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RICHARDSON BAY
EELGRASS RESTORATION AND ADAPTIVE MANAGEMENT PLAN

MARIN COUNTY, CALIFORNIA

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Marin County, California

PURPOSE AND INTRODUCTION

The Richardson Bay Regional Agency (RBRA) is a joint powers authority comprised of the City of Belvedere, the City of Mill Valley, the Town of Tiburon, and the County of Marin established in 1985. The mission of the Agency is to maintain and improve the navigational waterways, open waters, and shoreline of Richardson Bay. RBRA holds regulatory authority over large portions of Richardson Bay's waters (Figure 1).

Eelgrass restoration in general, and in Richardson Bay specifically, has been highlighted as a priority in several local, regional, and state conservation plans, including California Ocean Protection Council (OPC) goal of 1,000 acres of eelgrass restoration across the state by 2025 , the San Francisco Bay Restoration Authority goal of restoring at least 150 acres of submerged aquatic vegetation, and the San Francisco Bay Subtidal Habitat Goals Report, which identified Richardson Bay as a priority location for eelgrass restoration. The San Francisco Estuary Partnership's 2022 Estuary Blueprint calls for 75 acres of eelgrass restoration by 2031 and the Richardson Bay project is included on the San Francisco Bay Joint Venture's Priority Project List.

Over the past several decades, damage from anchors, chains, and other ground tackle (referred to as "anchor scour") has removed approximately 80 acres of eelgrass from Richardson Bay. Recent removal of derelict and abandoned vessels and the implementation of a No Anchor Area/Eelgrass Protection Zone has created an opportunity to restore much of what has been lost. This restoration is particularly urgent in the face of climate change and present predictions that Richardson Bay eelgrass will have the greatest resilience to sea level rise of all areas within San Francisco Bay (Gilkerson et al., in prep.).

The RBRA is undertaking a broad effort to improve the health, vibrancy, water quality and climate resilience of Richardson Bay, with support from the U.S. Environmental Protection Agency (EPA), and other partners and funding sources. Richardson Bay is a 3,100-acre embayment located just inside and north of San Francisco's Golden Gate and represents the largest eelgrass restoration opportunity within San Francisco Bay today. This expanded environmental focus provides greater protection to eelgrass and shallow bottom habitat from vessel anchoring and mooring within the shallows of Richardson Bay has afforded opportunities to restore eelgrass in damaged areas following mooring removals. This work has already been initiated under funding directed by NOAA's Restoration Center and would follow methods developed and implemented during prior restoration within Richardson Bay through funding administered by National Marine Fisheries Service and NOAA's Restoration Center that has been underway since 2014 (Merkel & Boyer 2022 and 2023).

In May 2023, the RBRA was awarded a $2.8 million grant from the San Francisco Bay Area Water Quality Improvement Fund of the EPA to support eelgrass restoration and other bay protection and improvement efforts, in collaboration with project partners. This work calls for the restoration of at least 15 acres of eelgrass over four years, development of plans for additional restoration and

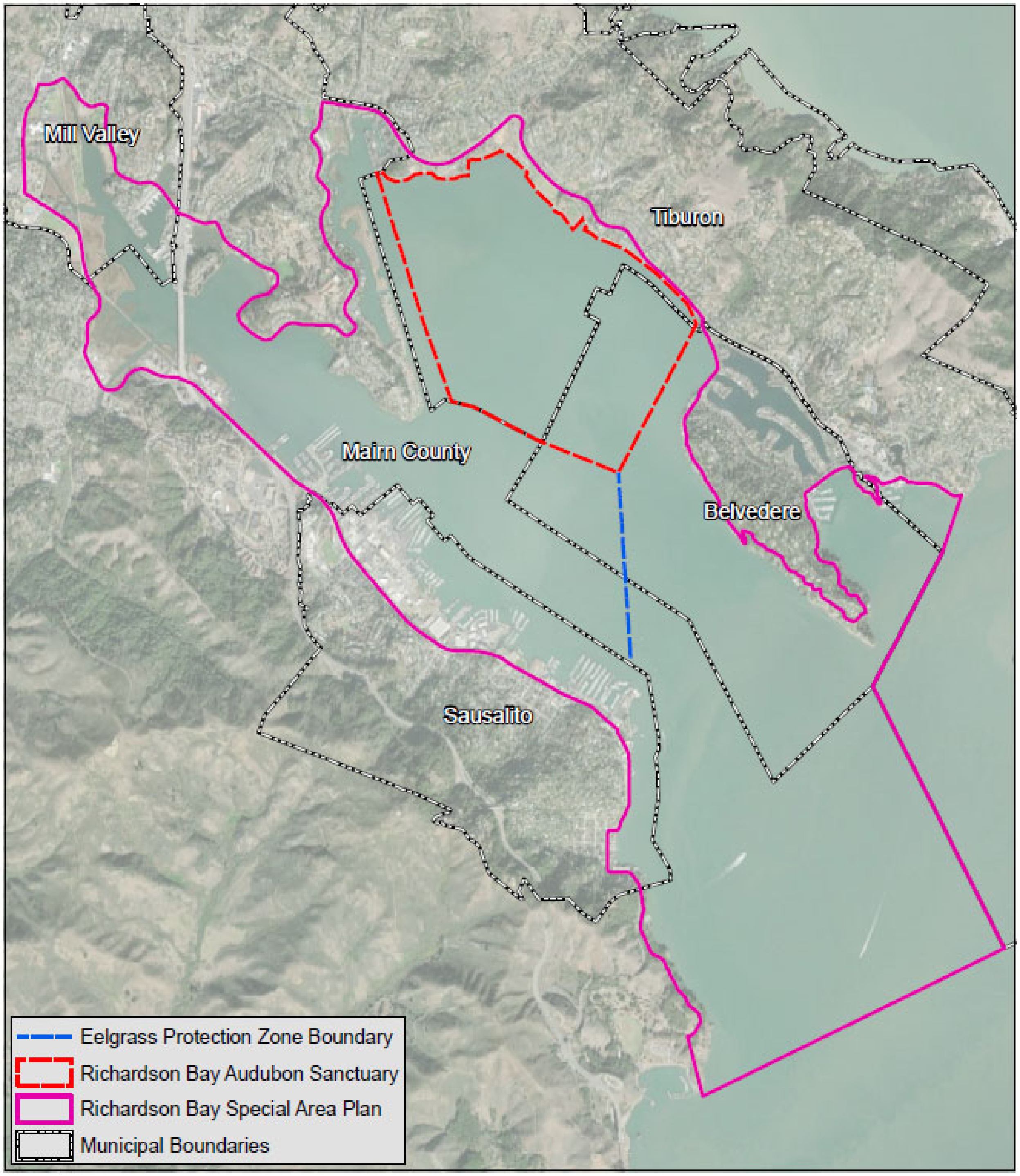


Figure 1. Richardson Bay Jurisdictional Map

adaptive management, training for early career conservationists from severely disadvantaged communities, and continued development of shareable, scalable best-practices for eelgrass restoration in areas of mooring and anchorage damage.

This document serves as the eelgrass habitat Restoration and Adaptive Management Plan (RAMP) and is intended to guide the initial restoration of at least 15-acres of eelgrass funded under the present EPA grant, while providing a broader road map targeting the ultimate restoration of approximately 75 acres of eelgrass to anchor scour areas. This plan has been formulated around positive adaptive restoration activities presently underway.

BACKGROUND

Boats have been anchoring in the calm, protected waters of Richardson Bay since at least the 1890s. The attributes that make Richardson Bay attractive to boaters are also those that contribute to ideal habitat for the seagrass, *Zostera marina*, known as common eelgrass. Shallow depths, regular tidal flushing, and relatively low turbidity have made Richardson Bay an eelgrass stronghold, even during periods of region-wide eelgrass decline. Eelgrass is critically important for the health of coastal estuaries as well as climate resilience for coastal communities. Eelgrass beds reduce coastal erosion, sequester carbon, reduce ocean acidification, and provide nursery habitat for commercially, recreationally, and ecologically important marine life (e.g., Pacific herring and Dungeness crab).

The San Francisco Bay Conservation and Development Commission (BCDC) adopted the Richardson Bay Special Area Plan in April 1984 to guide actions within Richardson Bay. This plan incorporated policies that called for restricting houseboats and live-aboards to marina berths, removal of anchor outs in Richardson Bay, and limitation on the number of live-aboards and houseboats within recreational boat marinas. Despite these policies, the number of anchor-out vessels grew from about 90 boats in the 1970s to over 215 vessels in 2014, with many boats experiencing disrepair and abandonment. When the number of boats using the Richardson Bay anchorage was relatively low and boats in the anchorage were well maintained, their effect on the eelgrass habitat was presumably modest. However, as more boats arrived in Richardson Bay and vessels migrated into the shallower eelgrass-supporting parts of the bay, an increasing impact to eelgrass began to be noted.

Vessels were anchored and moored in Richardson Bay on ground tackle of varying design and effectiveness, which resulted in considerable damage to eelgrass habitat. As a result, investigations were undertaken by RBRA to evaluate potential opportunities to implement a mooring program, which would retain the bay as an anchorage while protecting eelgrass. This led to the completion of Ecologically-based Mooring Feasibility Assessment and Planning Study (Merkel & Associates 2019). Concurrently, RBRA began to update and strengthen policies pertaining to anchoring and enforcement requirements for vessels on the bay. While progress was being made to address the anchor-out resource damage, a push was made towards establishing timelines and milestones to remove the illegally anchored vessels and restore the eelgrass habitat within the bay.

