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March 31, 2023
M&A #18-080-04

Rebecca Schwartz Lesberg
Coastal Policy Solutions
rebecca@coastalpolicysolutions.com

Re: 2022 Richardson Bay Eelgrass Inventory and 2019-2022 Change Analysis

Dear Rebecca:

This memorandum serves to transmit information regarding the 2022 Richardson Bay eelgrass (*Zostera marina*) survey results and the results of the 2019-2022 eelgrass change analysis.

PURPOSE AND INTRODUCTION

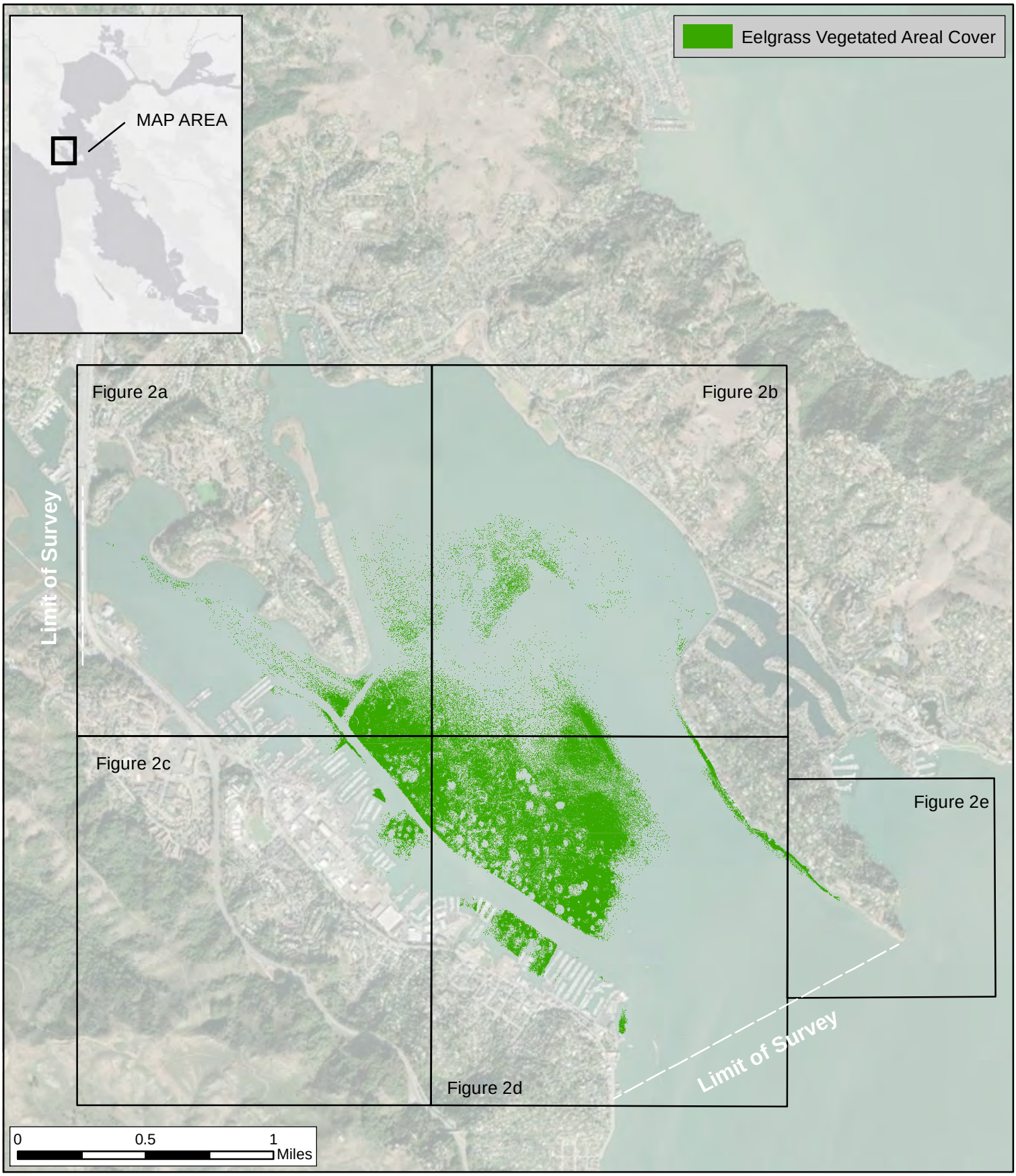
Merkel & Associates Inc. (M&A) was retained by Coastal Policy Solutions to conduct a baywide eelgrass (*Zostera marina*) survey within Richardson Bay. The purpose of the survey was to provide a tool for evaluation of change in the eelgrass habitat since the time of the last baywide survey, which was conducted in 2019. The results will contribute to the identification of maximum extent and frequency of eelgrass occurrence throughout Richardson Bay as the Richardson Bay Regional Authority (RBRA) commences implementation of eelgrass restoration and recovery practices within the bay. The survey results will facilitate the assessment of eelgrass impacts associated with moorings and support long-term assessment of the effects of the RBRA Eelgrass Protection and Management Plan (EPMP). The survey results will also facilitate planning for additional eelgrass restoration within Richardson Bay during subsequent seasons.

