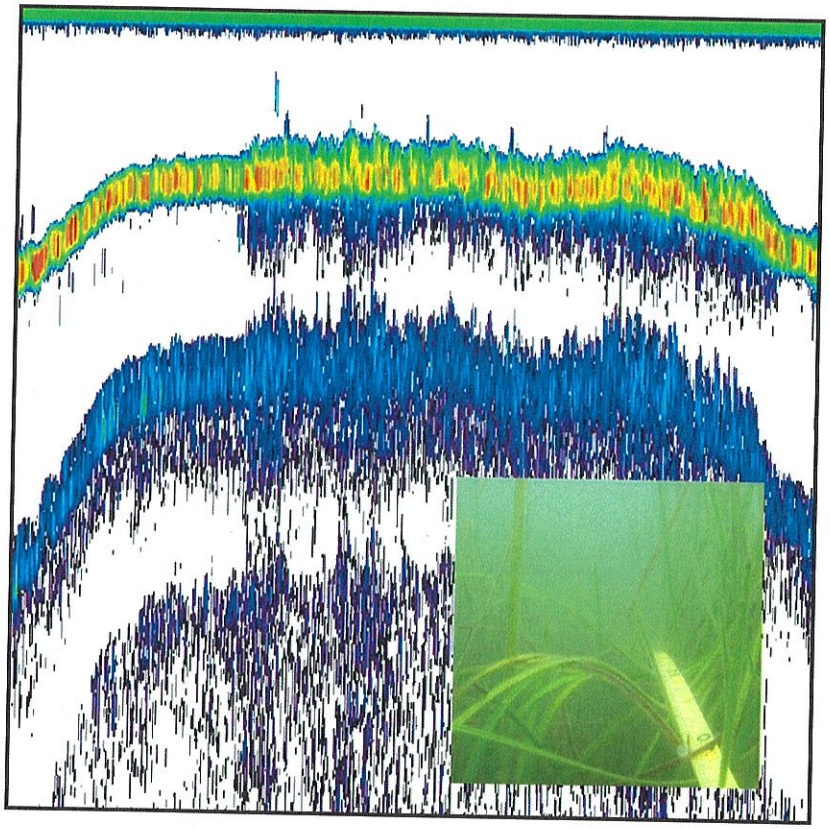
Evaluation of Temporal and Spatial Changes of Perennial Eelgrass (*Zostera marina*) Beds within San Diego Bay Using Permanent Transects



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1.0 Introduction

Eelgrass (typically *Zostera marina* and *Z. pacifica*) is a seagrass that is indigenous to the soft-bottom bays and estuaries of the northern hemisphere, where it is the most widely distributed marine angiosperm (Den Hartog 1970; Den Hartog and Kuo 2006). Along the west coast of North America, eelgrass is found from southeastern Alaska to southern Baja California, Mexico, and is typically in protected bays and estuaries from the low intertidal to a depth of approximately 20 meters (m; 66 feet [ft]) (Green and Short 2003). In the Southern California Bight, eelgrass is the most common seagrass species occurring in embayments (Dailey et al. 1993). San Diego Bay has historically contained expansive eelgrass beds where suitable habitat and conditions occur. Since 1994, eelgrass distribution throughout San Diego Bay has been regularly mapped and monitored by the U.S. Department of the Navy (Navy) (Navy 1994, 2000, 2005, 2009, 2010, 2012, and 2014).

Eelgrass communities form characteristic landscapes, ranging from highly fragmented to almost continuous meadows, covering extensive areas within coastal bays, estuaries, and semi-protected shallow soft-bottom environments of the open coast. Eelgrass beds function as habitat and nursery areas for commercially and recreationally important open ocean fish and invertebrates, as well as provide critical structural environments for resident bay and estuarine species (Hoffman 1986; Kitting 1994). In addition to biological contributions, eelgrass beds contribute physical benefits to bay and estuarine habitats by dampening wave and current action, trapping suspended particulates, and reducing erosion. Eelgrass also facilitates nutrient cycling, oxygenates the water column through photosynthesis, and has the potential to act as a significant means of sequestering carbon (Mateo et al. 1997; Laffoley and Grimsditch 2009).

Eelgrass beds are often characterized as stable communities because of their persistence within individual estuaries and bays. The meadows appear stable to the observer because they typically house a rich diversity of associated flora and fauna, thereby depicting a climax community (Greve and Krause-Jensen 2005). The apparent stability of the meadows conceals a dynamic balance involving a continuous loss and replacement of shoots (Duarte 1989; Olesen and Sand-Jensen 1994). Eelgrass populations show extensive spatial and temporal fluctuations (Kendrick et al. 1999; Robbins and Bell 2000), and within suitable environments they can expand, contract, disappear, and recolonize areas. Vegetated eelgrass areas have been found to expand by as much as 5 m (16 ft) and contract by as much as 4 m (13 ft) annually (Donoghue 2011). Consequently, it is recommended that eelgrass habitat mapping include the vegetated, as well as un-vegetated, spaces between eelgrass patches (Fonseca et al. 1998).

Eelgrass primarily grows within a limited depth range, sediment type, and water clarity (Thom 1990; Fonseca and Bell 1998; Borde et al. 2003; Duarte et al. 2007). A number of factors can influence the distribution of seagrasses, including light regime, substrate type, and energetics of the environment (Thom 1990; Fonseca and Bell 1998; Borde et al. 2003; Duarte et al. 2007). Additionally, biological controls, including epiphytic growth, spatial competitors such as benthic algae, and bioturbation, can have a substantial effect on the growth and distribution of eelgrass. High temperatures can restrict the occurrence of eelgrass and influence the species' metabolism, the reproductive mode of a population, and lead to unseasonal diebacks or complete absence of eelgrass within an affected area (Phillips 1984; Meling-López and Ibarra-Obando 1999).

Predicted increases in the rate of eustatic sea level rise (Church et al. 2001) has led to concerns over the stability of estuarine wetlands worldwide (Nuttle et al. 1997). Recent studies modeling the effects of sea level rise on eelgrass populations show the potential for increases in available habitat due to landward migration (Valle et al. 2014) and decreases in eelgrass populations due to loss of habitat (Shaughnessy et al. 2012). Studies in Pacific, Gulf of Mexico, and Atlantic coastal estuaries show that estuarine wetland vegetation may change dramatically in response to small changes in elevation (Warren and Niering 1993; Zedler and Callaway 1999; Ward 2000).

A number of studies have emphasized the importance of monitoring seagrass ecosystems and incorporating seagrass as an indicator into large-scale programs, assessing the health, function, and sustainable use of coastal ecosystems (Duarte 2002; Larkum et al. 2006). 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." To standardize and maintain a consistent policy regarding mitigation of adverse impacts to eelgrass beds, federal and state natural resource agencies (National Marine Fisheries Service [NMFS], U.S. Fish and Wildlife Service, and California Department of Fish and Game) developed the Southern California Eelgrass Mitigation Policy (SCEMP) (NMFS 1991). In 2009, a working group consisting of regulatory, environmental, and research organizations amended the SCEMP and developed a California Eelgrass Mitigation Policy (CEMP). The CEMP was completed in 2011 and, after going through public review and comment, was adopted in October 2014 (NMFS 2014).

While the intent of the CEMP is to provide a basis for consistent recommendations for projects that may impact existing eelgrass resources, it provides for circumstances (e.g., climatic events) where flexibility in the application of this policy may be applied. Consequently, deviations from the CEMP may be allowed on a case-by-case basis. The CEMP and its compliance criteria identify and describe recommended survey and monitoring strategies for quantifying the temporal distribution of distinct eelgrass communities and assessing eelgrass distribution, density, and health.

In 1994 the Navy, in conjunction with the Port of San Diego (Port), initiated a bay-wide eelgrass mapping effort for San Diego Bay. Subsequent mapping efforts were conducted in 1999, 2004, 2008, 2011, and 2014 (Navy 1994, 2000, 2005, 2009, 2010, 2012, and 2014). The use of side-scan sonar has greatly improved the cost and efficiency of recurring eelgrass monitoring on a regional scale. The CEMP identifies acoustics as a recognized survey method for mapping eelgrass extent. Single beam sonar has been used to map the extent of eelgrass cover along permanent transects in San Diego Bay since 2007. This report includes the results of the most recent sonar mapping surveys, conducted in Winter 2016 and Summer 2017, at the permanent transects with comparison to sonar data collected since 2007. The Navy's long-term monitoring of eelgrass at permanent transects contributes to the understanding of spatial and temporal variability of eelgrass communities throughout San Diego Bay, as well as providing a substantial baseline for future eelgrass assessments. In addition, several of the permanent transects are in Navy eelgrass mitigation sites, providing pertinent information relative to eelgrass banking by the Navy.

2.0 Methods

To examine the annual, seasonal, and regional changes in eelgrass cover, the Navy funded biannual surveys of permanent eelgrass transects in San Diego Bay beginning in 2007. Permanent transects were grouped by region, within similar depth and overlying water conditions, and have been evaluated over successive years during the same season, nearly continuously from 2007 (winter) or 2008 (summer) to present. The transects were apportioned among individual management areas (ecoregions) of San Diego Bay, recognized in the San Diego Bay Integrated Natural Resource Management Plan (Navy and Port 2013), as follows: 1) Outer Bay; 2) North Bay; 3) North Central Bay; 4) South Central Bay; and 5) South Bay (Figure 1). These ecoregions were previously developed by Largier et al. (1996) based on physical and biological distinctions.