This led to the development of an agreement between the RBRA and BCDC that set-forth next steps to advance bringing the bay back into compliance with the requirements of the Special Area Plan

(BCDC and RBRA 2021). Among the terms of the agreement are several that are specifically relevant to restoration and management of eelgrass in the bay. These are directly cited as follows:

- ***Eelgrass Habitat Protection**. RBRA will finalize its Draft Eelgrass Protection and Management Plan (EPMP) by December 15, 2021, and submit a copy to BCDC. If RBRA selects a boundary for the Eelgrass Protection Zone that is less protective of eelgrass than the alternatives presented in the RBRA's Draft EPMP then BCDC will consider the new boundary and inform RBRA if this Agreement must be amended to prevent the need for further BCDC oversight. Within 60 days of finalizing the EPMP, RBRA shall petition for any federal administrative action necessary to implement the EPMP's anchoring zone and Eelgrass Protection Zone/no-anchoring zone. BCDC agrees to provide letters of support for federal administrative actions consistent with the draft EPMP. RBRA will complete the administrative actions, including updating RBRA's Ordinances for consistency, by December 15, 2023, subject to extensions of time for circumstances beyond its control. Vessels will be removed from the Eelgrass Protection Zone as soon as possible, but moving boats can be done in phases based on consultation with experts selected by RBRA who are well versed in the California Eelgrass Mitigation Policy and its Implementing Guidelines (hereinafter, "CEMP") and its periodic updates. In any event, no vessels will anchor in the Eelgrass Protection Zone after October 15, 2024.*

- ***Eelgrass Habitat Restoration.** During 2022, RBRA will initiate active eelgrass restoration studies within the Eelgrass Protection Zone comparing restoration scenarios such as: (1) Passive (no intervention) restoration of scour pits; (2) Restoring the bay bottom grade of scour pits by adding clean dredged sediment without planting eelgrass; (3) Planting eelgrass in scour pits without first restoring the bay bottom grade of scour pits; and (4) Planting eelgrass in scour pits after restoring the bay bottom grade of scour pits by adding clean dredged sediment. RBRA will report its findings to BCDC.*

  RBRA will develop a ten-year adaptive management plan for eelgrass restoration in Richardson Bay and submit a copy to BCDC. RBRA will begin implementing this plan by December 15, 2023. The ten-year adaptive management plan will be consistent with the Bay Plan and the Richardson Bay Special Area Plan; incorporate the best available science on eelgrass habitat restoration & the CEMP and its periodic updates; and the results of RBRA's restoration study scenarios as they are obtained. Restoration work will be done in a phased approach pursuant to the ten-year adaptive management plan.

  RBRA agrees to pursue grants and other funding to implement the adaptive management plan. RBRA shall implement the ten-year adaptive management plan in a timely manner, notwithstanding any funding shortfalls.

- ***Restoration Collaboration.** BCDC and RBRA agree to collaborate on the reuse of dredged materials from Schoonmaker Point Marina or other local dredging projects for use in eelgrass restoration in Richardson Bay, subject to the Dredged Material Management Office (DMMO) determination that the dredged materials are clean and suitable for this purpose.*

- ***Prevention of Future Subtidal Habitat Damage.*** *RBRA shall prevent future subtidal habitat damage by identifying and undertaking all necessary and proper measure to ensure (1) that no new vessels anchor in the Eelgrass Protection Zone after December 15, 2021; and (2) that only seaworthy vessels, as defined in RBRA's Transition Plan and with standard removable marine anchoring equipment, are allowed to anchor in the anchoring zone after October 15, 2026. If subtidal habitat damage is caused by vessels relocated from the Eelgrass Protection Zone to the anchoring zone before the ten-year adaptive management plan for eelgrass restoration is implemented, RBRA will take necessary measures to halt the damage and restore habitat conditions within a reasonable timeframe as determined by qualified scientists selected by RBRA. Subtidal habitat damage that occurs after the ten-year adaptive management plan is implemented will be restored pursuant to the provisions of the ten-year adaptive management plan, and/or the Bay Plan and SAP, as applicable.*

- ***Ground Tackle/Moorings****. Removal of ground tackle/ moorings will be consistent with the CEMP and its periodic updates, as well as area-specific research as to what ground tackle will be removed, when it will be removed, and how it will be removed.*

- ***Reporting Requirements.*** *In addition to any reporting requirement specified above, RBRA will provide the following reports to BCDC:*

    a. *Monthly reports, provided to BCDC staff by the 12t h of each month, discussing:*

        i. *Vessel metrics. The number, type, category, and condition of registered and unregistered vessels entering, leaving, and currently anchoring in Richardson Bay; the number of anchoring permits RBRA has issued and any permits not adhered to; the number of moorings installed and their use; the amount of ground tackle/moorings removed or left behind and how this complies with CEMP; and the number of vessels removed or moved pursuant to this agreement by category .*

        ii. *Eelgrass metrics. Progress and results from restoration studies in the Eelgrass Protection Zone; progress on completing and implementing the 10-year adaptive management plan and how it meets the minimum requirements of the CEMP (including goals, performance standards, monitoring performance milestones, and contingency plans); findings on effectiveness of temporary moorings and their removal; new subtidal habitat damage and the RBRA's response.*

    b. *Quarterly reports, provided to BCDC's Enforcement Committee. RBRA staff commits to attend the Committee meeting and address any questions regarding the reporting. Quarterly reports will discuss all the above reporting requirements, and:*

        i. *Vessel metrics. RBRA's efforts to prevent importation of derelict vessels into Richardson Bay; whether RBRA is on pace to meet the obligations of this agreement.*

        ii. *Eelgrass metrics. RBRA's acquisition of restoration funds and how RBRA will address projected budget surplus and/ or deficits; progress on the beneficial* *reuse of dredged materials; effectiveness of eelgrass restoration planning and implementation.*

c. *Annual Reports, provided to the BCDC Commission. RBRA staff commits to attend the Commission meeting and address any questions regarding the reporting. The annual report will summarize the results of the monthly and quarterly reports, and RBRA's progress towards implementing this agreement by the October 15, 2026 deadline for the removal of all illegally anchored vessels.*

While the above terms of agreement are not exhaustive, they establish the essential framework elements for the current plan, which otherwise focuses on the technical process aspects of achieving the eelgrass restoration and management objectives.

EELGRASS RESTORATION IN SAN FRANCISCO BAY

HISTORY AND INSIGHTS INTO EELGRASS RESTORATION IN SAN FRANCISCO BAY

Eelgrass restoration projects have been undertaken in San Francisco Bay since 1985 with an experimental transplant occurring along the Richmond Harbor training wall (Fredette et al. 1987). This transplant met with low success but provided key insights into the factors needing to be considered in restoration within San Francisco Bay. Since this first documented transplant effort, there have been dozens of additional transplants conducted in the bay with mixed but improving success. Many of these have been done for research purposes integrating a regimented experimental design into the planting with manipulation of different variables to obtain information for further management actions. These investigations began heavily in the mid-1990s in association with planning for the Oakland Middle Harbor Enhancement Area that resulted in the fill of a deep dredged harbor to create a shallow embayment. Studies at that time included pilot plot planting to explore constraints on timing of restoration, differences between plating units (bareroot and sediment plugs), ad differences in planting unit size and spacing (Merkel & Associates 1999).

In 2004 investigations were undertaken to evaluate the potential for raising the bottom of the bay to support eelgrass restoration. Six small plateaus were constructed off the Emeryville Flats using sand mined from the bay at Presidio Shoals and Angel Island. The plateaus were constructed and planted with bareroot eelgrass (Merkel and Associates 2004). The planting had a low success rate believed to have been related to shifting sediment and mound erosion. Over a 60-week monitoring period, the plateaus lost over a half meter of elevation, leading to conclusions that such elevation adjustment enhancements in high energy environments should not be undertaken without adequate stabilization measures being taken and that such adjustments were better suited where an anchoring shoreline or headland provided some protection and/or sediment retention capacity. Following this initial investigation, a subsequent pilot eelgrass restoration site was constructed by raising the bay floor near the northern end of Berkeley's North Basin near Gilman Drive. This site was constructed by placing fill against the shoreline to create a shallow intertidal/subtidal plateau extending into the North Basin. The project was successful at supporting eelgrass for several years on a seasonal basis, with recurrent eelgrass development occurring year after year (Merkel & Associates 2009). However, the exposed flats of the plateau were heavily used by Canada geese from the adjacent turfed parklands and herbivory was a major source of eelgrass loss in these areas such that only the subtidal nose of the plateau continued to support eelgrass over the years. Research undertaken by the Boyer Lab on the long-known presence of apparent annual eelgrass populations at Crown Beach in Alameda demonstrated that the beds were not, in fact, genetically predisposed to annualism, but rather intense seasonal herbivory by Canada geese resulting in annual losses of the beds that recovered from seedlings in the spring (Boyer and Wyllie-Echeverria 2010, Kiriakopolos unpubl.data).

Through the early and mid-2000s eelgrass restoration work continued to advance through testing of restoration methods and timing, conducting investigations focusing on characterizing eelgrass habitat conditions, eelgrass genetics in the bay, and physical environment parameters that favored occurrence of eelgrass. This culminated in several pivotal works related to eelgrass restoration and management in the bay. Among the pivotal works during this period was the development of the San Francisco Bay Ecological Limits, Viability, and Sustainability (ELVS) model. This predictive model is a probabilistic model of eelgrass habitat suitability and was initially developed to guide 2003 baywide surveys for eelgrass (Merkel & Associates 2005). The second pivotal eelgrass-related effort in the early 2000s was the first-ever bayside eelgrass survey, which took place in 2003 (Merkel & Associates 2005). The third pivotal effort was an 8-year long-term monitoring program conducted with repeated surveys of the Emeryville Flats and Clipper Cove that revealed the extreme dynamism exhibited by eelgrass in San Francisco Bay (Merkel & Associates 2008). The Boyer Laboratory continued considerable eelgrass restoration and eelgrass habitat research during this period. In 2010, as an element of the San Francisco Bay Subtidal Habitat Goals (California State Coastal Conservancy, et al. 2010) a compendium on eelgrass in San Francisco Bay was assembled and provided recommendations on the design and implementation of adaptive restoration of eelgrass within the bay (Boyer and Wyllie-Echeverria 2010).