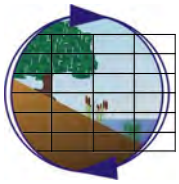
PROJECT LOCATION AND SURVEY AREA

Richardson Bay is located on the west side of San Francisco Bay near the Bay's ocean inlet. The bay is just north of San Francisco in southern Marin County. The survey covered approximately 2,500 acres of the Bay but did not include the marinas and marina basins along the Sausalito shoreline locations or the extreme shallows extending towards Mill Valley above the Highway 101 Bridge (Figure 1).

SURVEY METHODOLOGY

M&A conducted a baywide comprehensive eelgrass inventory in Richardson Bay, California between June 15 and July 5, 2022. Eelgrass habitat was mapped using a combination of interferometric sidescan sonar (ISS) to survey subtidal eelgrass and low-altitude unmanned aerial vehicle (UAV) true color imagery to capture intertidal eelgrass distribution throughout the bay. Overlap in the survey methodologies provided a good means to examine the consistency and accuracy of the two methods. Surveys provide comprehensive coverage of Richardson Bay.





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Eelgrass Distribution - August 2022
2022 Richardson Bay Eelgrass Survey
Richardson Bay, CA

Figure 1

Subtidal eelgrass surveys were conducted off of Merkel and Associates' survey vessel Ocean King I using a 468kHz SEA SWATHplus-H sonar with sub-decimeter accurate RTK GPS and an integrated inertial motion unit (IMU) and sound velocity sensor. The total propagated error with this system is approximately 0.5-1 m horizontal and 0.1 m vertical in the survey water depths. Sidescan backscatter data were acquired with a swath width setting of 31 meters on both the starboard and port channels for a 62-m wide swath. The rigid hull mounted interferometric sidescan system integrates motion sensors to control for heave, pitch, and roll as well as a dual antenna positioning system and electronic compass to control for vessel position and yaw. This rigid integration of the ISS transducers within the positioning, attitude, and sound velocity sensors provides significantly increased precision and accuracy over conventional towfish sidescan sonar equipment.

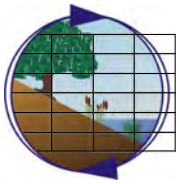
The survey was conducted by navigating parallel tracklines, spaced to allow for overlap between adjoining sidescan swaths. Survey swaths were navigated until the entirety of the navigable survey area was captured in the survey report. All data were collected in latitude and longitude using the North American Datum of 1983 (NAD 83) and converted to the Universal Transverse Mercator system in meters (UTM). Following completion of the survey, sidescan sonar traces were joined together and geographically registered as photomosaics of the bayfloor. The ISS backscatter imagery was then interpreted in ArcGIS software in conjunction with ground-truth information to assess the distribution of subtidal eelgrass.

UAV aerial surveys were conducted during low-tide conditions from an altitude of 275 feet above water level, using automated flight control software to ensure consistent image overlap (75%) and seamless coverage of the bay. Following processing of the aerial imagery into a rectified orthomosaic, targets acquired during the ISS survey (supported by RTK GPS positional information) were used to georeference the resulting orthomosaic and co-register the hydroacoustic and aerial imagery data. Eelgrass from the UAV imagery was mapped using a combination of raster analysis and vector mapping to digitize eelgrass throughout the survey area. Eelgrass data representing intertidal and subtidal components of the bay's eelgrass population were merged into a single shapefile layer for subsequent analysis.

RESULTS

Eelgrass distribution within Richardson Bay during the 2022 inventory follows the same general pattern as that previously documented with the core eelgrass area being found in the shallows of the central portion of the bay and a lobe of eelgrass extending to the northeast into the Richardson Bay Audubon Sanctuary (Figures 1 and 2a-e). Additional eelgrass extends along the shoreline margins of Belvedere and Sausalito. Eelgrass spatial data developed from this inventory are provided for planning and large-scale management purposes only and should not be used for project-specific impact assessment applications.

Eelgrass mapping during 2022 was conducted to be spatially explicit in order to support restoration planning wherein eelgrass gaps associated with keel drags and mooring scars can be fully identified. However, prior regional surveys have relied on eelgrass cover class mapping to define the distribution of eelgrass within the bay. As such, a similar mapping has been developed for 2022. In cover class mapping, the percent bottom cover of eelgrass has been mapped within binned ranges at covers of <5%, 5-20%, 20-40%, and 40-100% eelgrass cover (Figure 3). The quantified area within each cover class is provided in Table 1.