Utilizing existing transect data collected in 1999/2000 and 2005 by Naval Facilities Engineering Command (NAVFAC) Southwest, five permanent transects within documented perennial eelgrass beds were selected from within each of the five ecoregions of San Diego Bay. Transects were selected based on historical baseline data, an ability to resample the areas, and varied in length, exposure, and depth, with five transects placed in each of the five ecoregions. Biannual sampling was conducted in the winter (March and April), and in the summer (September and October), during mostly high slack tide time periods.

Transect surveys were performed in the summer (October) of 2016 and winter (March) of 2017, using identical sonar equipment and methods that were used to acquire percent cover eelgrass data for the years of 2007 through 2016. Surveys were conducted using a 15-ft Boston Whaler and a *BioSonics DT4000* portable echosounder with a 420 kilohertz, six-degree single beam transducer that generates monotone pulses (pings) at a user-set rate (10 pings/second) and duration (0.1 milliseconds) to acquire hydroacoustic data. The echosounder was connected to a laptop computer, which ran *BioSonics Visual Acquisition* software. Real time geo-referencing of the boat and sonar track was acquired using a *Trimble AG 122*. Differential correction was provided through the Trimble unit, utilizing the *Coast Guard COORS DGPS* signal, providing 1-m (3.28-ft) resolution for tracking and navigation. Individual transects were evaluated seasonally and annually in the same direction over a two- to three-day period, under similar tidal conditions.

After field data collection, the resulting geo-referenced data were processed in *EcoSav* software and imported into *ESRI Arc Map®*. Maps were cropped to conform to the corresponding transect start and end points. The resulting files, bearing ping numbers with distinct start and end points for each transect survey, were then evaluated for eelgrass presence/absence. Individual files were subsequently entered into a *Visual Analyzer* program, which graphically displayed the hydroacoustic data in the form of a sonogram (Figure 2). Strings of successive pings identified to contain eelgrass were enumerated and the resulting total number of pings were compared to the total number of pings sampled over the permanent transects, which resulted in a percent cover calculation. To ensure sufficient tracking of eelgrass expansion and contraction events, transect start and end points extended beyond identified perennial eelgrass beds.

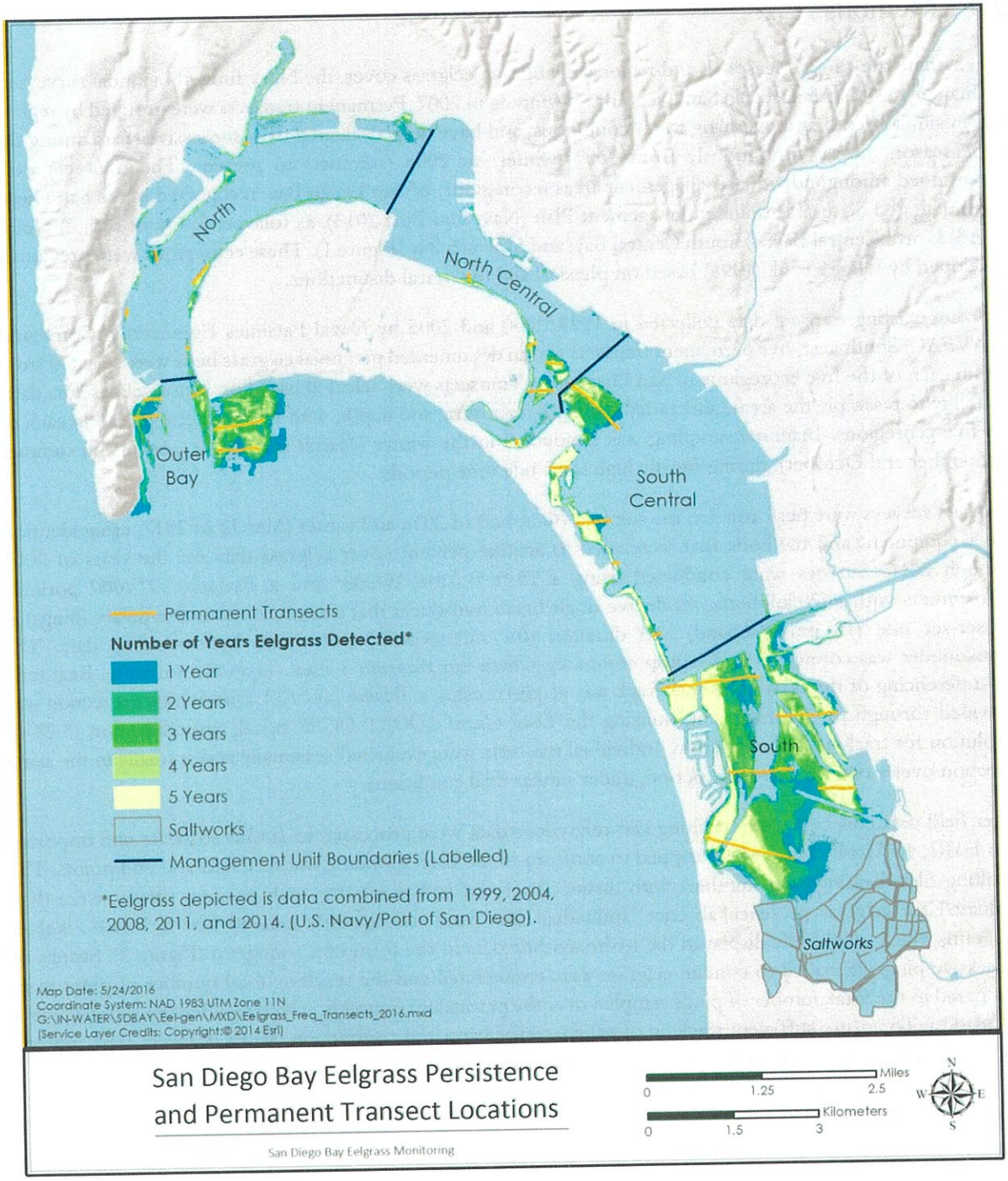

Figure 1. San Diego Bay Permanent Transect Locations Located Within Persistent Eelgrass Beds.

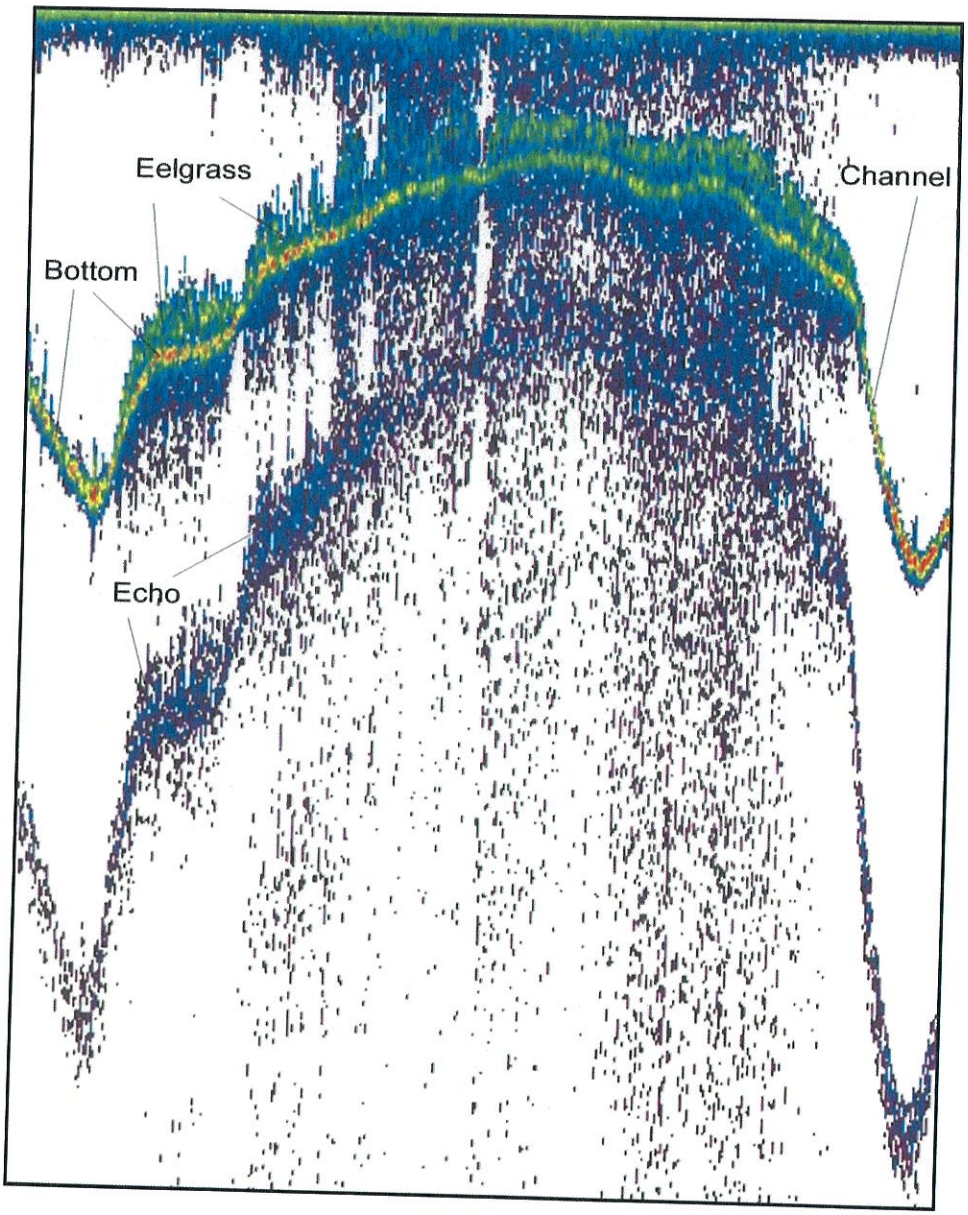

Figure 2. Example Sonogram of Eelgrass Transect.