Eelgrass restoration and experimental transplants for restoration research have been widespread within San Francisco Bay but generally clustered within the north-central bay (Figure 2). Most of this eelgrass restoration and associated eelgrass restoration research has been centered out of San Francisco State University's Estuary and Ocean Science Center. These restoration projects and the associated experimental transplants have been instrumental in informing the present state of eelgrass restoration science for San Francisco Bay.

Overall Eelgrass Restoration Approach for San Francisco Bay

Eelgrass restoration within San Francisco Bay has generally been guided by principles of adaptive management practices outlined within the San Francisco Bay Subtidal Habitat Goals (California State Coastal Conservancy et al. 2010). The methods outlined in Appendix 8-1: Eelgrass Conservation and Restoration in San Francisco Bay: Opportunities and Constraints (Boyer and Wyllie-Echeverria 2010), have been developed based on a growing understanding of eelgrass spatial and temporal dynamics in the bay. The restoration approach is phased and adaptive in that it follows a process of installation of test plots, evaluation of plot response, and adaptation to what is learned from the test plots prior to scaling the restoration up to larger restoration plots. The planting and monitoring methods while relatively standardized, are subject to variability in timing of planting, density and configuration of planting plots, and a variable scaling of planting plots based on site knowledge and past restoration success or failure. During some seasons, stressful environmental conditions may adversely affect donor eelgrass beds or jeopardize restoration success making it desirable to adjust the planting plans and/or donor sites, or even stand-down until the subsequent season.

The approach includes multiple phases outlined as follows (Boyer and Wyllie-Echeverria 2010):

- *Phase I. Experimental Restoration*
  - *Phase I-1: No prior knowledge; conduct basic site survey*
  - *Phase I-2: Limited site knowledge; conduct preliminary site evaluation*
  - *Phase I-3: Experimental restoration (small-scale test plots)*
- *Phase II: Pilot restoration (0.5 acre or less)*
- *Phase III: Larger-scale restoration project (1 acre or greater)*

This adaptive management approach has underpinned experimental and large-scale restoration efforts conducted in the bay since 1996 and the adaptive design has been critical to achieving successful restoration and managing resource investment in an efficient manner to achieve maximum eelgrass distribution and abundance through restoration.

Figure 2. Eelgrass Restoration and Eelgrass Research Pilot Transplants (1985-Present)

EELGRASS MANAGEMENT AND ADAPTIVE RESTORATION

The robust efforts RBRA and its partners have undertaken over the past several years has paved the way for this project, which is the largest eelgrass restoration opportunity in the San Francisco Bay Area. Given the lack of incoming live-aboard vessels in Richardson Bay, ongoing daily on-the-water patrols, active vessel enforcement with support from the Marin County Sheriff, and good relations between the RBRA Harbormaster and legacy anchor outs currently being transitioned off the anchorage, we are confident that any eelgrass restored under this opportunity will be safe from anchor scour and other preventable damage.

Eelgrass Protection Efforts in Richardson Bay

Over the past several years, RBRA and its partners have worked diligently to stem the tide of incoming boats through active vessel enforcement (no new permanent anchor outs have settled in Richardson Bay since August 2019) and abatement of existing abandoned and derelict vessels. With support from the CA Department of Boating and Waterways' Surrendered and Abandoned Vessel Exchange (SAVE) Program and two NOAA Marine Debris Program grants, the total number of vessels in Richardson Bay is down to 42 boats and one floating home – lower than pre-1970s numbers.

In addition to reducing the total number of vessels anchored in Richardson Bay, RBRA has codified an Eelgrass Protection Zone (EPZ) in the northern portion of the anchorage with support from the California Ocean Protection Council. The EPZ is defined by a southern boundary that extends from the southwestern corner point of the Richardson Bay Audubon Sanctuary southward to channel day-marker "4" on the east side of the federal navigation channel, and the EPZ includes waters to the west and north of this line (Figure 3). The Audubon Sanctuary already restricts vessel mooring. Within the EPZ, boats are no longer allowed to anchor for any period in order to protect the Bay's eelgrass beds. The EPZ extends only within RBRA waters and does not extend into the City of Sausalito. The EPZ was adopted by the RBRA Board of Directors as part of its August 2021 Eelgrass Protection and Management Plan (Lesberg 2021). The EPZ and Audubon Sanctuary include approximately 88 percent of all eelgrass that has historically occurred within Richardson Bay based on eelgrass surveys conducted in 2003, 2009, 2014, 2019, and 2022 (Merkel & Associates 2015 and unpub. data). The northern portions of the EPZ have been cleared of all but a few anchored vessels in over 300 acres of water. With a concerted north to south and east to west effort to remove vessels from the EPZ, areas for eelgrass restoration are being made available. Outside of the official EPZ, RBRA regulations also prohibit any actions that damage or disturb eelgrass within Richardson Bay waters (RBRA Code §5.05.010, 2022).

RBRA's vessel enforcement and eelgrass protection efforts are functioning in parallel with efforts to support social services for individuals transitioning off the anchorage. RBRA staff works closely with Episcopal Community Services and Marin County's Department of Health and Human Services to connect vessel occupants with supportive housing opportunities. To incentivize compliance with vessel regulations, RBRA has initiated a Vessel Buyback Program that offers vessels in anchorage on the day-in-time survey, payment to the documented owner, for their vessel if they turn it over to RBRA for proper disposal. All these efforts will continue in the coming years as RBRA works with partners to support compassionate enforcement of laws aimed at public and environmental safety for Richardson Bay.

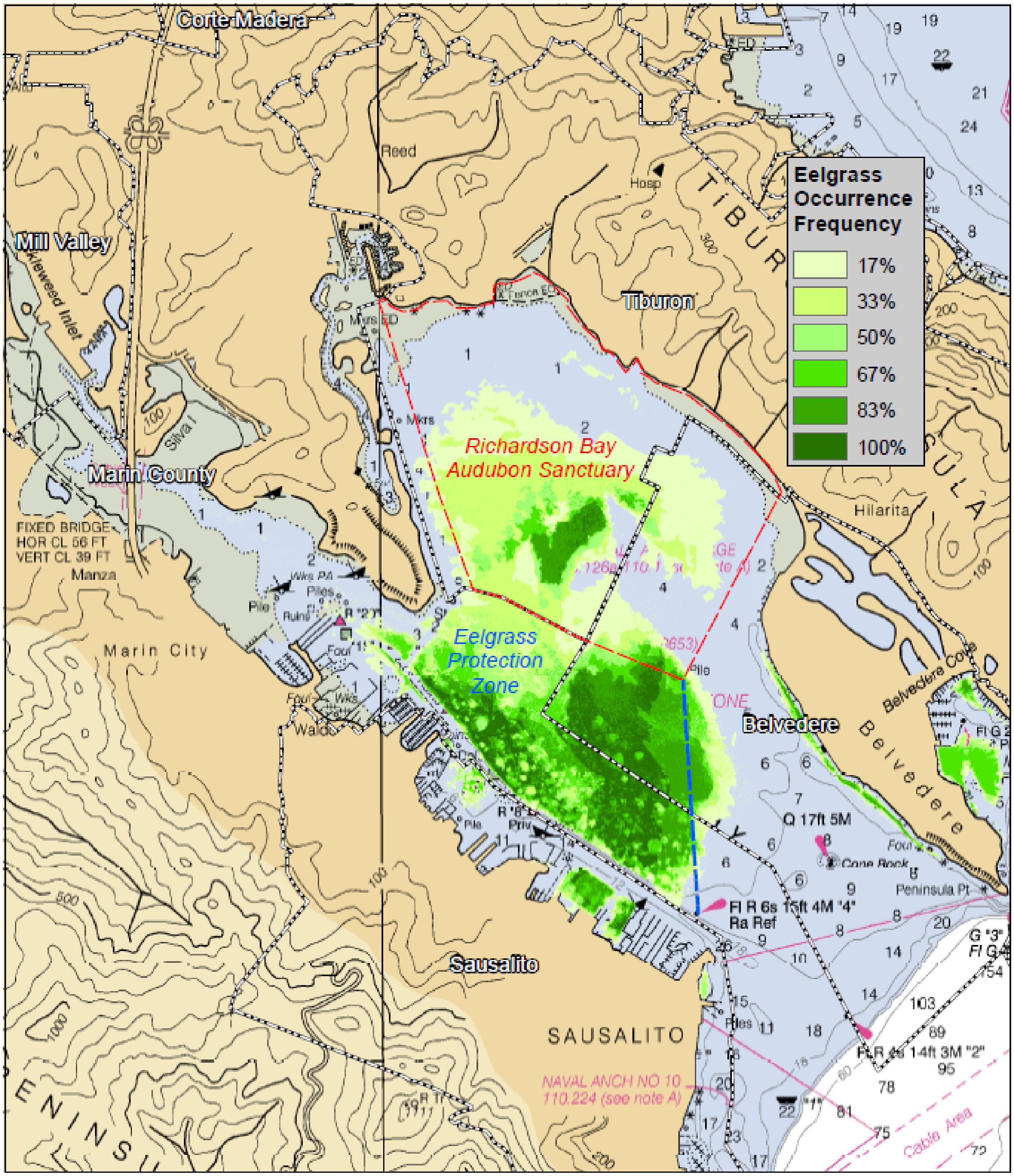


Figure 3. Richardson Bay Conservation Area and Historic Eelgrass Distribution and Stability

Eelgrass Restoration Efforts In Richardson Bay

Broader Richardson Bay Eelgrass Restoration

Richardson Bay has been a focal area of interest for eelgrass restoration for multiple reasons. First, it supports a large portion of the Bay's eelgrass and is recognized as one of the more stable areas of eelgrass relative to interannual dynamics due to its proximity to the mouth of the bay and protection against significant salinity depression that can affect other areas of the bay. Second, Richardson Bay hosts the San Francisco Bay's most significant and consistent spawning areas by Pacific herring and 90% of the 2019-2020 spawning herring spawning biomass occurred in Richardson Bay (CDFW 2020). Pacific herring use eelgrass as a spawning substrate. Richardson Bay is also a critically important stopover site on the Pacific Flyway, with tens of thousands of migratory waterbirds stopping in the bay to feed. Finally, Richardson Bay eelgrass beds exhibit the greatest extent of anthropogenic damage of all areas within San Francisco Bay and hold the greatest capacity for significant eelgrass gains by restoration of damaged areas.