Eelgrass Distribution - August 2022

2022 Richardson Bay Eelgrass Survey
Richardson Bay, CA

Figure 2a

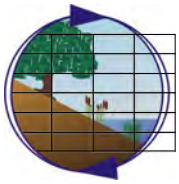


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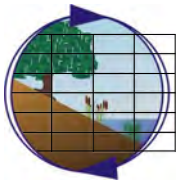
Figure 2b



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Eelgrass Distribution - August 2022

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Figure 2c

Eelgrass Distribution - August 2022

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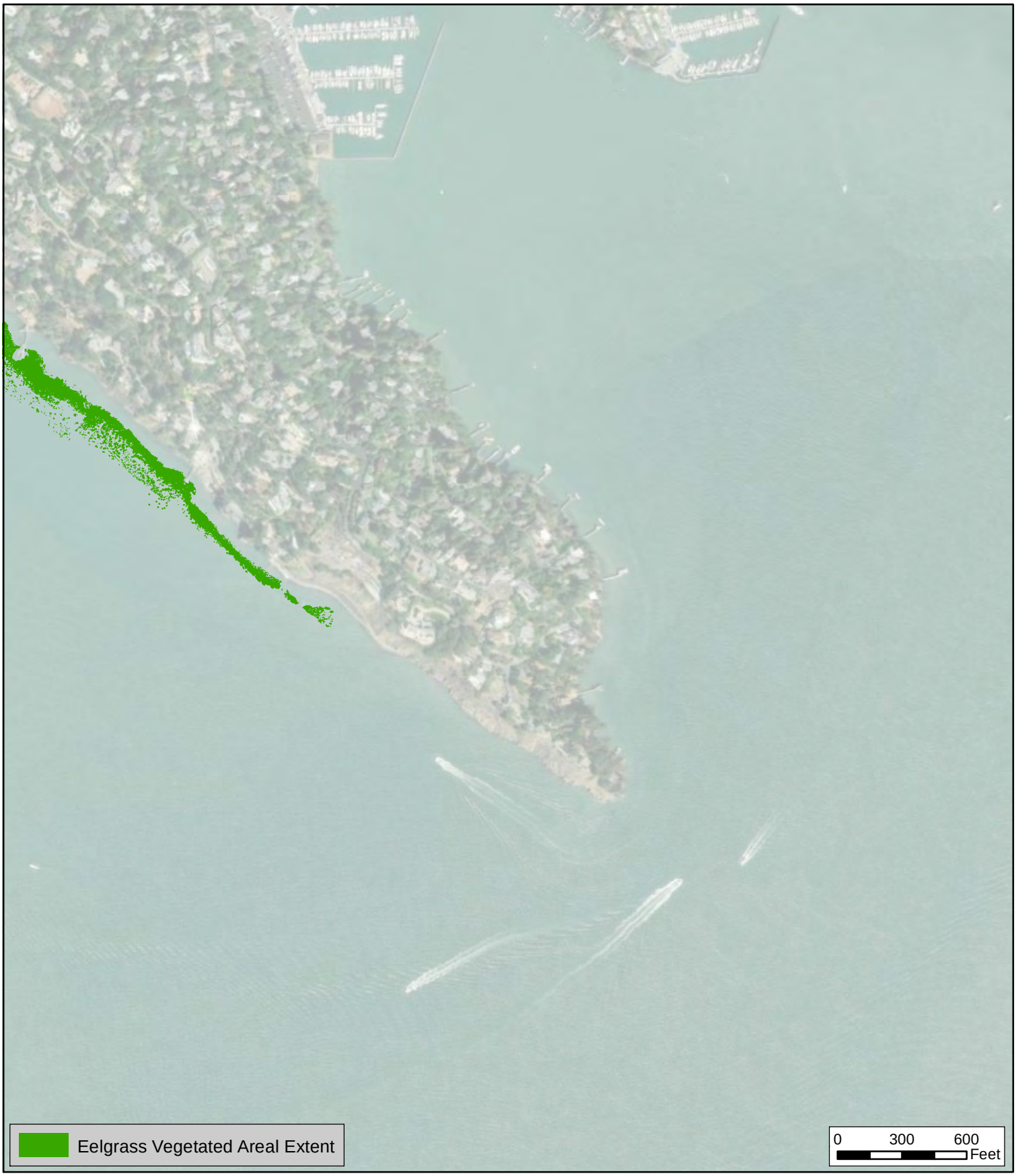
Richardson Bay, CA