3.0 Site Overviews

Permanent transects, within each of the bay ecoregions, were selected based on existing perennial eelgrass occurrence, historical transect data, and to provide representation of various exposures. Start and end locations of the permanent transects were reported in UTM NAD 83 coordinates (Tables 1-5). Figures 3 through 7 show the locations of permanent transects overlaid on historical bay-wide eelgrass cover data.

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 1,100 m in length. Water depths along the transect range from -4 to -14 ft Mean Lower Low Water (MLLW).			
Start Location:	479072.77 W 3615685.66 N	End Location:	480125.88 W 3615857.96 N
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 1,100 m in length. Water depths along the transect range from -7 to -15 ft MLLW.			
Start Location:	480154.46 W 3615332.20 N	End Location:	480125.88 W 3615320.81 N
Transect Outer Bay 3 (OB3)			
Transect OB3 is located west of Zuniga Jetty at the entrance of San Diego Bay and is 280 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. Water depths along the transect range from -6 to -34 ft MLLW.			
Start Location:	478704.83 W 3616277.00 N	End Location:	478957.21 W 3616396.08 N
Transect Outer Bay 4 (OB4)			
Transect OB4 is located on the northwestern boundary to the entrance of San Diego Bay and is 340 m in length. Transect OB4 is sampled from east to west. Water depths along the transect range from 0 to -10 ft MLLW.			
Start Location:	478197.28 W 3616236.98 N	End Location:	477860.62 W 3616245.59 N
Transect Outer Bay 5 (OB5)			
Transect OB5 is just offshore (south) of OB4. Transect OB5 is approximately 480 m in length and is sampled west to east. Water depths along the transect range from -2 to -12 ft MLLW.			
Start Location:	477685.00 W 3616236.98 N	End Location:	478164.89 W 3616245.70 N

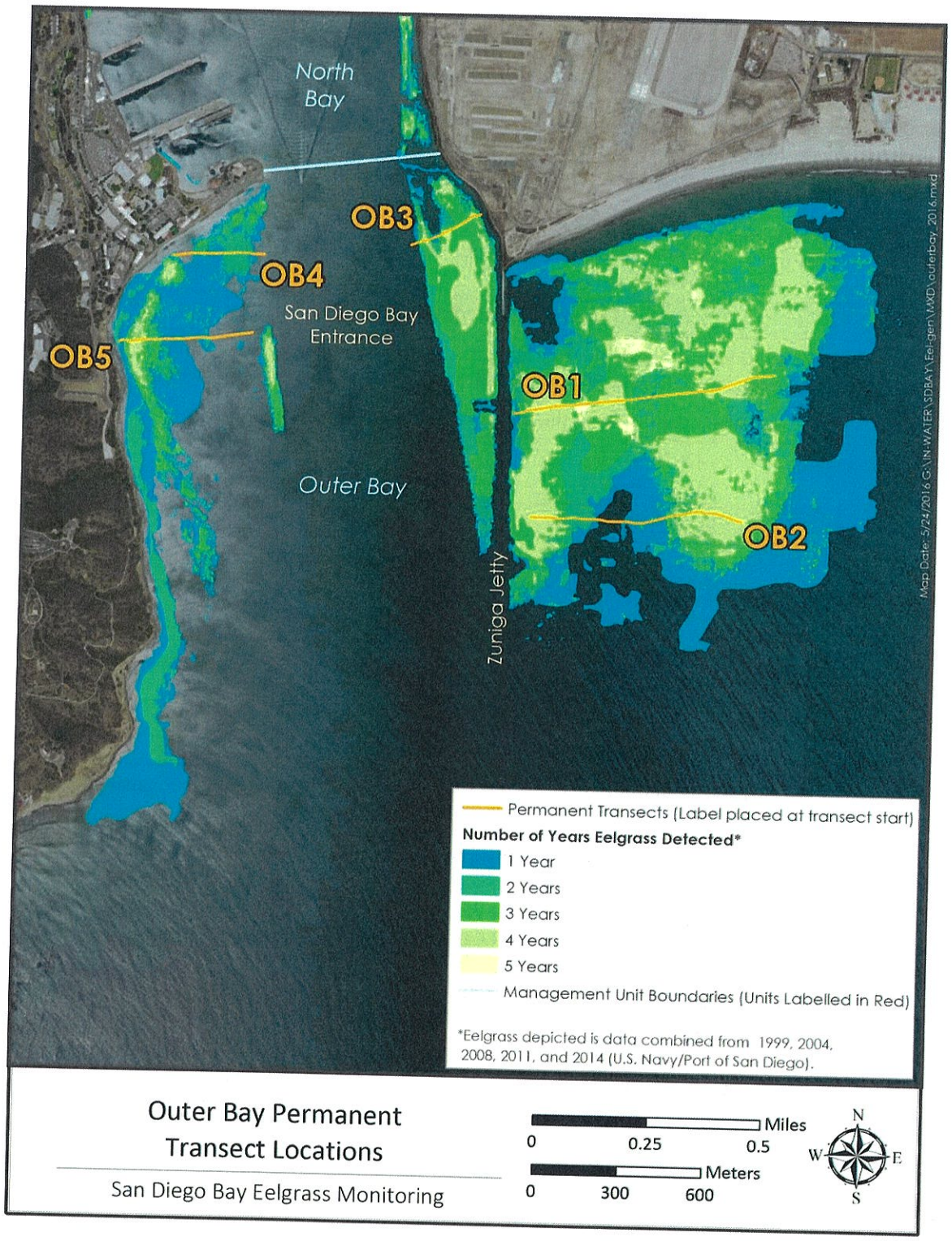

Figure 3. Outer Bay Eelgrass Communities with Associated Permanent Transects.

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 450 m in length and is sampled parallel to shore in a north to south direction. Water depths along the transect range from -4 to -30 ft MLLW.			
Start Location:	479043.12 W 3618589.93 N	End Location:	478754.04 W 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 80 m long and is sampled in an east to west direction. Water depths along the transect range from -2 to -26 ft MLLW.			
Start Location:	478704.01 W 3617145.57 N	End Location:	478630.46 W 3617121.18 N
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 170 m in length and is sampled parallel to the shore in a south to north direction. Water depths along the transect range from -6 to -10 ft MLLW.			
Start Location:	477592.61 W 3617687.53 N	End Location:	477621.56 W 3617853.31 N
Transect North Bay 4 (NB4)			
Transect NB4 is located at the entrance of the Shelter Island yacht basin and is approximately 200 m in length. Transect NB4 is sampled in a north to south direction. Water depths along the transect range from -4 to -18 ft MLLW.			
Start Location:	478133.17 W 3618846.88 N	End Location:	478146.21 W 3618653.29 N
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. Water depths along the transect range from 0 to -16 ft MLLW.			
Start Location:	479696.26 W 3620722.57 N	End Location:	479798.03 W 3617853.31 N