Notwithstanding the general stability of eelgrass in Richardson Bay, it does experience significant variability, particularly within the shallowest margins of the Bay, such as within the eastern areas of the Audubon Sanctuary. Richardson Bay suffered a surprising significant eelgrass decline between 2009 and 2014 falling from 674.73 acres down to 334.56 acres, a remarkable decline of 50 percent. However, this change followed a 50 percent increase between 2003 and 2009 when eelgrass cover in Richardson Bay rose from 449.26 acres to 674.73 acres (Merkel & Associates 2015).

Two major restoration programs were initiated in 2014-15 leading to continuous eelgrass restoration over the past several years. From 2014 through spring 2022, NMFS, West Coast Region has administered funds from the San Francisco-Oakland Bay Bridge Eelgrass Mitigation Fund to restore eelgrass and conduct the 2014 San Francisco Baywide eelgrass survey. This program included installation of 13.8 acres of eelgrass with the net effect reaching a peak of 34.17 acres and falling to 30.00 acres by the completion of the effort. This exceeded the initial target goal of 10.8 acres of eelgrass by 178 percent. Within this restoration total, 24.33 acres (81 percent) of the eelgrass gains were seen in Richardson Bay (Merkel and Boyer 2023).

Since 2015, NOAA's Restoration Center has led eelgrass restoration and monitoring efforts on behalf of the Cosco Busan Trustee Council through funds derived under the Cosco Busan Oil Spill natural resource damages settlement. The overall intent of the restoration and monitoring efforts is to expand the current densities and spatial coverage of eelgrass in the bay to provide suitable spawning and nursery grounds for multiple forage fish, in particular herring. The program has a 9-year goal of expanding eelgrass in San Francisco Bay by 70 acres, with 36 acres resulting from planting and the remainder generated by bed expansion. This program has resulted in gains of 31.15 acres of eelgrass as of the latest analysis and had reached a peak of eelgrass gain in 2019 at 41.15 acres (Merkel and Boyer 2022). Of these gains the peak of eelgrass expansion in Richardson Bay reached 31.87 acres in 2019, while the latest quantification for 2022 was 21.90 acres of gain in Richardson Bay.

Richardson Bay Eelgrass Restoration Related to Anchor Scars

In 2020, the NOAA Restoration Center and Cosco Busan Trustee Council authorized eelgrass planting within vacated anchor scars based on RBRA's progress towards addressing illegal anchoring in Richardson Bay. This was not done in earlier restoration, in favor of planting within the Richardson Bay Audubon Sanctuary where lower risk of restoration area damage existed. In 2021, with the Trustee Council approvals for planting in the anchor scars, RBRA granted access to conduct the first eelgrass plantings within vacated mooring areas where scars from ground tackle and vessel dragging had removed eelgrass and scoured depressions in the bottom of the bay. These areas of damage are referred to as "anchor scars" in most RBRA documents but will be referred to as "mooring scars" in this document in order to maintain consistency with previous reports. For the purposes of interpreting this and other policy guidance, "mooring scar" and "anchor scar" should be assumed to have the same meaning when referring to vessel-related damage to eelgrass in Richardson Bay. Five half acre mooring scars were planted. These plantings were the beginning phases of restoration of broader damage to eelgrass from moorings and were to serve as pilots to understand what is required to restore the mooring damage. Planting of the mooring scars continued in 2022; planting was conducted within Richardson Bay in 12 mooring scars. Four larger scars were planted with half-acre plots, while 8 smaller scars were planted with quarter-acre plots. During this same period, vessel grounding damage restoration was conducted on the Belvedere shoreline, and a quarter-acre rectangular planting plot was installed in a vacated mooring scar with the authorization of BCDC and RBRA. In 2023, an additional four half-acre mooring scars were planted with Cosco Busan funding (Figure 4). From 2021-2023, 6.75 acres of mooring scars have been planted within the northern end of the central portion of the Bay within the designated EPZ. These planted scars as well as vacant reference scars are being investigated under a separate but related effort to evaluate potential means of accelerating recovery in areas where moorings have been removed (Boyer, in progress). Vessel mooring damage will continue to be a focus of restoration in Richardson Bay as the removal of moorings provides the greatest single opportunity for major eelgrass gain within herring spawning habitat in San Francisco Bay.

At the time of establishing planting plots, two types of reference plots were also established. These include mooring references, wherein the plots continue to support active moorings with ground tackle, and scar references, wherein the moorings have been removed, but no planting has been performed within the scars. These two reference types are monitored concurrent with the planted plots to support assessment of the restoration, natural recovery processes, and the effects of ongoing moorings on eelgrass beds.

As moorings are removed from present mooring reference sites, they will either transition to a scar reference, or will be advanced to an active restoration site. It is recognized that the status of reference sites is subject to change over time as moorings are removed and information value from a particular reference location diminishes. For this reason, new reference sites are added as new restoration sites are selected.

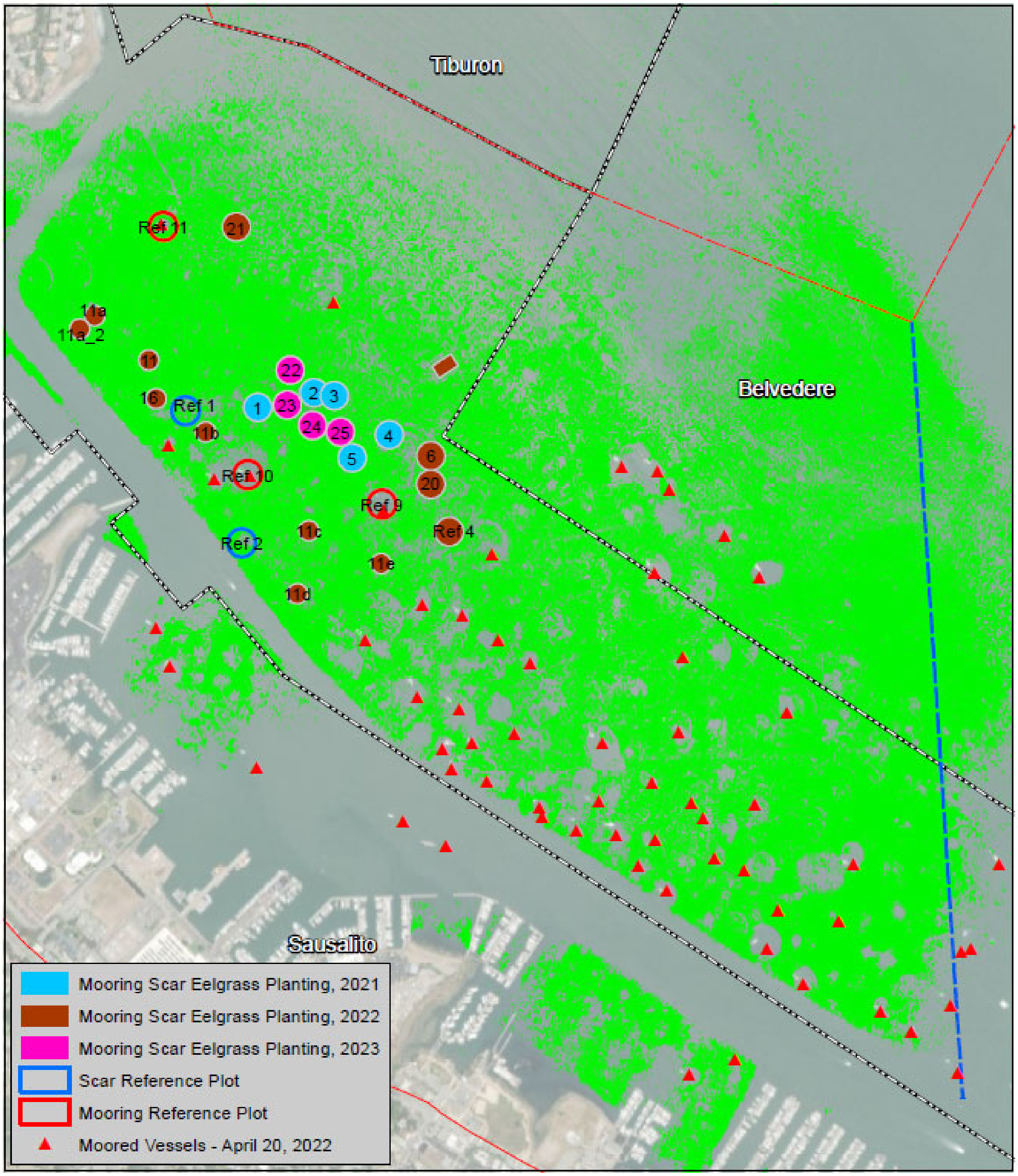


Figure 4. Richardson Bay Mooring Scar Eelgrass Planting Conducted 2021-2023

PLANTING METHODS DEVELOPMENT

Eelgrass planting methods for restoration are numerous; however, they can generally be classified into overarching categories based on the type of planting units including: bareroot, sediment plug, temporary frames, and seeding methods.

