mean coverages showed increases from the prior 2017 summer. The summer of 2017 was notably unseasonably warm and considerable losses of eelgrass were noted in other systems. It is also likely that losses of a similar nature occurred in San Diego Bay. Ecoregions experiencing the greatest eelgrass declines between the summers of 2016 and 2017 were the ecoregions that experienced eelgrass gains in 2018, while more gradual losses observed in the Outer Bay and North Central Bay ecoregions showed continued losses from summer 2017 through 2018.

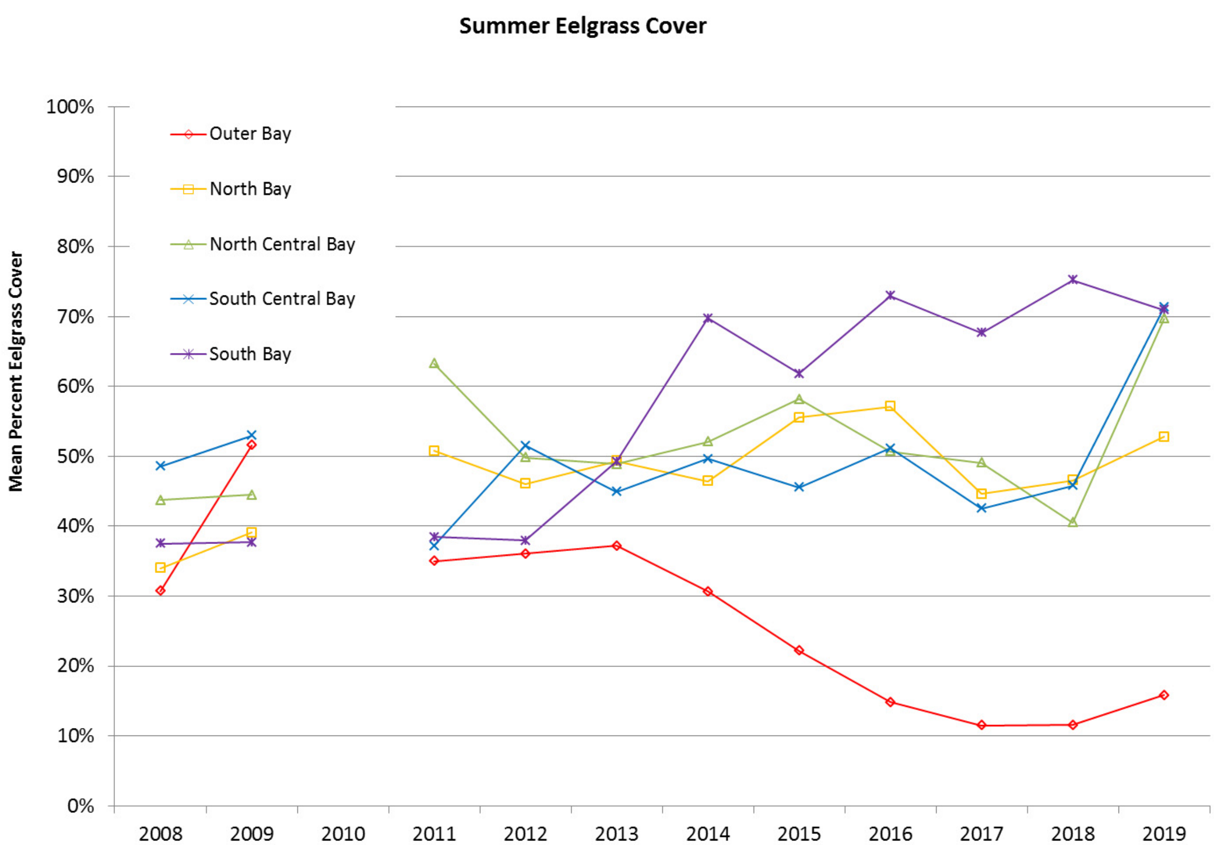

Figure 12. Mean Annual Percent Eelgrass Cover of Summer Surveys within Five Ecoregions of San Diego Bay

5.0 RECOMMENDATIONS

As noted in the prior monitoring report, there are tremendous benefits to having a long-term regimented sampling program data set when evaluating eelgrass dynamics within San Diego Bay. However, the program as presently structured is limited in many respects by the structure of the analysis and assumptions bestowed on what the transects reflect. Within the long-term monitoring program, individual transects were divided into separate management areas based on delineated ecoregions and transects within these ecoregion blocks have been treated as replicates for characterizing the ecoregions and ultimately the bay. However, the transects themselves are not replicates within these ecoregions due to inherent differences between transects and the variability of conditions of eelgrass beds within the individual ecoregions. As such, they should not be treated as replicates as they have historically been treated and as they are presently treated in this report.

The historic treatment of transects as replicates characterizing ecoregions dampens the capacity to detect true interannual an interseasonal eelgrass bed dynamics and limits the potential of the monitoring program to provide robust estimates of eelgrass cover variability beyond the transects themselves. The identification of this weakness in the program has been noted in prior monitoring reports (TDI 2018, Merkel & Associates 2019). This very issue has been the basis of considerable investigations into how best to handle inherent differences in the environment that can strongly influence how well transect sampling programs will characterize eelgrass beds. The outcome of these investigations has been the development of a methodology that uses comprehensive benchmark surveys wherein eelgrass is segmented by geography and shared characteristics that are then monitored by well-placed transects that represent the features of the environment supporting eelgrass within the individual bed segments. The extent of eelgrass along each transect is then scaled by that which occurred during the benchmark years to determine how much the eelgrass bed segment the transect represents is likely to have changed (Merkel & Associates 2008, Bernstein et al. 2011). This methodology has been tested over multiple years and applied in several areas and has been found to provide a robust estimator of eelgrass conditions within transect sampled systems.

In the current circumstance, the 12-year baseline sampling of transects provides a record of eelgrass persistence and variability that is impossible to replace. As such, it argues for developing a segment analysis regime for the existing transects rather than segmenting beds and then selecting transects. While this is more difficult to do and would not be expected to be as robust as developing the program without this constraint, the long-term baywide monitoring record and the historic transect record does provide very useful tools that can be applied in the bed segmentation process to strengthen the representative nature of the transects to newly defined segments.

Another recommendation that would normally be made to follow other regional programs would be to employ swath (belt) transects from sidescan sonar to the mapping rather than one dimensional single-beam sonar transect sampling. This generally provides a better representation of the eelgrass, allows greater understanding of how eelgrass has changed between sampling and in many instances the nature of the variability points to causative agents (e.g., boat scarring, seedling recruitment events or clonal expansion, or degradation of beds within the core, shallow, or deep margins). Under the present monitoring program, the transition to sidescan sonar is still considered to be a useful action relative to obtaining greater perspective on the eelgrass dynamics. However, given the 12-year history of centerline eelgrass coverage sampling, it is recommended that the centerline coverage of eelgrass continue to be the metric of change for eelgrass analyses. This can be equally extracted from ISS as single-beam sampling so either sampling methodology would provide the requisite numeric data for the quantitative analyses.

For the present investigations, it is possible to continue the existing analyses unaltered from the prior monitoring program without giving up capacity to data mine the collected information and develop a posteriori segmentation analysis framework for the data collected in order to inject more utility into the program. However, it would be beneficial to implement such a program sooner than later in order to minimize the reprocessing effort.

6.0 REFERENCES

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