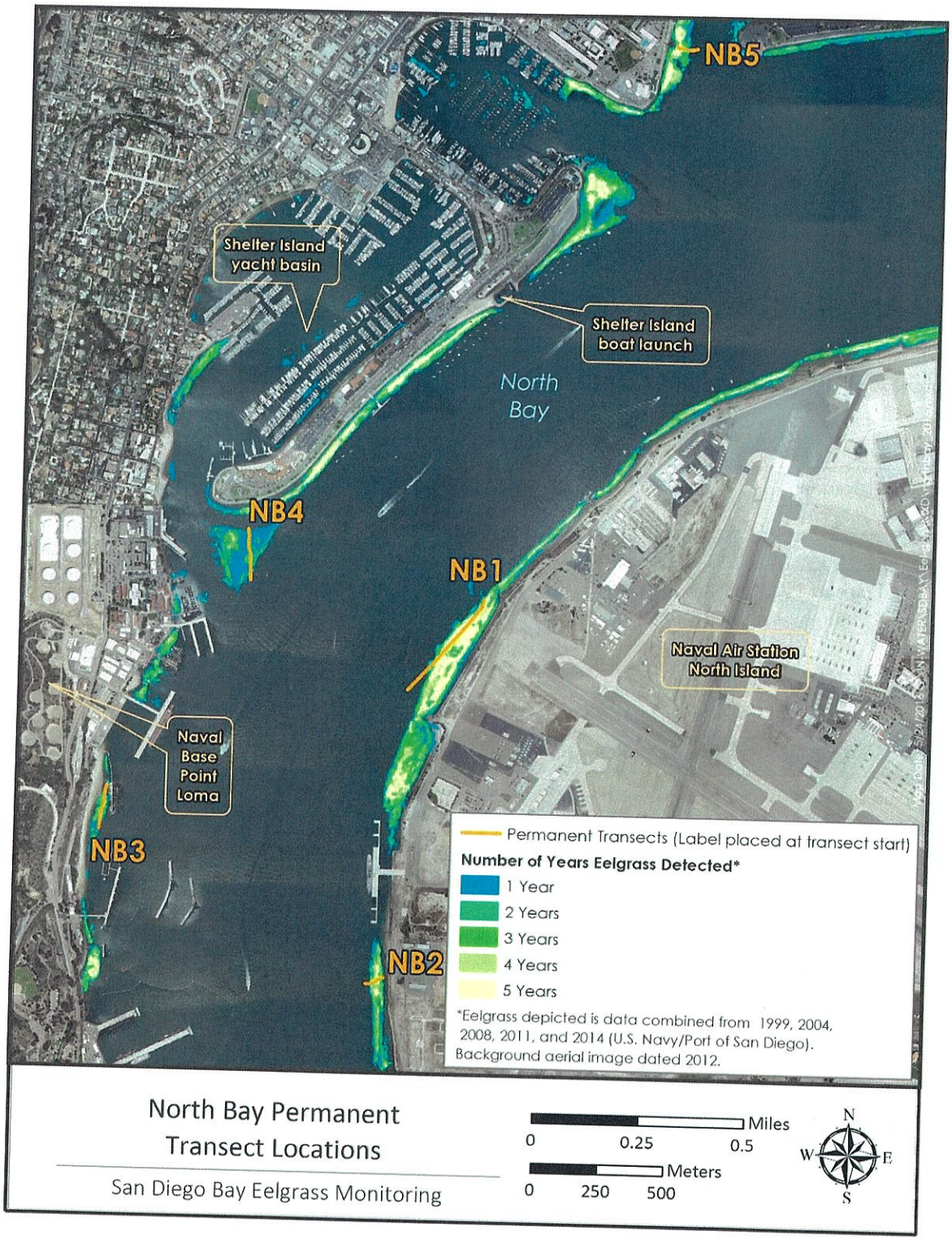

Figure 4. North Bay Eelgrass Communities with Associated Permanent Transects.

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 shore of the City of Coronado, just east of the aircraft carrier turning basin across from the convention center. Transect NC1 is 210 m in length and is sampled in a north to south direction. Water depths along the transect range from 0 to -26 ft MLLW.			
Start Location:	483617.87 W 3618349.80 N	End Location:	483639.38 W 3618141.46 N
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 205 m in length and is sampled in a west to east direction. Water depths along the transect range from -2 to -16 ft MLLW.			
Start Location:	484615.58 W 3617049.38 N	End Location:	484807.56 W 3617118.50 N
Transect North Central 3 (NC3)			
Transect NC3 is located southeast of NC2, outside the yacht moorings, and is 315 m in length. Transect NC3 is sampled in a west to east direction. Water depths along the transect range from -6 to -12 ft MLLW.			
Start Location:	484948.58 W 3616758.15 N	End Location:	485260.09 W 3616743.92 N
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 485 m in length and is sampled in an east to west direction. Water depths along the transect range from -2 to -18 ft MLLW.			
Start Location:	485096.94 W 3616261.04 N	End Location:	484613.27 W 3616253.50 N
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 162 m in length and is sampled in a south to north direction. Water depths along the transect range from 2 to -14 ft MLLW.			
Start Location:	484414.92 W 3615277.78 N	End Location:	484416.28 W 3615429.67 N

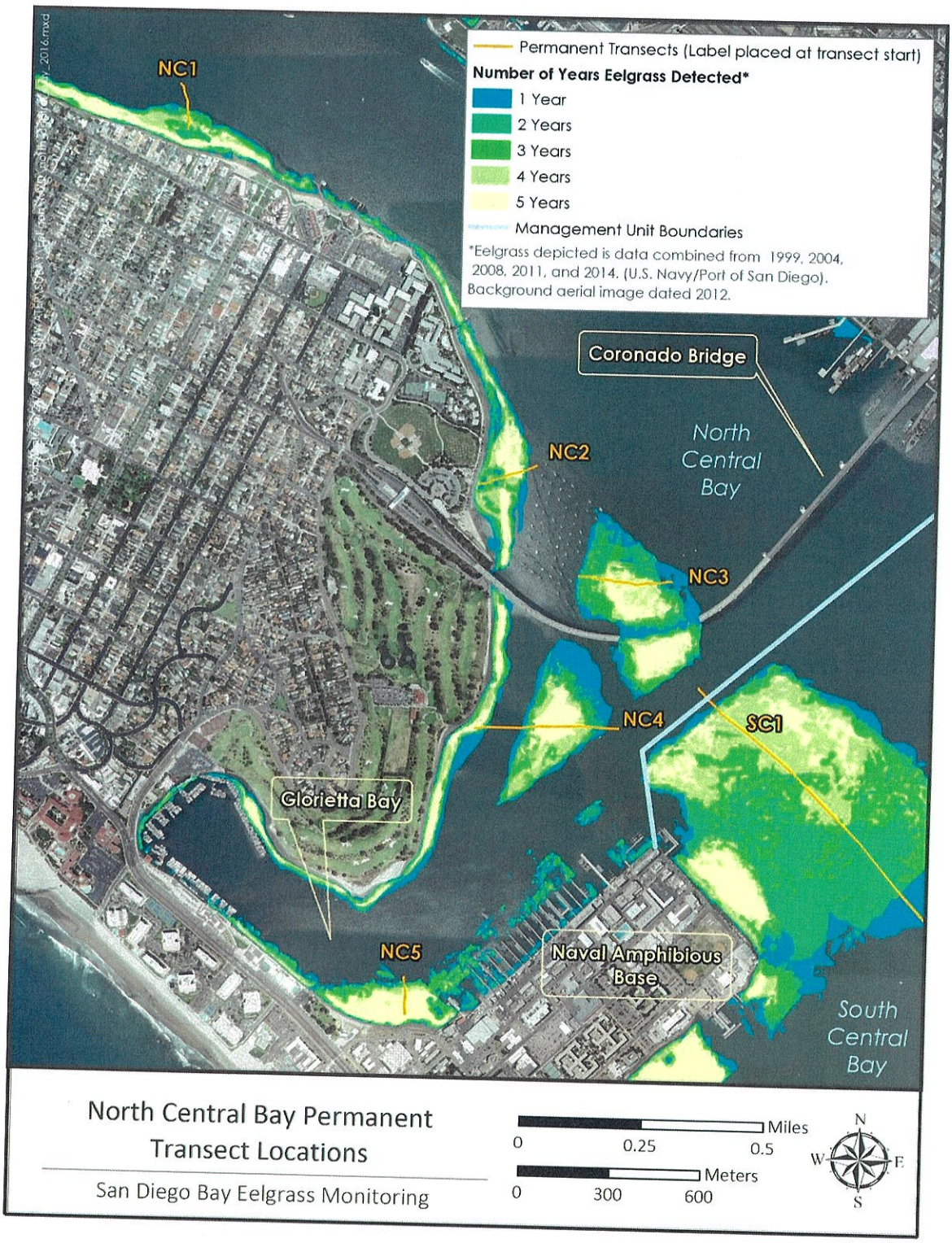

Figure 5. North Central Bay Eelgrass Communities with Associated Permanent Transects.