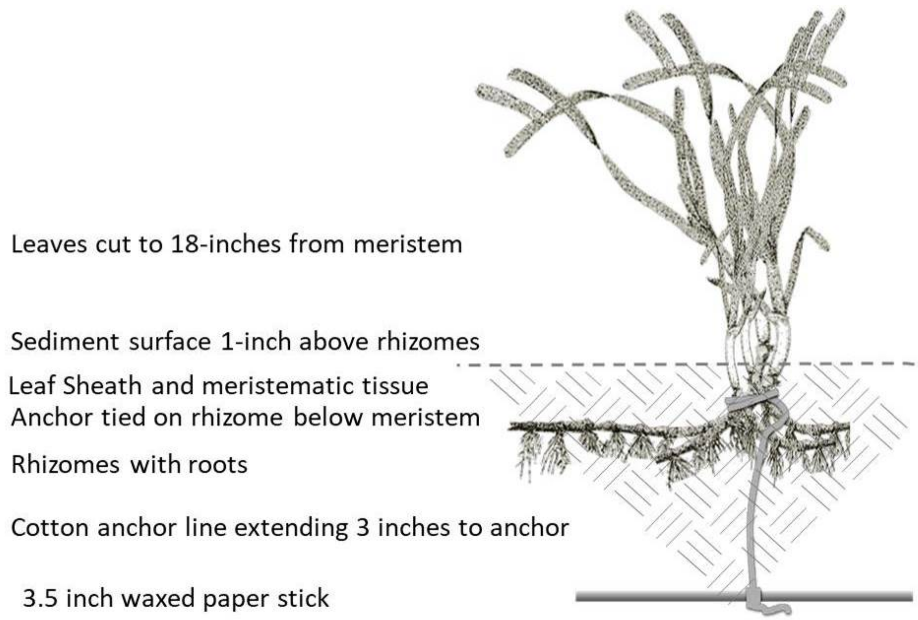
Bareroot Planting Units

Merkel & Associates typically uses a biodegradable anchored bareroot transplant unit that makes use of a cotton twine collar around rhizome bundles that is connected to a horizontally placed paper stick that holds the newly planted eelgrass units firmly in the sediment (Figure 5a). Over a brief period of approximately 3-6 months, the paper and cotton twine disintegrate, while the natural expansion of the rhizome-root complex becomes the plant anchors (Merkel 1987). This planting unit has been in use for 37 years and has been employed on both the Pacific and Atlantic coasts of North America as well as in northern Europe. Since development, over a million of these units have been used within more than 100 eelgrass restoration projects. Within San Francisco Bay, this type of unit has been employed in 23 eelgrass planting efforts since 1998 (Merkel & Associates, unpubl. data).

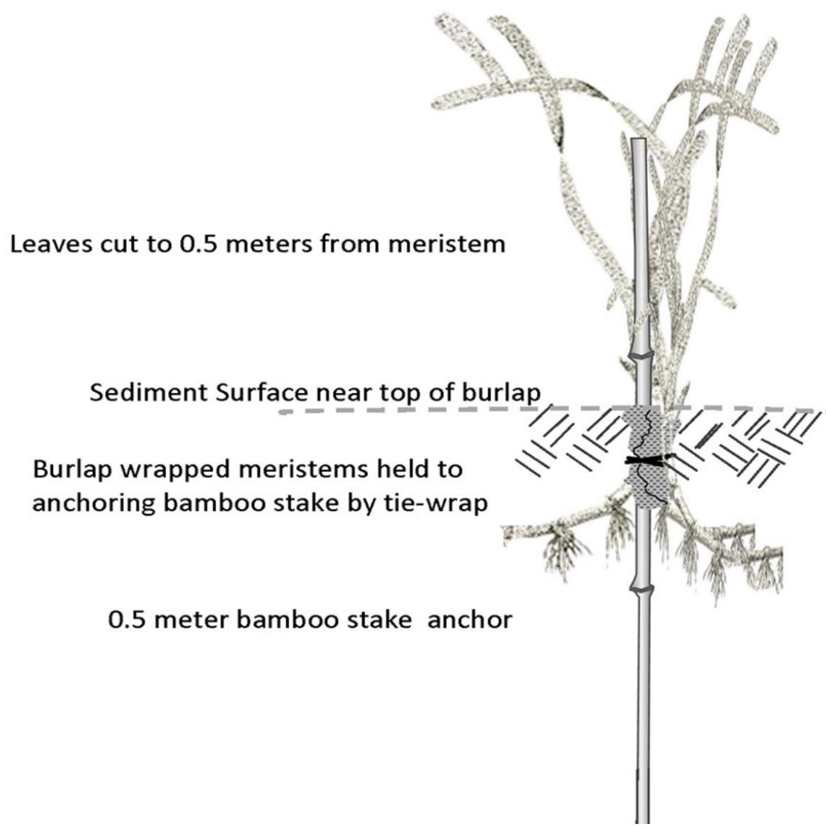
Merkel and Associates (2006) planted anchored bareroot planting units at the Emeryville Flats to compare different shoot bundle sizes (the number of vegetative shoots per planting unit) and trimmed versus untrimmed leaf lengths. This study found that larger bundles (8-20 shoots) outperformed smaller planting unit bundles (2-6 shoots) in establishment success; however, the gains of planting unit size diminished rapidly post-unit survival. It was determined that trimming the leaves did not lead to enhanced planting unit survival. This led to recommendations of using intermediate bundle sizes as a compromise between individual planting unit survival and donor resources and cost effectiveness of planting. In subsequent investigations and methods development, it has been determined that the optimal balance of units per planting unit is lower than that recommended by Merkel & Associates (2006) and the planting unit sizes presently being applied to bareroot planting units has typically ranged from 2-3 shoots per unit with leaves being clipped to 0.5 meters in length (Merkel & Associates and Boyer Lab, Estuary and Ocean Science Center [Merkel and Boyer] 2022). Greater shoot counts are still occasionally used when donor plant materials have small rhizomes.

In 2007, SFSU graduate student Stephanie Kiriakopolos developed a bareroot planting method using a bamboo stake anchor that has been used effectively in several small-scale restoration projects around the Bay (Boyer 2008; Boyer and Carr 2009). In this method, vegetative shoots are wrapped loosely at the base of a bamboo stake with a small piece of burlap and secured with a wire twist-tie (Figure 5b). The stake is installed vertically such that it protrudes above the sediment, allowing positive verification of the initial planting locations in future monitoring. This aids in assessment of mortality and spread rates, over the completely subsurface paper stick anchor.

Comparative planting tests suggest no difference in survival between the paper stick and bamboo stake anchored bareroot planting units, but each having unique strengths in their application to restoration. As planting in the Bay has evolved and several hundreds of thousand planting units have been installed in San Francisco Bay restoration projects, the paper stick and bamboo stake anchored bareroot planting units have become the most regularly used planting unit types and are employed together to maintain efficiency and provide indicator tools to track planting units during monitoring (Merkel and Boyer 2022).



a) Merkel (1987) paper stick eelgrass planting unit



b) Kiriakopolos bamboo stake eelgrass planting unit

Figure 5. Anchored Bareroot Planting Units Used in San Francisco Bay

Seed Buoys

Seed buoy eelgrass transplants at Marin Rod & Gun Club, San Francisco Bay

Seed-based restoration methods may help to alleviate the problem of genetic diversity decreases in previous restoration attempts using whole shoot transplants (Williams and Davis 1996; Williams 2001) and can theoretically be less time consuming than whole shoot transplant methods. The Boyer Lab has used buoy-deployed seeding (seed buoys or BuDS) with some successes and some failures in several locations in the Bay (Boyer and Wyllie-Echeverria 2010). This technique uses harvested flowering shoots suspended in mesh bags buoyed above the sediment of a targeted restoration area (Pickerell et al. 2005). This technique simulates long distance dispersal of detached reproductive shoots (Harwell and Orth 2002; Orth et al. 2012) and takes advantage of the natural slow release of seeds as they mature. This technique permits placing flowering shoots at the restoration site the same day as collection (or only temporary holding overnight), and thus does not require facilities for seed collection and storage as in broadcast seeding.

Boyer has used seed buoy methods successfully and unsuccessfully at several sites in San Francisco Bay (Boyer et al. 2008) and the methods are ready to be "scaled-up" to larger restoration efforts. The seed buoy system was applied in 2014 transplants for the Cosco Busan DARP restoration and used a temporary anchor attached to a float that supported a 9mm mesh bag that held fertile flowering shoots harvested from donor populations. As the seeds within the flowering shoots matured, they were released and fell through the mesh to the bay floor beneath the bag.

The 2014 Cosco Busan seed buoys were ineffective at stimulating substantial seedling recruitment and were therefore not used in the subsequent restoration efforts except for occasional experimental applications. Rather, seed buoys are now considered to be a secondary tool for reconsideration in expanding eelgrass once establishment of beds from bareroot transplants is achieved at a site. Subsequent discussions between Boyer and the method developer, Chris Pickerell, have indicated that similarly secondary application of the method have now been adopted elsewhere as well. In future planting efforts, seed buoys are expected to be added to the transplant methods once a site is determined to be suited to eelgrass restoration based on survival and growth of bareroot planting units. It is not planned to be used as a primary planting method but will be retained in the program as an experimental method applied sparingly.