Figure 2d



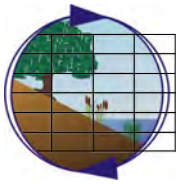


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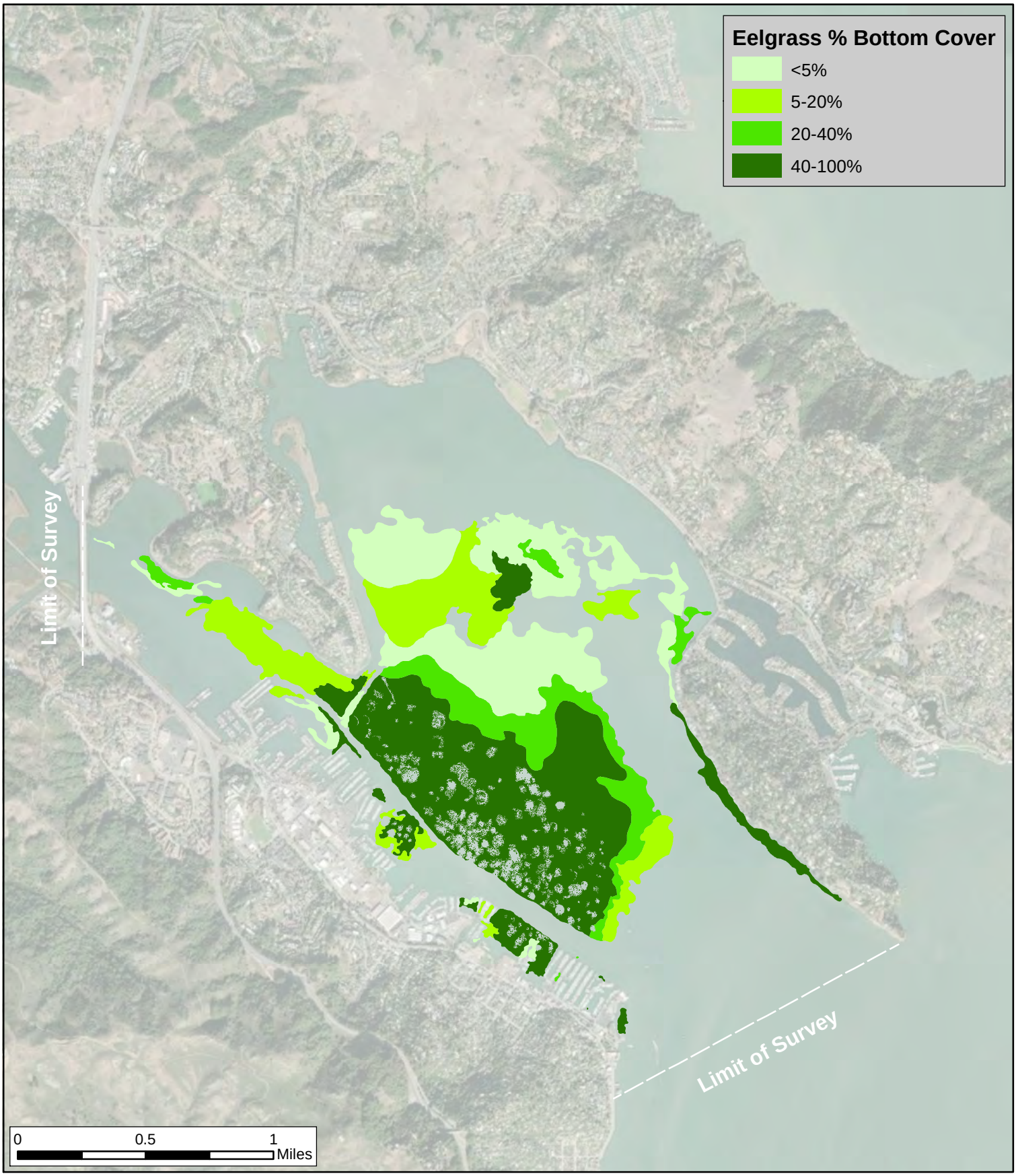
Figure 2e



Eelgrass Percent Bottom Cover
2022 Richardson Bay Eelgrass Survey
Richardson Bay, CA

Figure 3

Table 1. 2022 Eelgrass Area by Cover Class

Density Cover Class	Area (Acres)	% of Total
40-100%	402.6	42.1
20-40%	118.0	12.3
5-20%	173.8	18.2
<5%	262.2	27.4
Total	**956.5**	**100.0%**

CHANGE ANALYSIS

There are multiple ways to examine the change in eelgrass over time. The first is a binary change wherein mapped occurrence of eelgrass, irrespective of cover class, are compared to evaluate change from one period to another. This approach provides a simplified view of the overall change in eelgrass presence across the bay landscape. A second method of examining the change is to evaluate shifts in eelgrass cover class over time. In this case, areas of the beds that increase or decrease in bottom cover can be tracked along with the degree of change in coverage. Using this approach, it is possible to evaluate changes in bed condition through time, even where beds continue to persist. This second method provides information about the nature of declines as they occur, and by examining patterns of increase or decrease in the bed bottom cover levels, it is possible to make inferences about possible driving mechanisms of change.