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. Water depths along the transect range from -4 to -20 ft MLLW.			
Start Location:	485348.57 W 3616406.52 N	End Location:	486221.97 W 3615551.29 N
Transect South Central 2 (SC2)			
Transect SC2 is located southwest of SC1 and inshore of Homeport Island. Transect SC2 is 350 m in length and is sampled in a west to east direction. Water depths along the transect range from 2 to -12 ft MLLW.			
Start Location:	484988.77 W 3614913.87 N	End Location:	485340.45 W 3614908.16 N
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 615 m in length and is sampled in an east to west direction. Water depths along the transect range from 2 to -12 ft MLLW.			
Start Location:	486033.26 W 3613973.45 N	End Location:	485414.10 W 3613935.40 N
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 135 m in length and is sampled in an east to west direction Water depths along the transect range from -2 to -10 ft MLLW.			
Start Location:	486168.21 W 3613230.09 N	End Location:	486036.00 W 3613227.23 N
Transect South Central 5 (SC5)			
Transect SC5 is located on the eastern shore, just south of Fiddler's Cove Marina. Transect SC5 is 170 m in length and is sampled in an east to west direction. Water depths along the transect range from 4 to -16 ft MLLW.			
Start Location:	486858.50 W 3611983.59 N	End Location:	486697.90 W 3611936.88 N

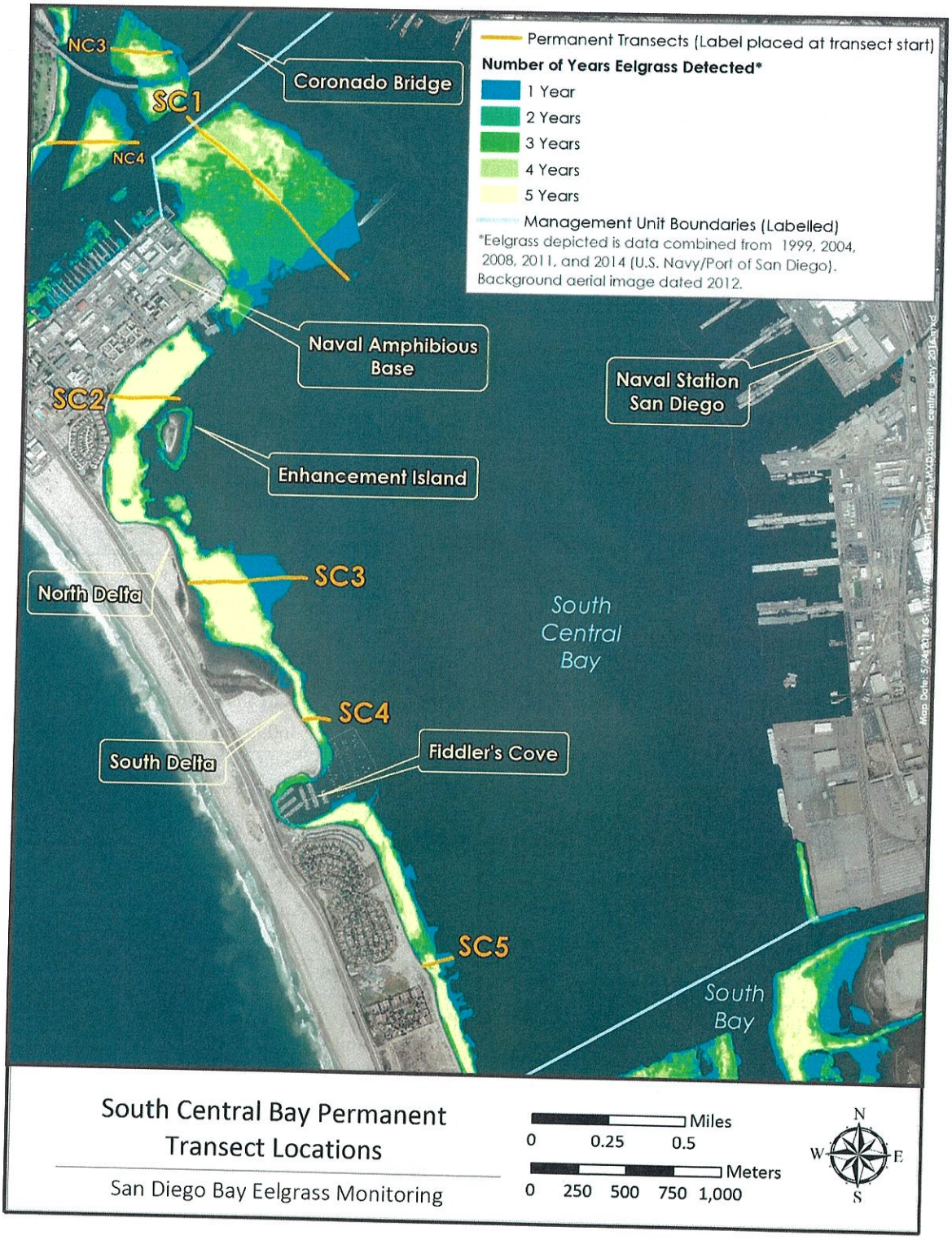

Figure 6. South Central Bay Eelgrass Communities with Associated Permanent Transects.

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 1,760 m in length and is sampled in a west to east direction. Water depths along the transect range from -2 to -12 ft MLLW.			
Start Location:	486833.63 W 3610996.46 N	End Location:	488574.09 W 3611161.79 N
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. Water depths along the transect range from -2 to -24 ft MLLW.			
Start Location:	489931.56 W 3610508.26 N	End Location:	488835.50 W 3610477.71 N
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 1,200 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. Water depths along the transect range from 0 to -10 ft MLLW.			
Start Location:	487929.63 W 3609515.15 N	End Location:	489127.91 W 3609520.96 N
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 680 m in length and is sampled in a west to east direction. Water depths along the transect range from -2 to -6 ft MLLW.			
Start Location:	490227.92 W 3609183.78 N	End Location:	489552.07 W 3609170.16 N
Transect South Bay 5 (SB5)			
Transect SB5 is located in the southern-most portion of the bay near Emory Cove. Transect SB5 is 1,640 m in length, is almost perpendicular to shore, and is sampled in an east to west direction. Water depths along the transect range from -2 to -8 ft MLLW.			
Start Location:	489107.11 W 3607953.72 N	End Location:	487531.07 W 3608384.96 N

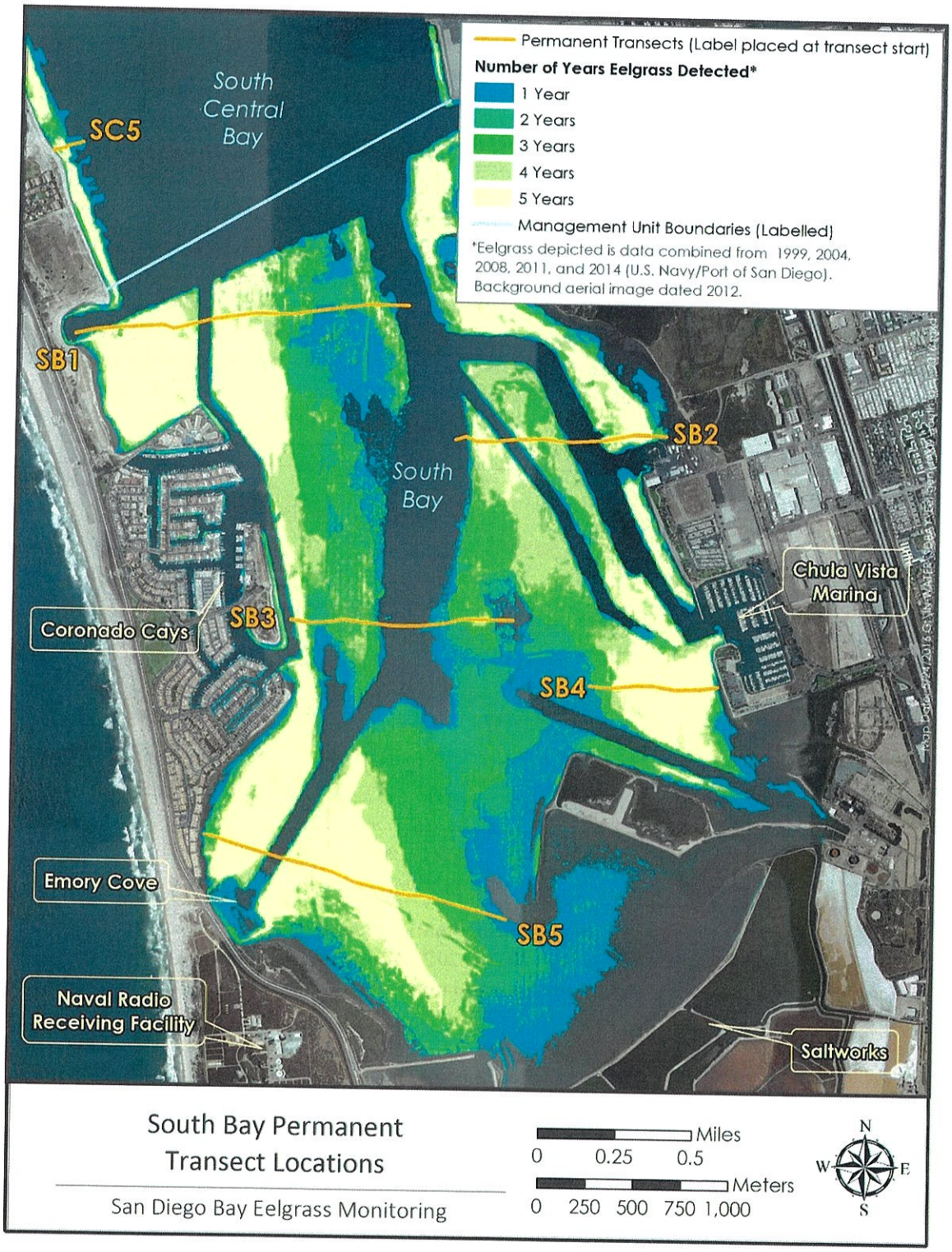

Figure 7. South Bay Eelgrass Communities with Associated Permanent Transects.