Merkel and Boyer (2022) noted that seed buoy planting technique may be most suited to discrete and transient environmental conditions prevailing in the bay and, as a result, may only be effective in certain years and areas. It is most suited to expanding eelgrass in areas where suitability to support eelgrass has already been established. Even under such conditions, seed buoy deployment still has low certainty of success considering that there are multiple potential points of failure in seedling establishment from seed buoy restoration. These include but are not limited to seed sterility, seed herbivory at the buoy or on the bottom, seed loss to current and wave transport from the site, seed loss into deep burrows within areas of high biogenic benthic infauna activities, and herbivory of seedlings.

Other Eelgrass Transplant Methods Not Proposed for Use

In addition to bareroot and seed buoy planting methods, other approaches have been explored and tested in San Francisco Bay. These methods have included TERFS (Transplanting Eelgrass Remotely with Frames System, Short 2002), hand-broadcast seeding (Granger et al. 2002), surface broadcasting of anchored bareroot planting units (Merkel, unpubl. data), and translocation of sediment plugs containing eelgrass (Merkel, unpubl. data). When tested, buoy-deployed seeding was by far the most successful non-bareroot planting method, while TERFS were not effective, nor efficient and broadcast seeding had very poor success rates (Boyer et al. 2007 and 2008). Merkel noted sediment plug transplants to be labor intensive, ineffective in sandy sediment, and potentially damaging to donor beds for large scale restoration. Further, they did not offer the same establishment success as did bareroot units. For this reason, they have been dropped from restoration practices in the bay. Finally, in the case of broadcast anchored bareroot units, these are more labor intensive to prepare than are standard bareroot units in use; however, they offer an advantage of not requiring diving or labor intensive restricted low tide work. When deployed, they were less effective as the rhizomes are not embedded in the sediment but rather are placed firmly against the sediment surface. In areas with moderate to high wave energy, the units drag and do not become established. They further cannot be positioned evenly in a planting area. This method remains experimental and is not proposed for the present restoration program.

EELGRASS RESTORATION

California Department of Fish & Wildlife Scientific Collecting Permit

The California Department of Fish & Wildlife regulates the harvest and planting of aquatic plants. The work under this plan requires authorization by the Department. It is anticipated that the work in 2024 would be conducted under an annual amendment to the Scientific Collecting Permit (SCP) for the San Francisco Bay Eelgrass Restoration Program (S-190240006-21100-002) held by Merkel & Associates. However, since this three-year permit is to expire in July 2024, a replacement permit will be processed and may be in place prior to all of the planting being completed.

The SCP limits the extent of allowable harvest of eelgrass shoots to 10 percent of a donor site and requires pre- and post-harvest surveys to be conducted of the donor sites. The permit also requires annual reporting of the transplant information. The permit is amended annually to allow the Department to consider each harvest area relative to factors that may cause concern over the extent of harvest.

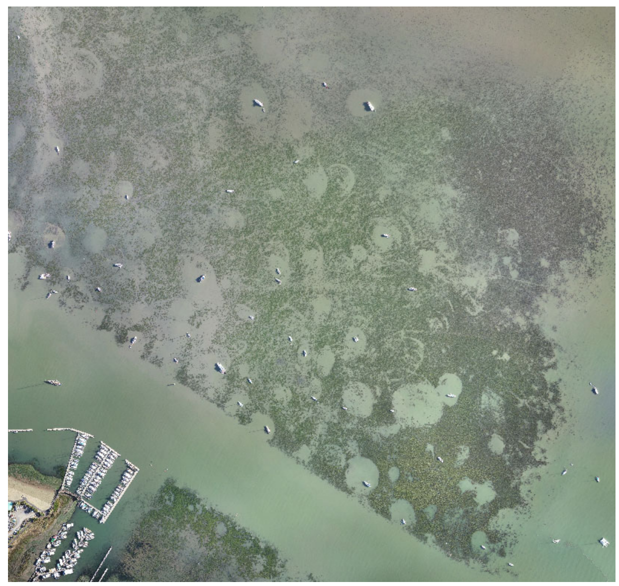
Application for the SCP amendment is presently in preparation so that restoration activities may commence in the spring of 2024. Pre-harvest surveys will be conducted prior to commencement of work in order to determine the allowable harvest level within each donor bed. Post-harvest surveys will be completed at the end of the season when all harvesting has been completed in each of the donor beds.

EELGRASS PLANTING SITE SELECTION

Mooring Removals and Relocations

Planting for the present restoration program is responsive to opportunities for planting derived from mooring scars being opened for planting by vessel removals and relocations. This effort is being separately undertaken by RBRA and community and social support partners. As the rate and locations of vessel removals are not fully predictable, the first actions undertaken each spring is to complete a census of the eelgrass beds and anchor-out vessels present on the bay in order to identify restoration planting opportunities. The restoration team coordinates with RBRA on planned restoration with the goal of continuing to advance restoration in a south and westward progression in parallel with vessel removals.

Spring restoration planning surveys are completed by conducting a low tide, low altitude survey flight by unmanned aerial vehicle (UAV) to prepare an orthorectified mosaic of the eelgrass beds from which moored vessels and eelgrass may be mapped using GIS tools. The resolution of the imagery is adequate to identify the locations of vessels and the presence of associated eelgrass scarring. This imagery is used as a coordination tool with the RBRA Harbormaster to further refine planting objectives considering the vessel removal and mooring removal actions underway.



Spring 2022 low altitude aerial survey to support restoration planning.

Planting Site Screening and Selection

After mapping the vessels and eelgrass, multiple candidate scars are selected for potential planting during the spring-summer planting period. An example of how the site selection is undertaken is illustrated in Figure 6. In this example, the April 2022 areal image has been plotted along with completed restoration. A few moorings present at the time of this survey have been randomly removed to support the identification of candidate vacate mooring scars for restoration. The scars would typically exceed those planned for planting during a given season by approximately 50 percent such that capacity exists to further screen sites for final planting selection. Concurrent with this effort, additional candidate mooring references and scar references ae selected.

This approach has been undertaken for all of the prior mooring scar plantings conducted thus far (Figure 4). The analysis allows the restoration team to track the distribution of vessels and scars through time and thus select planting sites for the season's planting activities.

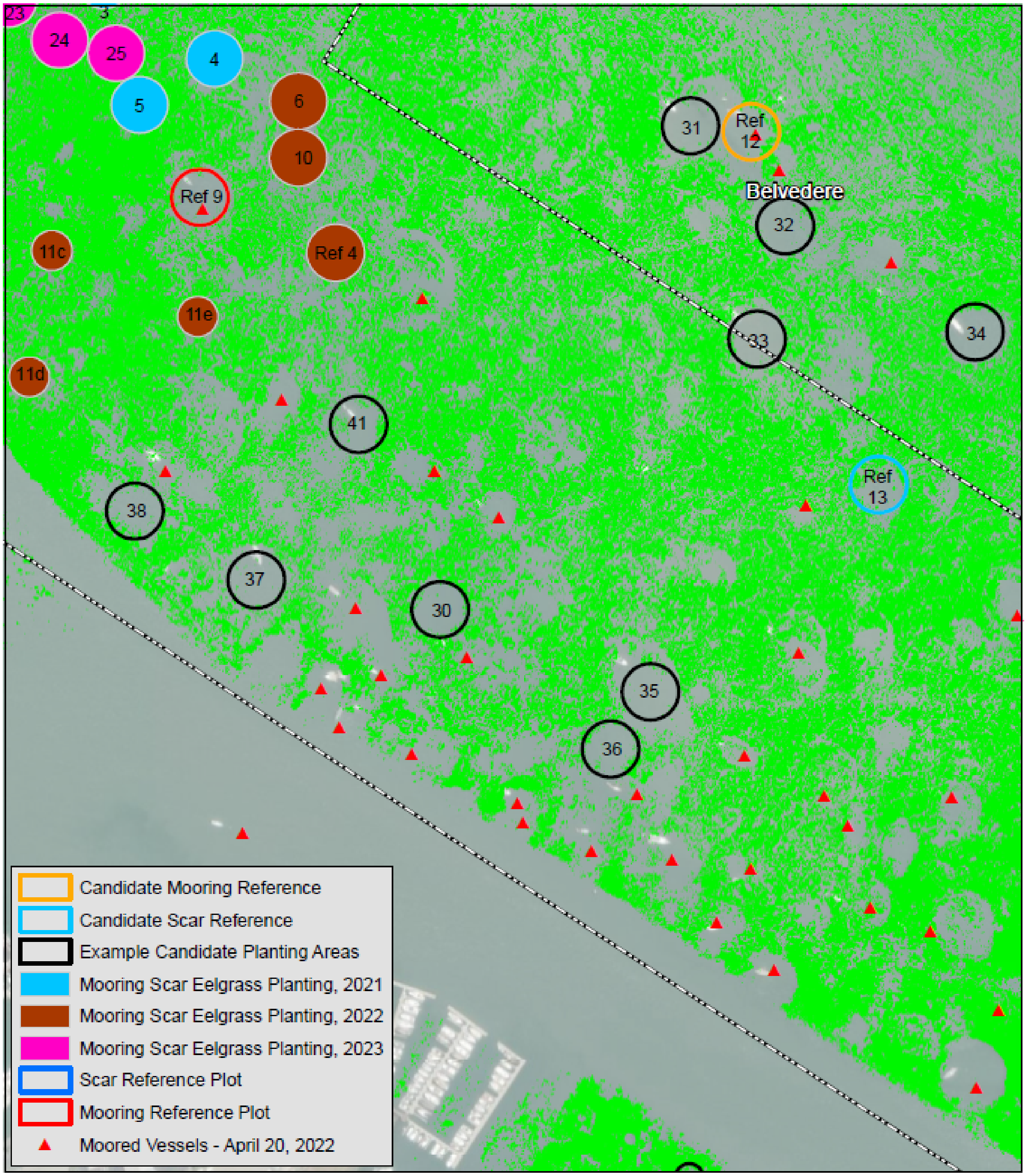


Figure 6. Typical Planning Map for Mooring Scar Restoration Planning

Final screening of scars for preference in planting is based on consideration of multiple factors, with the goal of optimizing the probability for stable success early in the planting program. This is done by preferentially selecting sites occurring within areas surrounded by historic stable eelgrass (Figure 3).