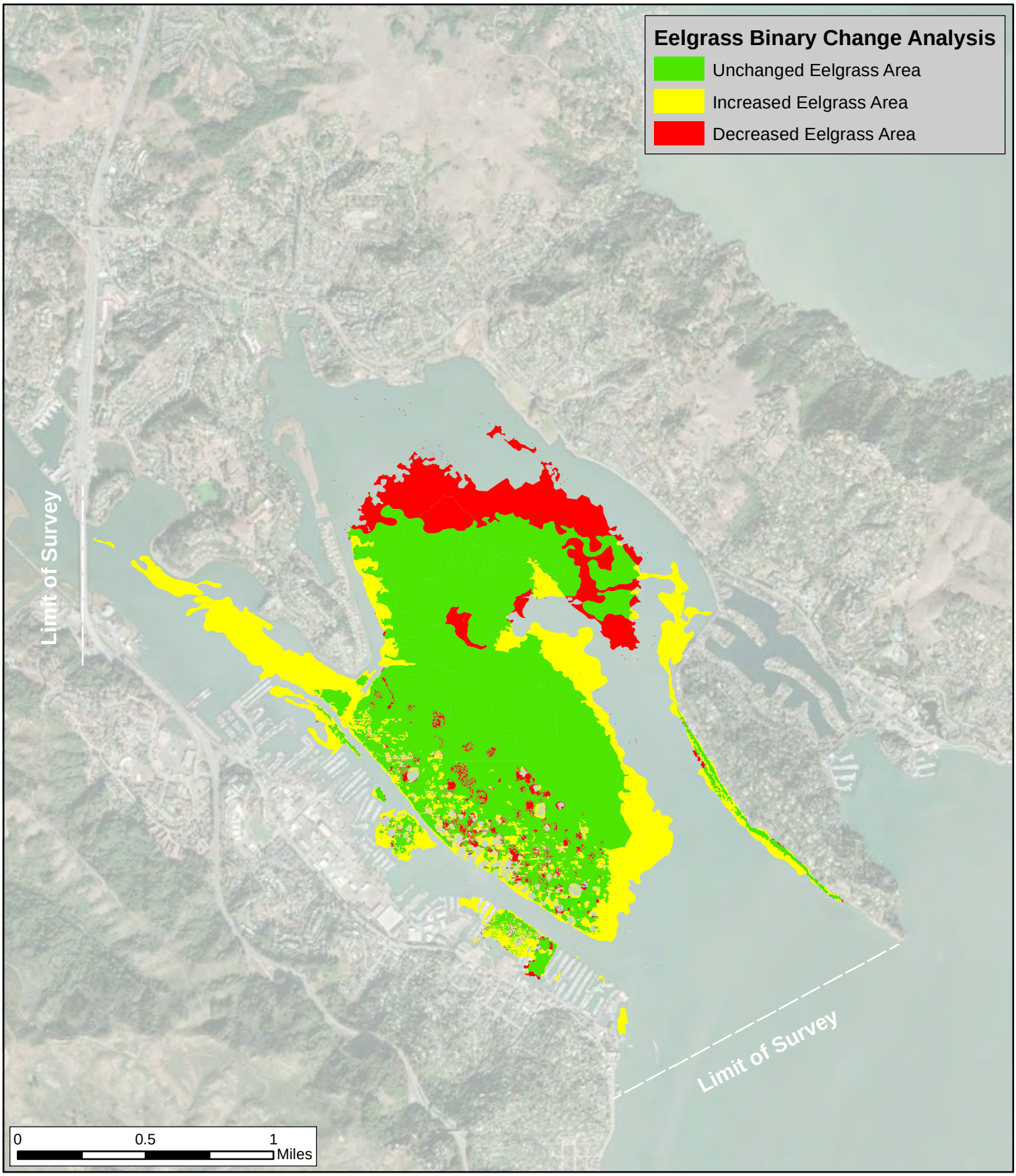
BINARY EELGRASS DISTRIBUTION CHANGE (2019-2022)

Under a binary change analysis mapped eelgrass is collapsed into a single layer of eelgrass and compared to another layer from a different time step. In the present case, the 2022 eelgrass distribution has been compared to the 2019 distribution. Eelgrass is then classified as increasing, decreasing, or remaining unchanged between analyzed time steps. Eelgrass in Richardson Bay principally expanded in deeper waters and along the northwestern arm towards the Highway 101 Bridge. Concurrently, the northeastern shallows revealed a general decline in eelgrass extent. Within the core of the eelgrass beds, the changes in density are more mixed and generally associated with shifting patterns of anchor out vessels on moorings in the eelgrass beds, as well as commencement of mooring scar restoration activities (Figure 4).