4.0 Results

4.1 Overall Seasonal and Ecoregional Results

Seasonal average eelgrass cover across all permanent transects is shown for the current survey period compared to historical data in Figure 8. The Winter 2017 survey average was 47.33%, down 1.83% from the Winter 2016 survey. The Summer 2016 survey average was 49.35%, up 0.7% from the Summer 2015 survey. Summer and winter annual average eelgrass cover trends differ, winter values have been higher for the last five years compared to prior years while summer values have been higher for the last three years compared to prior years.

Eelgrass mean percent cover by ecoregions for the recent summer and winter surveys are shown in Figure 9. Eelgrass mean percent cover was similar and relatively high for three of the ecoregions (North Bay, North Central Bay, and South Central Bay) for Summer 2016 (51.15-57.13%) and Winter 2017 (46.70-55.66%). South Bay had a similar mean percent cover of eelgrass as other ecoregions in the bay during winter (55.69%); however, eelgrass mean percent cover was substantially higher during summer (72.91%). The lowest mean percent cover was observed for the Outer Bay for both summer and winter surveys (14.86 and 24.89%, respectively).

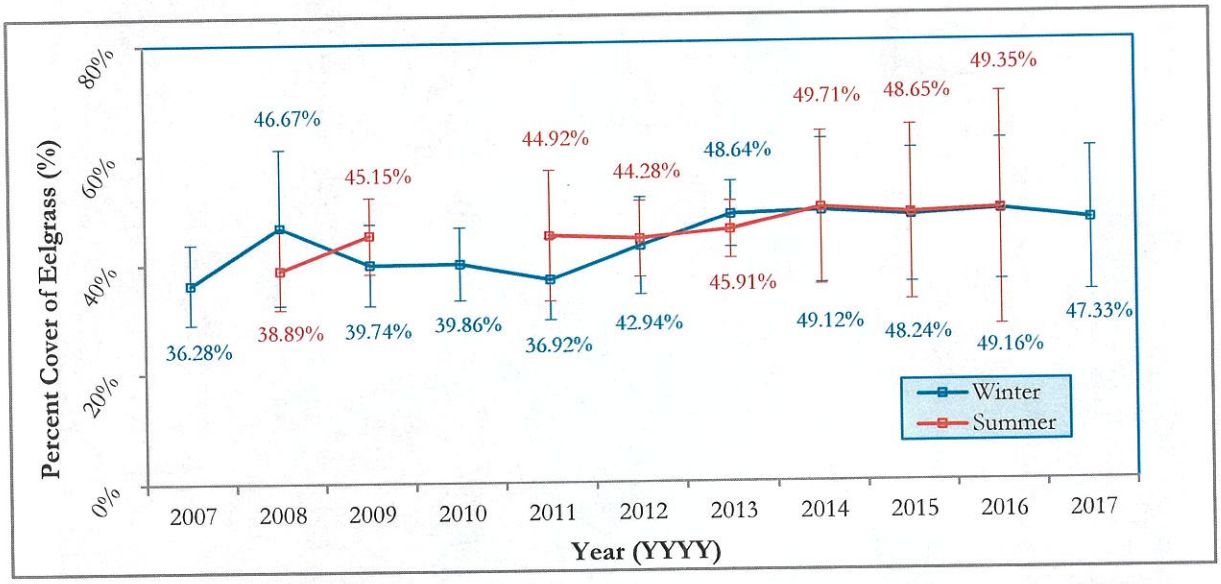

Figure 8. Mean Percent Cover of Eelgrass During Summer (September And October) and Winter (March/April) Surveys in San Diego Bay, 2007 to 2017. Annual Means Based on 25 Transects (5 Transects per 5 Ecoregions). Error Bars are the Standard Deviation from the Annual/Seasonal Means.

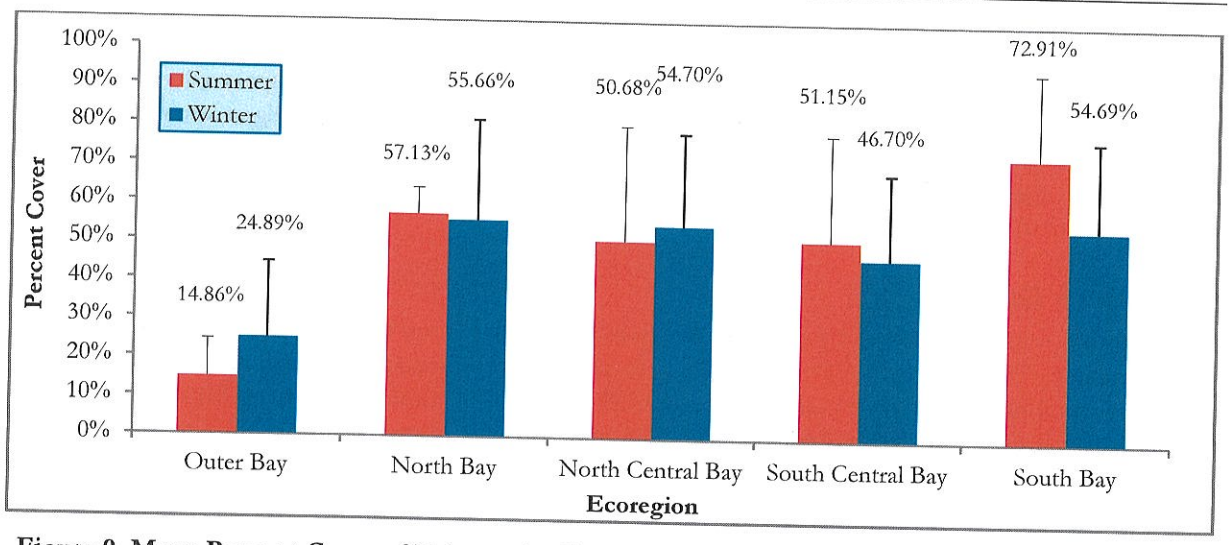

Figure 9. Mean Percent Cover of Eelgrass by Ecoregion in Summer (September/October) 2016 and Winter (March/April) 2017. Ecoregion Means Based on 5 Transects per Season. Error Bars are the Standard Deviation from the Ecoregion Means.

4.2 Summer 2016 Results by Ecoregion and Compared to Prior Years

4.2.1 Outer Bay

Summer 2016 average eelgrass cover was 14.86%, down 7.32% from Summer 2015, reaching its lowest level since surveys began in 2008 (Figures 9 and 10). Eelgrass percent cover was relatively low (<30%) across all transects, with individual transects ranging from 3.51 to 29.57% (Table 6). Transect OB3 had the highest cover (29.57%); Transects OB1, OB 2, and OB 4 had relatively similar cover (11.26 to 15.73%); and Transect OB5 had the lowest cover (3.51%).

4.2.2 North Bay

Summer 2016 average eelgrass cover in the North Bay ecoregion was 57.13%, up 1.57% from Summer 2015 (Figures 9 and 10). Eelgrass percent cover of individual transects ranged from 50 to 63.26% (Table 6). Transect NB1 had the highest cover (63.26%) and Transect NB2 had the lowest cover (50%). No data were collected for transect NB4 due a software malfunction that we were not able to rectify before the end of the survey period. Transect NB5 could not be surveyed due to the relocation of the Navy marine mammal facilities causing obstructions in the transect path and security concerns.

4.2.3 North Central Bay

Summer 2016 average eelgrass cover in the North Central Bay ecoregion was 50.68%, a substantial decrease of 7.47% from Summer 2015 (Figures 9 and 10). Eelgrass percent cover of individual transects varied widely, ranging from 20.19 to 93.14% (Table 6). Transect NC5 had the highest cover (93.14%); Transects NC2, NC3, and NC4 had moderate cover (31.31 to 66.79%); and Transect NC1 had the lowest cover (20.19%).

4.2.4 South Central Bay

The South Central Bay ecoregion showed a modest increase in average percent eelgrass cover during the Summer 2016 survey reaching 51.15%, up by 5.59% from 2015 (Figures 9 and 10). Eelgrass percent cover of individual transects varied widely, ranging from 10.91 to 84.22% (Table 6). Transect SC2 had the highest cover (84.22%); Transects SC3, SC4, and SC5 had moderate cover (43.27 to 63.96%); and Transect SC1 had the lowest cover (10.91%).

4.2.5 South Bay

The South Bay ecoregion showed considerable increases in average percent cover during the Summer 2016 survey reaching 72.91%, up by 11.1% from 2015, to its highest level since surveys began in 2008. Eelgrass percent cover of individual transects ranged from 50.23% to 100.00% (Table 6). Transects SB4 and SB5 had the highest cover (91.55 to 100%); Transects SB1, SB2, and SB3 were relatively similar (50.23 to 66.34 %).