Planting elevation is also a factor as it pertains to bed stability and planting team composition required (wading or diving staff). The most stable beds in Richardson Bay are reflected by those that have had the highest occurrence frequency over multiple surveys. When depth distribution of eelgrass in the bay is charted along with the frequency of eelgrass occurrence through time it is possible to identify the bay floor elevations that have had the most consistent presence of eelgrass (Figure 7). This chart reveals that elevations of -4 to -5 feet have held the most consistent eelgrass through time. As such, these elevations should be preferentially targeted to obtain the most stable success. While early restoration should include some of the easy areas to achieve success, these should be balanced with work on more complicated restoration in dynamic portions of the beds such that adaptive restoration research and methods development can continue to advance. The overall restoration objective is to restore damaged areas across all elevations and geography of the beds. Omitting these areas would ultimately result in a failure to achieve the restoration objectives and would push the most difficult areas to restore to later periods of the restoration program when funding is less certain. As sea level rise progresses, higher elevations of the bay floor will become more important for retaining eelgrass resiliency in the bay (Gilkerson et al., in prep.).

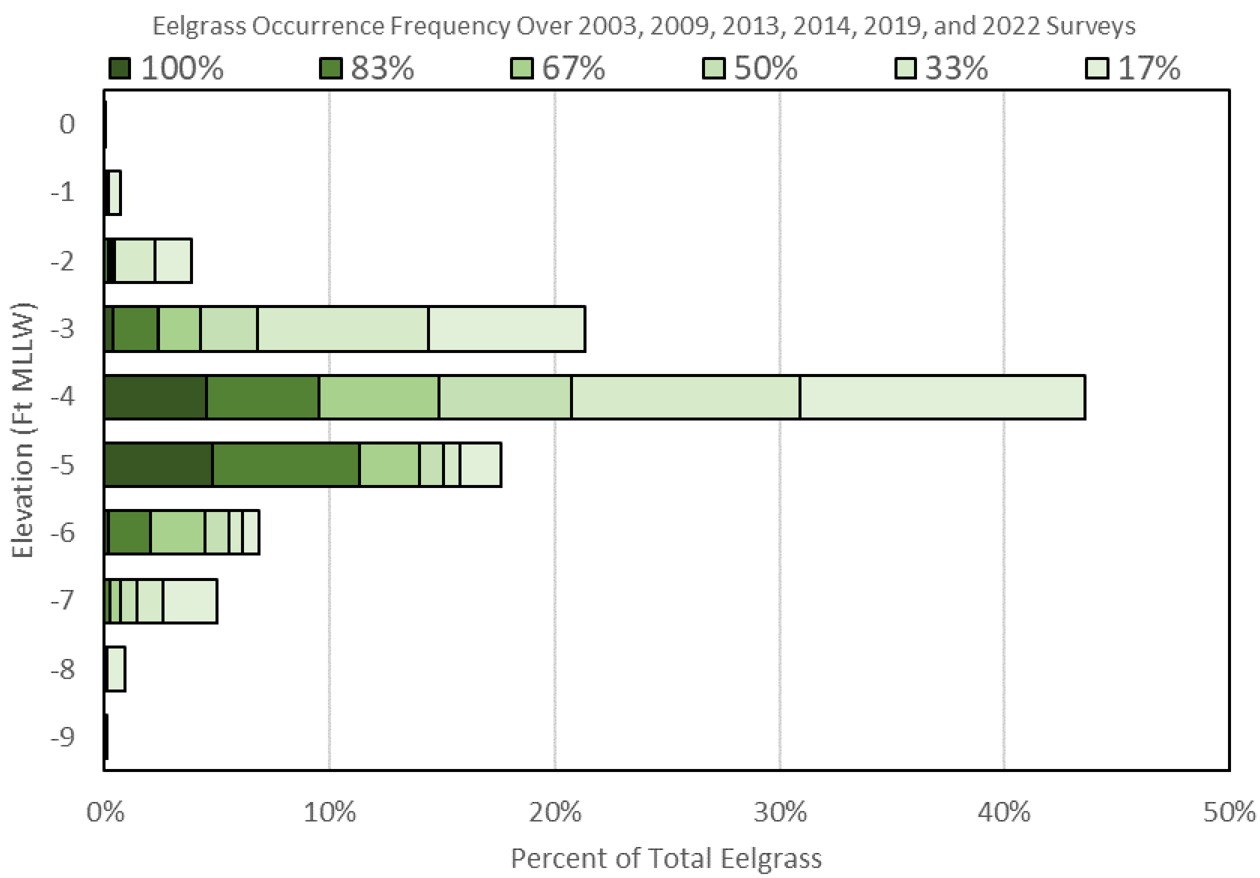


Figure 7. Eelgrass Depth Distribution and Eelgrass Bed Stability

Other factors considered in annual planting area selection includes restoration and monitoring staff safety and avoidance of adverse interactions with adversarial members of the anchor out community. While most of the anchor out community members are peaceful and polite to the restoration staff, some are weary and antagonistic. As a result, it has been the restoration team's practice to locate planting plots as far as practical from vessels on moorings unless those in the moored vessels have been supportive of the restoration activities. This often has resulted in "day of" decisions to omit planting in some plots in favor of other plots. In addition, the plots and associated reference sites require follow-up monitoring. This is typically done by smaller crew sizes and may occur during odd hours of the day to conduct work during extreme low tides. As a result, these follow-up monitoring needs are also considered relative to crew safety and degree of potential for disturbing anchor-outs.

Finally, another factor considered in the restoration of scars is the extent of non-vessel marine debris on the bottom. If a mooring scar supports a high degree of debris on the bottom that would preclude planting, the scar is identified and not planted, pending debris removal to enhance planting suitability. Debris removal is discussed later in this plan. Once debris is removed from a scar, it is again identified as a candidate for restoration.

EELGRASS DONOR SITE SELECTION

Donor Site Selection and Locations

Eelgrass donor sites are existing eelgrass beds from which plant material is harvested for use in preparation of planting units. The proposed planting units for this restoration effort would be drawn from four large and widely distributed beds from which eelgrass has been previously harvested for restoration purposes. These include four different donor sites: 1) Point San Pablo/Point Pinole, 2) Point Molate, 3) Richardson Bay, and 4) Bay Farm Island (Figure 8). At least three donor sites will be drawn from for each season of planting.

Donor sites were selected for multiple reasons. First, the donor areas all supported relatively extensive, well studied beds that could provide adequate donor material to support on-going Cosco Busan restoration efforts in parallel with the present EPA funded restoration program. Second, the beds in these areas are large enough to support all years of the multiple eelgrass restoration efforts presently underway without taxing the donor sites. Third, these donor sites are broadly distributed across multiple physically stressful environments with respect to substrate, salinity, water clarity, and environmental energy. For this reason, if there is any adaptive advantage to the material under differing environments, a broad spectrum of environmental conditions are represented by the donor stock and would be expected to be reflected in progeny of these mixed donors. Finally, all of these beds have been investigated genetically and been found to be unique from each other (Ort et al. 2012; Talbot et al. 2004). This provides a high potential for maintaining and expanding genetic diversity within the restored beds, over the diversity of any single donor site.

During prior San Francisco Bay Eelgrass Restoration Program efforts CDFW did not authorize the use of Richardson Bay eelgrass beds as donors in 2019 due to low levels of spawning by Pacific herring in Richardson Bay eelgrass during the prior winters. While donor use was eventually provided for 2021, it was too late in the planning stages to be integrated. Instead, Bay Farm Island was substituted in to provide an additional source of donor plant material. For 2022, donor sites remained Point San Pablo, Point Molate, and Bay Farm Island. Evidence suggests that planting units

Figure 8. Eelgrass Donor Beds

comprised of Richardson Bay donor stock performed better than eelgrass transplants from other sites, as did mixed donor transplants (Patten et al. 2019). For this reason, use of Richardson Bay donor beds will continue to be regularly pursued for this effort. Retaining four donor sites from which material will be drawn from three sites each year allows for a back-up should Richardson Bay donor sites be rejected for use during any given year based on herring fishery concerns or should one of the other sites be deemed unsuitable during a given year.

Harvesting and Handling Donor Material

Eelgrass material harvesting is to be done by gleaning rhizomes with intact shoots from the sediment within the donor beds. The harvest targets collection of rhizomes that include at least three intact rhizome nodes and an undamaged shoot. No more than 10 percent of the shoots are to be harvested within a donor bed. This is managed by conducting pre-harvest density sampling using quadrats to determine the average density of the beds. A total of 20 widely spaced quadrats are distributed across the beds and shoot counts are conducted. The density is standardized to mean shoots per square meter ± 1 standard deviation. The density is determined during the spring prior to harvesting and typically ranges between 50 and 120 shoots/m^2. This is then used to establish the maximum number of shoots that can be collected per given square meter of the donor bed. The harvest level is managed on a per square meter basis such that the biologists conducting the harvest move through the bed taking no more than 10 percent of the shoots per square meter prior to moving forward to the next square meter of bed.