Overall, from 2019 to 2022 the mapped eelgrass increased in overall mapped distribution from 841.8 acres to 956.5 acres. However, this change included both a 15.2 percent decline in beds that were represented in the 2019 data, accompanied by a greater 26.6 percent increase in eelgrass elsewhere in the bay. A total of 58.1 percent of the eelgrass remained stable in distribution between 2019 and 2022 (Table 2).

Table 2. 2019 to 2022 Eelgrass Distribution Change

Change	Area (Acres)	% of Total
Unchanged Eelgrass Area	656.0	58.1%
Increased Eelgrass Area	300.5	26.6%
Decreased Eelgrass Area	171.6	15.2%



Eelgrass Binary Change Analysis 2019-2022

2022 Richardson Bay Eelgrass Survey
Richardson Bay, CA

Figure 4

DENSITY CLASS CHANGES (2019-2022)

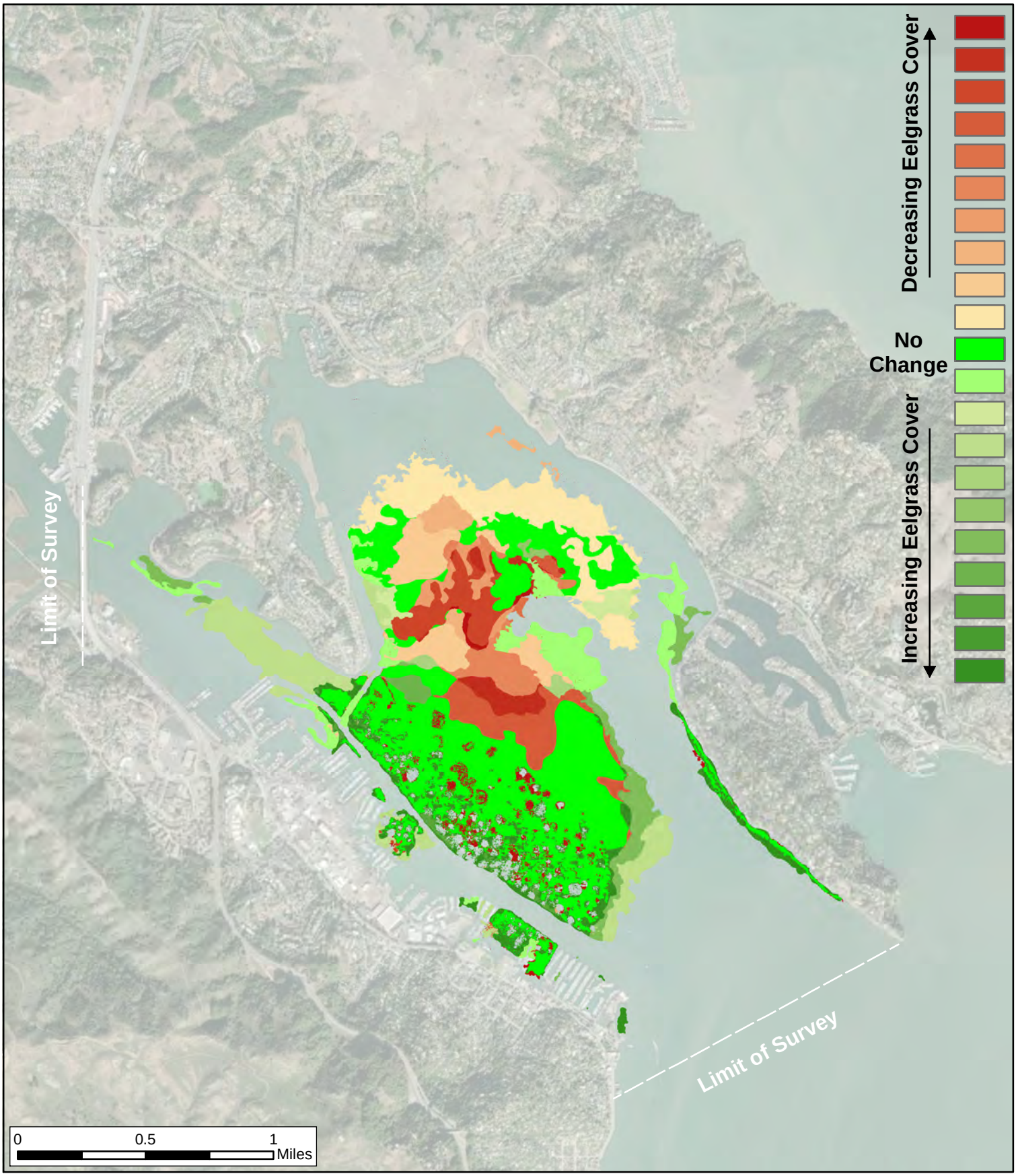
To evaluate changes in eelgrass cover across the bottom, the eelgrass cover class polygons for 2019 and 2022 were attributed with the mean percent cover value within each class and converted to raster layers. The 2019 cover class raster was then subtracted from that of the 2022 survey to provide a surface that represents changes in cover from survey to survey. This process produces a spectrum of change from a maximum increase to a maximum decrease in cover. The maximum increase is when areas that lacked eelgrass in 2019 had a 40-100% cover class in 2022. The maximum loss would occur with the reciprocal change. When eelgrass cover class conditions did not change, the subtraction led to a zero value that was identified as no change (Figure 5).