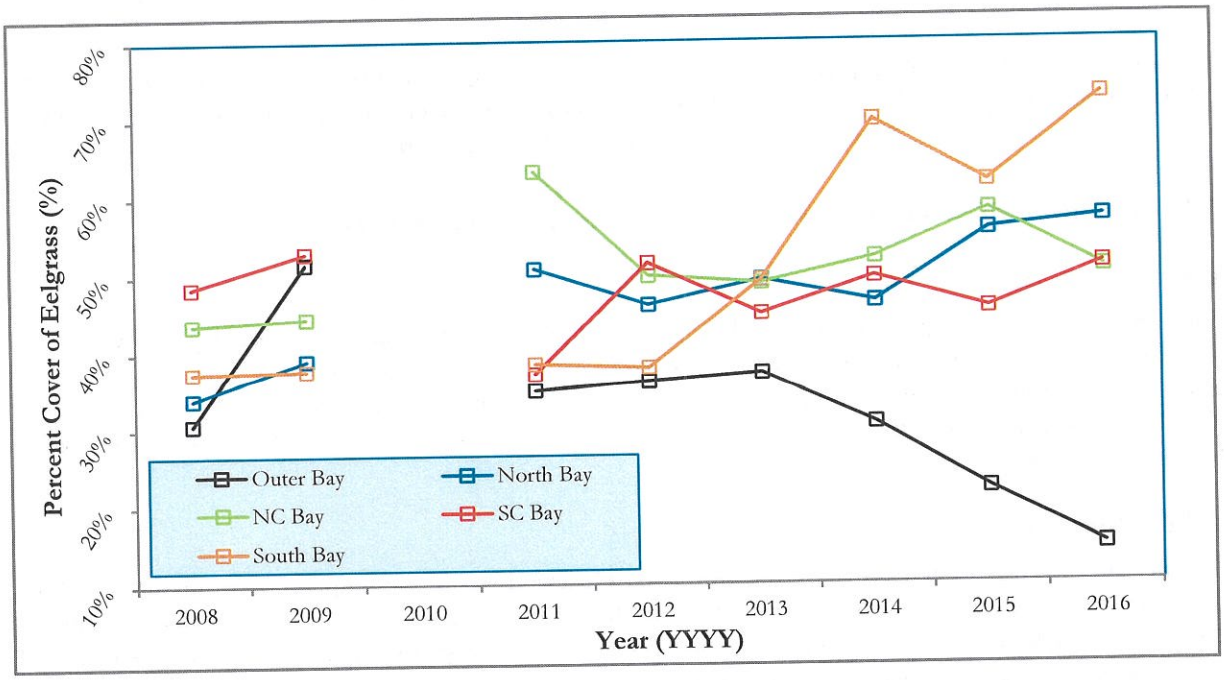

Figure 10. Mean Percent Eelgrass Cover by Ecoregion During Summer Surveys (September/October), 2008 to 2016. Ecoregion Means Were Based on 5 Transects per Season/Year.

Table 6. Summer Eelgrass Percent Cover by Year and Averages and Standard Deviations Across Years by Transect, 2008-2016. High Cover/Low Cover for Individual Years.

Region	Site	Percent Cover by Year									2008-2016	
		2008	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Avg*	*St Dev*
Outer Bay	OB1	47.33%	72.46%	No Data	43.11%	45.49%	50.58%	31.11%	25.90%	15.73%	41.46%	17.36%
	OB2	12.33%	44.38%	No Data	26.78%	38.71%	45.54%	35.34%	17.67%	14.22%	29.37%	13.49%
	OB3	43.86%	59.85%	No Data	57.35%	71.12%	52.89%	66.86%	59.25%	29.57%	55.09%	13.22%
	OB4	22.53%	27.22%	No Data	**3.00%**	7.27%	13.54%	**3.59%**	8.07%	11.26%	12.06%	8.74%
	OB5	27.50%	53.85%	No Data	44.63%	17.84%	23.28%	16.40%	**0.00%**	**3.51%**	23.37%	18.58%
North Bay	NB1	56.99%	No Data	No Data	85.21%	73.82%	74.86%	68.98%	68.68%	63.26%	70.26%	9.00%
	NB2	48.09%	53.27%	No Data	34.89%	37.33%	53.75%	45.88%	60.26%	50.00%	47.93%	8.50%
	NB3	25.96%	55.34%	No Data	65.76%	63.44%	56.07%	62.50%	85.73%	58.14%	59.12%	16.50%
	NB4	6.80%	**11.66%**	No Data	11.46%	**6.81%**	**8.57%**	8.36%	7.56%	No Data	8.75%	2.04%
	NB5	32.05%	35.94%	No Data	56.42%	48.93%	53.33%	No Data	No Data	No Data	45.33%	10.78%
North Central Bay	NC1	29.29%	41.30%	No Data	44.33%	25.23%	18.87%	13.66%	17.94%	20.19%	26.35%	11.23%
	NC2	26.77%	28.36%	No Data	49.90%	24.46%	36.33%	40.58%	75.23%	66.79%	43.55%	18.98%
	NC3	22.73%	55.16%	No Data	72.80%	65.97%	53.42%	70.23%	72.70%	41.97%	56.87%	17.60%
	NC4	51.58%	53.11%	No Data	59.98%	60.56%	49.75%	47.68%	41.03%	31.31%	49.38%	9.68%
	NC5	**88.24%**	No Data	No Data	**89.41%**	72.86%	**86.00%**	88.28%	83.82%	93.14%	85.96%	6.46%
South Central Bay	SC1	50.87%	41.86%	No Data	40.83%	44.67%	34.72%	23.33%	8.79%	10.91%	32.00%	15.85%
	SC2	82.57%	**79.17%**	No Data	79.74%	**79.12%**	80.00%	76.63%	82.11%	84.22%	80.44%	2.39%
	SC3	46.30%	61.63%	No Data	28.01%	53.19%	45.04%	50.10%	46.69%	53.38%	48.04%	9.70%
	SC4	41.73%	47.97%	No Data	22.25%	52.51%	34.10%	52.94%	48.87%	63.96%	45.54%	12.80%
	SC5	21.26%	34.07%	No Data	15.04%	27.96%	30.74%	45.29%	41.35%	43.27%	32.37%	10.79%
South Bay	SB1	41.11%	45.18%	No Data	33.41%	33.73%	42.13%	50.64%	37.34%	50.23%	41.72%	6.73%
	SB2	32.11%	26.62%	No Data	43.14%	32.03%	47.11%	71.52%	65.10%	66.34%	48.00%	17.61%
	SB3	**6.45%**	No Data	No Data	16.30%	15.27%	23.36%	39.97%	26.85%	56.45%	26.38%	16.93%
	SB4	49.46%	42.15%	No Data	36.91%	53.39%	61.79%	**98.09%**	**95.15%**	**100.00%**	67.12%	26.43%
	SB5	58.26%	36.90%	No Data	62.39%	55.28%	71.86%	88.41%	84.63%	91.55%	68.66%	18.95%

4.3 Winter 2017 Results by Ecoregion

4.3.1 Outer Bay

Eelgrass cover in the Outer Bay ecoregion has been highly variable among winter surveys over the course of the study (Figure 11). Average winter eelgrass cover (24.89%) in 2017 declined since 2016, reaching lows comparable to those observed in 2007 and 2011 (Figures 9 and 11). Eelgrass percent cover of individual transects ranged from 2.93% to 46.03% (Table 7). Transect OB2 had the highest cover (46.03%); Transects OB1 and OB3 had similar cover (38.97 and 30.84% respectively); and Transects OB4 and OB5 had similar percent cover (5.66 and 2.93%, respectively).

4.3.2 North Bay

The North Bay ecoregion average eelgrass percent cover was 55.66% in Winter 2017, up 6.35% from 2016, its highest cover since surveys began in 2007 (Figures 9 and 11). Eelgrass percent cover of individual transects varied widely, ranging from 17.65 to 73.43% (Table 7). Transect NB1 had the highest cover (73.43%); Transects NB2 and NB3 were similar (66.67 and 64.89% respectively); and Transect NB4 had the lowest cover (17.65%). Transect NB5 cannot be effectively surveyed due to the relocation of the Navy marine mammal facilities causing obstructions in the transect path and security concerns.

4.3.3 North Central Bay

North Central Bay average eelgrass percent cover for Winter 2017 was 54.70%, up 2.31% from 2016, continuing a steady increase seen since 2012 to its highest level since surveys began in 2007 (Figures 9 and 11). Eelgrass percent cover of individual transects varied widely, ranging from 24.7 to 88.6% (Table 7). Transect NC5 had the highest cover (88.6%); Transects NC2, NC3, and NC4 had moderate cover (47.67 to 63.85%); and Transect NC1 had the lowest cover (24.7%).

4.3.4 South Central Bay

South Central Bay average eelgrass percent cover for Winter 2017 was 46.7%, a slight increase of 2.28% from 2016 (Figures 9 and 11). Eelgrass percent cover of individual transects varied widely, ranging from 17.72 to 75.33% (Table 7). Transect SC2 had the highest cover (75.33%); Transects SC3, SC4, and SC5 had moderate cover (35.39 to 56.36%); and Transect SC1 had the lowest cover (17.72%).

4.3.5 South Bay

The South Bay ecoregion average eelgrass percent cover in Winter 2017 was 54.69%, a marked decrease of 12.89% from 2016 (Figures 9 and 11). Eelgrass percent cover of individual transects varied widely, ranging from 34.2 to 90.95% (Table 7). Transect SB4 had the highest cover (90.95%); Transects SB1, SB2, and SB5 had moderate cover (40.65 to 61.2%); and Transect SB3 had the lowest cover (34.2%). Eelgrass cover for Transect SB5 was notable displaying a substantial decrease of 47.78% from winter 2016 to 2017.

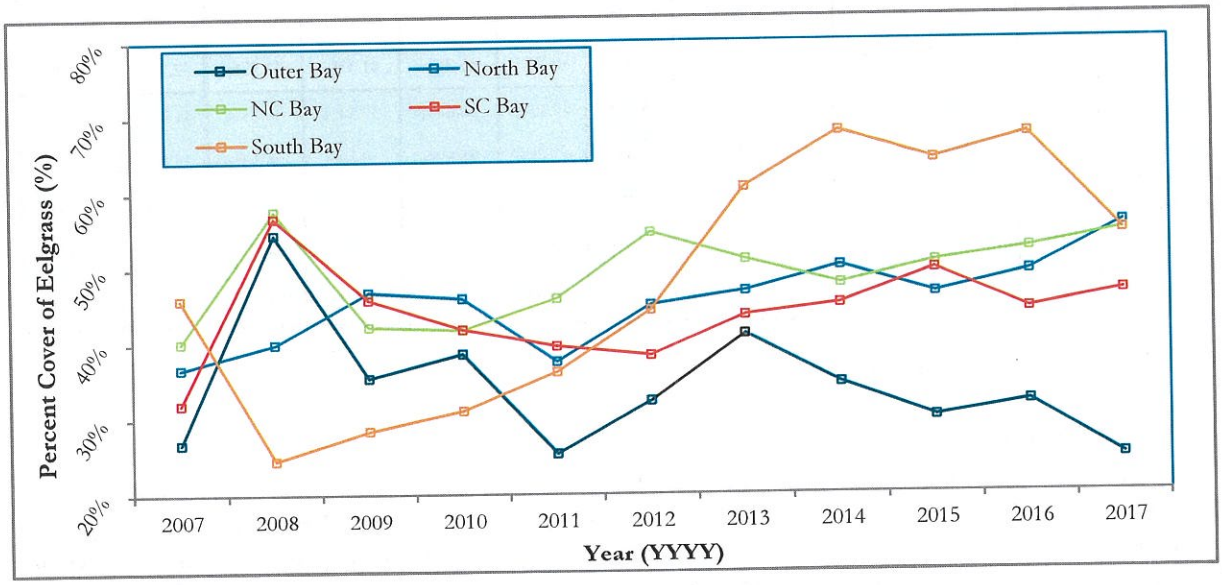

Figure 11. Mean Percent Eelgrass Cover by Ecoregion During Winter Surveys (March/April), 2007 to 2017. Ecoregion Means were Based on 5 Transects per Season/Year.

Table 7. Winter Eelgrass Percent Cover by Year and Averages and Standard Deviations Across Years by Transect, 2007-2017. High Cover/Low Cover for Individual Years.

Region	Site	Percent Cover by Year											2007-2017	
		2007	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*Avg.*	*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%	46.22%	17.18%
	OB2	49.35%	74.43%	17.05%	22.93%	20.45%	27.38%	52.15%	33.75%	40.32%	49.00%	46.03%	39.35%	16.33%
	OB3	31.41%	51.90%	39.69%	60.13%	56.10%	62.98%	60.17%	71.58%	58.26%	61.65%	30.84%	53.16%	12.77%
	OB4	16.42%	34.05%	30.51%	17.82%	9.73%	**8.53%**	**10.11%**	10.08%	8.94%	9.03%	5.66%	14.63%	8.99%
	OB5	20.38%	35.95%	34.18%	26.95%	18.18%	13.45%	20.80%	13.85%	**2.00%**	**2.47%**	**2.93%**	17.38%	11.42%
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%	75.72%	6.23%
	NB2	33.76%	24.64%	68.06%	33.24%	15.55%	45.35%	45.50%	52.51%	50.34%	62.29%	66.67%	45.27%	16.32%
	NB3	24.57%	43.88%	32.12%	52.67%	59.33%	52.21%	56.95%	72.25%	50.83%	48.67%	64.89%	50.76%	13.02%
	NB4	13.64%	8.68%	13.71%	12.99%	4.56%	11.89%	16.09%	**4.88%**	12.20%	12.50%	17.65%	11.71%	3.95%
	NB5	24.33%	41.56%	47.24%	42.94%	35.88%	47.11%	42.86%	No Data	No Data	No Data	No Data	40.27%	7.41%
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%	19.35%	9.75%
	NC2	31.84%	71.80%	25.41%	30.27%	43.62%	52.65%	41.28%	56.12%	55.50%	56.56%	63.85%	48.08%	14.09%
	NC3	38.53%	73.07%	34.02%	68.36%	65.72%	58.09%	56.97%	43.51%	58.80%	43.81%	47.67%	53.50%	12.23%
	NC4	64.00%	52.27%	37.17%	43.85%	53.08%	54.72%	54.44%	51.46%	44.54%	41.28%	48.66%	49.59%	7.15%
	NC5	58.19%	78.91%	76.83%	53.67%	47.85%	**72.26%**	**88.61%**	75.48%	82.95%	94.62%	88.60%	74.36%	14.51%
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%	29.46%	18.33%
	SC2	62.43%	**85.86%**	**77.05%**	60.52%	65.28%	54.85%	82.70%	76.60%	73.36%	79.78%	75.33%	72.16%	9.48%
	SC3	39.47%	No Data	40.62%	43.72%	40.23%	34.18%	44.40%	46.39%	46.26%	49.09%	48.81%	43.32%	4.45%
	SC4	31.52%	58.82%	54.30%	No Data	33.80%	33.50%	48.00%	56.30%	58.96%	43.68%	56.36%	47.52%	10.56%
	SC5	13.18%	14.96%	26.09%	11.69%	15.00%	30.90%	29.32%	39.04%	41.43%	38.95%	35.29%	26.89%	10.87%
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%	38.76%	10.83%
	SB2	27.65%	18.72%	20.80%	14.01%	30.85%	49.66%	50.24%	60.04%	60.00%	60.00%	61.20%	41.20%	18.01%
	SB3	33.42%	**3.17%**	**3.12%**	**4.92%**	**0.35%**	21.75%	37.13%	55.48%	32.23%	43.58%	34.20%	24.49%	18.10%
	SB4	63.23%	26.54%	41.32%	54.45%	**76.91%**	46.37%	84.07%	**94.50%**	**100.00%**	**100.00%**	**90.95%**	70.76%	24.56%
	SB5	58.37%	51.04%	47.34%	48.58%	55.84%	62.97%	78.65%	87.94%	81.55%	88.43%	40.65%	63.76%	16.57%

5.0 Discussion

Annual average percent cover for Summer 2016 and Winter 2017 were similar (49.35 and 47.33%, respectively), and within 1 to 2% of corresponding seasonal values of the prior year. Generally, the recent survey values were consistent with overall seasonal values over the past three years, ranging from 49 to 50% during summer and 47 to 49% during winter for the 2014-2017 period. In contrast, the period between 2007/2008 and 2013 ranged from 39 to 46% during summer and 36 to 47% during winter.

Eelgrass mean percent cover during the 2016-2017 survey period was similar and relatively high for three of the San Diego Bay ecoregions (North Bay, North Central Bay, and South Central Bay), ranging from approximately 51 to 57% for summer and 47 to 56% for winter. The South Bay mean percent cover of eelgrass was within the range of other bay ecoregions during winter (56%); however, eelgrass cover expanded and was substantially greater during summer (73%).

Mean eelgrass cover was substantially lower in the Outer Bay ecoregion across seasons (15 to 25%) compared to other ecoregions within San Diego Bay. This difference likely relates to the more exposed environment at the entrance to the bay, compared to the more protected conditions within the bay.

Long-term interannual variability in eelgrass cover has differed among the ecoregions. Overall eelgrass cover across transects has varied within a relatively narrow range, between 30 and 60%, for the North Bay, North Central Bay, and South Central Bay ecoregions. In contrast, overall eelgrass cover across transects has ranged from less than 20 to more than 50% for the Outer Bay and from less than 20 to more than 70% in the South Bay.

Long-term temporal variability in average cover of eelgrass in the Outer Bay area appears to have been influenced by more intense storm and wave conditions associated with El Niño conditions. The 2015-2017 El Niño was one of the strongest on record (National Oceanic and Atmospheric Administration [NOAA] 2017); average eelgrass cover in the Outer Bay during this period was low during both summer and winter periods (<35%). Smaller El Niño events occurred in 2007 and 2010 (NOAA 2017); average eelgrass cover values were low (<30%) during winter of those events, and likely affected summer values, which were relatively low in 2008 and 2011 (<35%). Though variable between winter and summer, eelgrass cover generally ranged between 30 and 55% during other survey years with more moderate climate conditions.

The South Bay ecoregion has had an overall increase in eelgrass cover since 2013. This ecoregion is characterized by predominantly shallow water depths with narrow, deeper channels. Most eelgrass occurs at depths of -2 to -6 ft MLLW in this area. Visibility generally is less in this area of the bay, and likely limits the depth distribution of eelgrass. As noted in Figure 7, eelgrass persistence has been less along the main channel margins; water depths decrease to -6 ft and deeper in this area.

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