This analysis approach allows for evaluating spatial dynamics across the cover classes and provides an indication of where significant gains and losses are occurring in the beds. More specifically, areas represented by low bottom coverage of <5% that go to 0% cover are not as surprising or alarming as areas that have high coverage that decline more precipitously, even though they may retain eelgrass at low densities.

This analysis reveals that a fairly substantial decline in eelgrass beds within the northeast quadrant of the bay had begun to materialize between 2019 and 2022, even though it was not detectable in the binary change analysis. Also of note, is that this change is believed to have commenced between late 2022 and mid-2023, based on examination of more focused surveys conducted in October 2022 that did not reveal the observed changes seen in the 2023 survey data. Coincident with these changes have been increases in lower cover classes of eelgrass along the deeper margins of beds and, somewhat interestingly, up the channel towards Mill Valley (Figure 5).

The observed patterns of loss suggest a potential spread of decline from the shallows of the Richardson Bay Audubon Sanctuary to the southwest into the core of the eelgrass beds. This type of shallow to deep decline within areas that do not have a freshwater input source such as a river delta is often associated with thermal stress. Past observations support this potential for initial eelgrass decline spread. However, in mid-2022, Audubon California documented a near complete loss of eelgrass within a portion of the core of the beds, extending to the west of the southern extent of declines noted in this inventory (Audubon California 2022). The declines observed by Audubon, are pronounced and significant in scale. Further, they occurred in less than a month between surveys conducted by M&A and those conducted by Audubon on August 14, 2022. Further, a follow-up survey in October 2022 confirmed the void observed in aerial flights by Audubon were complete losses of eelgrass rather than a haze in the water column.

The spread of decline in beds from the northern shallows and into the core of subtidal eelgrass, and the rate and severity of decline noted are suggestive of an outbreak of eelgrass wasting disease. This is based on indirect evidence including the rapid rate of decline and the impact to core eelgrass beds, as well as a spread from intertidal to subtidal beds. Unfortunately, no direct evidence has been noted to confirm this suspicion. Wasting disease is caused by the commonly occurring protist *Labyrinthula zosterae* that is found in most eelgrass beds. Normally, this species is associated with the breakdown of dead and dying eelgrass tissues. However, on occasion, the species becomes virulent, attacking healthy tissue resulting in a pattern of rot that severs leaves from the plants resulting in rapid mortality of plants in the beds. Disease spreads by contact of infected tissue with non-infected leaves. As leaves are detached, the infected floating leaves drag over heathy leaves reaching the surface at low tide. This tends to result in an intertidal to subtidal spread pattern and concentrated losses in the densest eelgrass. While the triggers for virulence are not well known, there is a correlation between elevated temperatures, high nutrient levels, and elevated salinities.



Eelgrass Cover Class Change Analysis 2019 - 2022
2022 Richardson Bay Eelgrass Survey
Richardson Bay, CA

Figure 5

LONG-TERM CHANGES IN EELGRASS WITHIN RICHARDSON BAY

To evaluate the changes in eelgrass extent over time, it is useful to examine both the cumulative cover class area as well as the 100 percent equivalency area (Figure 7). This is the total area of eelgrass that would be present at a 100 percent bottom cover if the eelgrass were aggregated within a consolidated footprint. This value is beneficial when evaluating eelgrass bed productivity, biomass, or other metrics dependent upon plant density, such as carbon cycling and storage. The 100 percent equivalency is determined by multiplying the area of each cover class by the mean percent cover represented by the class and then summing across all classes. The results of the two analyses show that while the overall area of eelgrass expanded 13.6 percent between 2019 and 2022, the diminishing cover density observed in 2022 means that the 100 percent cover equivalency declined by 24.2 percent between the same years. While not reflected in the changes observed by July 2022, it is expected the continued declines of the core of the eelgrass beds observed by Audubon California in August 2022 and Merkel & Associates in October 2022, would further impair the eelgrass extent by late 2022.

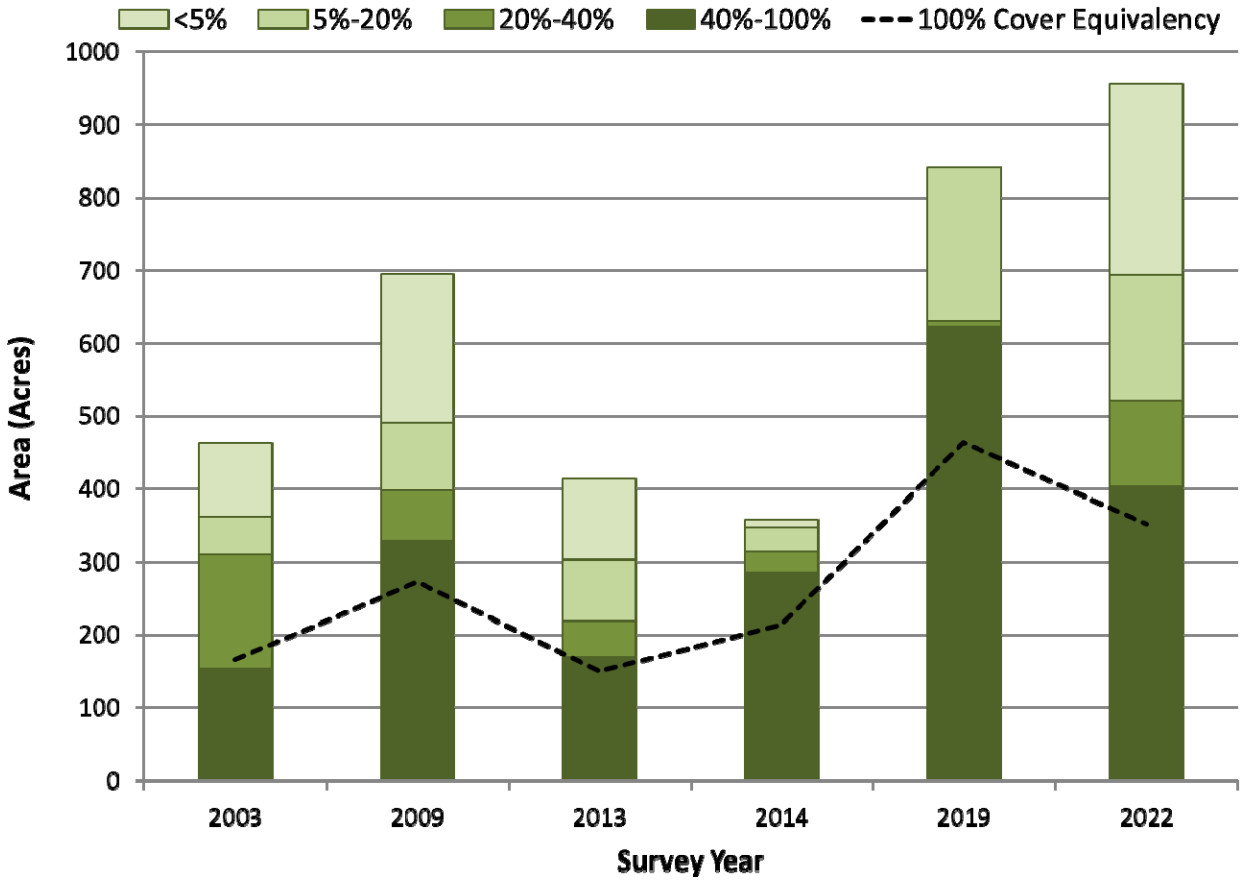


Figure 6. Changes in Richardson Bay Eelgrass Area Through Time

The present survey documents substantial declines in the densest portions of the eelgrass beds within Richardson Bay between 2019 and 2022. Simultaneously there was an expansion of bottom coverage at lower densities. This expansion may be the beginning of bed expansions towards deeper elevations, or it may be a temporary expansion that will ultimately see contractions in the future.

It has been a pleasure to support you and the RBRA in this endeavor and look forward to the next phases of action. If you have any questions regarding the results or analysis presented herein, feel free to contact me at (858) 560-5465.

Sincerely,

Keith W. Merkel
Principal Consultant

REFERENCES

Audubon California. 2022. Measuring Eelgrass Damage in Richardson Bay. December 2022.

Coastal Policy Solutions. 2021. Richardson Bay Regional Agency: Richardson's Bay Eelgrass Protection and Management Plan.

Merkel & Associates. 2019. Richardson's Bay Regional Agency Ecologically-based Mooring Feasibility Assessment and Planning Study. November 2019.