The harvest is performed either by SCUBA diving within subtidal beds, or intertidally by walking or crawling through the beds and collecting donor materials. This harvesting methodology progresses through the beds with hand extraction of shoots and intact rhizomes at a low-density harvest level. Using this harvest approach the visual results of harvesting are often undetectable following the harvesting. Further, because planting is typically targeted to occur early in the growing season and shoot density generally increase through the growing season, it is not uncommon for the post-harvest density assessments to show a greater density of shoots than did the pre-harvest survey.

Harvesting of material from subtidal areas of Richardson Bay and intertidal areas at the Point San Pablo/Point Pinole donor sites by Merkel & Associates and SFSU project team members.

As plants are harvested, they are either laid in bins under wet burlap to avoid desiccation and thermal stress, or they are retained in mesh bags in the bay water until they are transported to the Estuary and Ocean Science Center within one to three hours of harvest where they are placed in flow-through large seawater tanks for storage prior to preparation of bareroot planting units. Tanks are set to circulate flow-through sea water and air stones are placed in each tank.

Flow-through seawater tanks used to store eelgrass from donor sites until processed into planting units. Tanks were then used to store processed planting units until they were planted at the transplant receiver sites.

Managing Donor Site Harvest Impacts

In 2015, some concern was raised by CDFW over the effects of significant harvesting to support the large eelgrass restoration projects getting underway in the Bay. To address this concern, two actions were undertaken.

First, the large San Francisco Bay eelgrass restoration projects were folded into a single San Francisco Bay Eelgrass Restoration Program. This action was taken such that application for Scientific Collecting Permit (SCP) could be submitted with a full disclosure and consideration of cumulative harvest levels. Further, it allowed the harvest efforts to be fully coordinated such that there was no risk of double harvesting the same beds without knowledge.

Second, the team agreed to conduct an opportunistic investigation on plots that were thinned by the Boyer Lab for other purposes associated with evaluation of the effects of bed density on predator-prey interactions as an element of the *Zostera* Experimental Network (ZEN) investigations for which the Boyer Lab is a collaborator. Plots were thinned in July 2015 from the original bed density by 0 percent, 50 percent, and 80 percent for the ZEN studies. These plots were subsequently tracked to determine the differences in eelgrass bed density over time. The study indicated that at a 50 percent harvest level there were no differences between harvested and unharvested plots within six months of the harvesting. However, notably at 80 percent harvest levels, depressed shoot densities were observed through at least April 2016, 10 months into the post-harvest monitoring (Boyer et al. 2016). The study demonstrates that at the standard harvesting rate of 10 percent, it is reasonable to expect a lack of substantial and lasting effects on the donor beds. Similar donor bed recovery studies have been completed in prior years in San Diego's Mission Bay (Merkel, 1986 unpublished data) and at Bay Farm Island in San Francisco Bay (M&A 1999). These investigations also documented rapid recovery of donor beds from high harvest levels.

Not addressed in the current studies is that ground (low tide walking or wading) harvesting on very soft sediments can result in high donor bed damage due to disruption of the supporting sediments and damaging a far greater proportion of the bed than is harvested. For this reason, harvest methods have been established to only harvest intertidally on more firm sediments or on softer sediments in shallow waters where a degree of buoyancy reduces the harvester loading on the substrate. In subtidal harvesting by SCUBA diver, the softness of the sediment is not a factor as divers are not walking on the bottom. The present methods of harvest were developed in the late 1980s based specifically on development of protocols to protect eelgrass donor beds from damage.

PREPARATION OF PLANTING UNITS

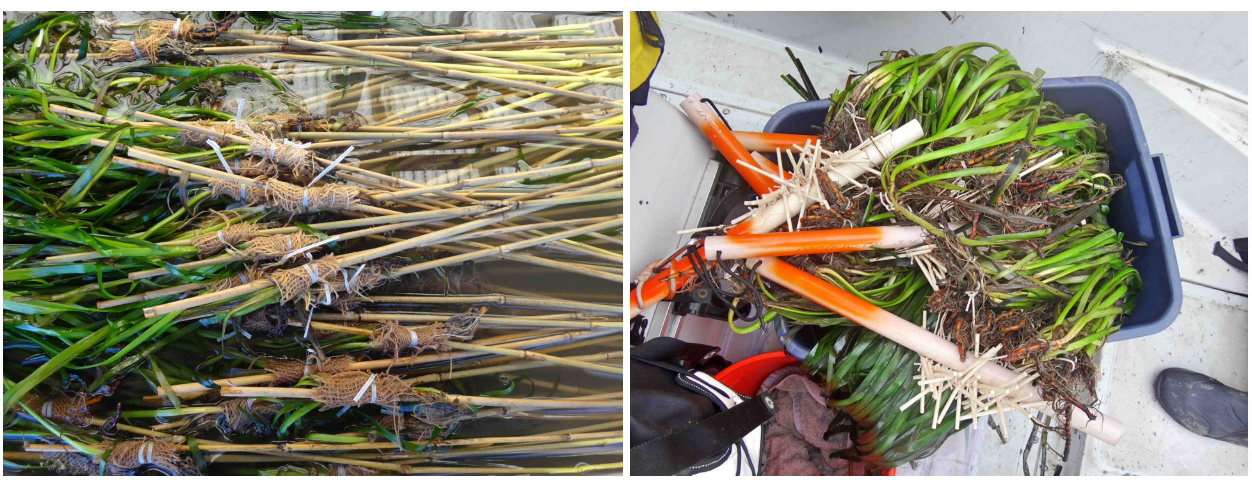
Bareroot Planting Units

Eelgrass donor material is processed into uniform bareroot planting units at the EOSC where materials are held and processed within flow-through seawater tanks and water tables. As needed, plants are moved from the storage tanks to water tables where they were prepared into anchored bareroot planting units using either the Merkel paper stick anchors or the Kiriakopolos bamboo stake. Generally, the less efficient bamboo state units are made in smaller quantities as they are used as plot markers and units for integrated restoration research elements of the program.

Some of the donor eelgrass beds host the herbivorous invasive amphipod, *Ampithoe valida*, while others do not. As a result, eelgrass arriving from donor beds is inspected for amphipods and amphipod nests. When infested donor material is noted, the plants are subject to multiple freshwater dips and rinses to osmotically shock and remove amphipods prior to preparation of planting units. This method has been demonstrated to remove 93-97 percent of the amphipods (Duffy 1990).

Planting units are generally prepared within 24 hours of harvest of the eelgrass and are then stored once more in the flow-through seawater tanks to keep them cool and oxygenated until they are planted, typically within 48 hours. Planting units are identified by color coding of either the bamboo stakes or the carrying fids used for paper stick anchor units. Each donor site had a consistent unique color that has been maintained through the San Francisco Bay Eelgrass Restoration Program since 2014. When planting units are placed back into the seawater baths prior to planting, they were grouped in a manner that supported planting of each discrete planting area based on the site size and intended donor plant materials to be used in the restoration. This allowed plants to be picked up and loaded onto boats for each planting day in a manner that minimized handling and potential for planting errors.

Water-tables used to process donor eelgrass into bare root units. The eelgrass units being prepared in the photograph are Kiriakopolos bamboo stake units.



Prepared planting units of Kiriakopolos bamboo stakes and Merkel paper stick anchors ready for transplant. Color coding denotes the donor source material in the planting units.

Seed Buoys Units

As discussed previously, seed buoys are not proposed to be used as a primary means of completing restoration based on general low effectiveness and inefficiencies for practices restoration teams. However, seed buoys hold considerable interest as a tool that is well suited to community-based restoration programs and educational and training programs focused on eelgrass restoration. This is because harvesting flowering shoots, evaluating seed development stages, preparation of buoys and deployment moorings, and deploying and retrieving buoys are work elements that can be readily accomplished by large groups with a high degree of safety, a good exposure to restoration science and practice, and engagement in laborious tasks. By maintaining this planting method as a research and development element, meaningful expansion of the restoration team can occur in a manner that further engages educational institutions and the engaged public. This element will also provide a recruiting pool to evaluate and draw from for the bareroot harvesting and planting elements of the program.

Seed buoy preparation entails monitoring the status of flower development and evaluating the stages of seed development following DeCock (1980). When seed development is adequate for continued maturation on detached flowering shoots, a harvesting of flowering shoots will be conducted from ripe beds. The same donor beds will be used to collect flowering shoots as are used to provide bareroot transplant material. As with bareroot harvesting, the harvest level will be limited to 10 percent of the shoots present.

Flowering shoots will be sorted into seed buoy mesh bags with a small float and attached to small temporary 10-pound mooring blocks by floating polypropylene line. These will be deployed at selected experimental plot locations within the restoration moorings for a period of approximately 30 days to allow seed to continue to develop on the flower stalks and be naturally released within the swing arch of the buoy. After the seed has matured and dropped, the buoys and moorings will be retrieved for future reuse. This restoration method will require special permit through the RBRA for the temporary mooring placement.

PLANTING EELGRASS

Planting Site Layout

The planting sites for mooring scars follow closely with the design of test plots and half-acre plots that have been used extensively within the Cosco Busan and SFOBB eelgrass restoration programs since 2014 (Merkel & Boyer 2023). This involves a configuration where discrete donor sources are planted separated from each other, and a mixed plot derived from the multiple donors is also planted. The color-coded donor sources are deployed on each leg of a cross that is oriented in a north-south alignment (Figure 9). Between the legs additional plantings are planted using the same donor on the leg located adjacent in a counterclockwise direction. These plots may be omitted for use in seed buoy testing, experimental plots, or recruitment investigations that are conducted as funding from other sources allows or as information needs arise for the current adaptive restoration need. One specific use is an assessment of accretion rates within the centers and perimeters of scars that have been planted and those that have not been planted to evaluate the sediment trapping benefits that may occur with vegetation development in the scars.

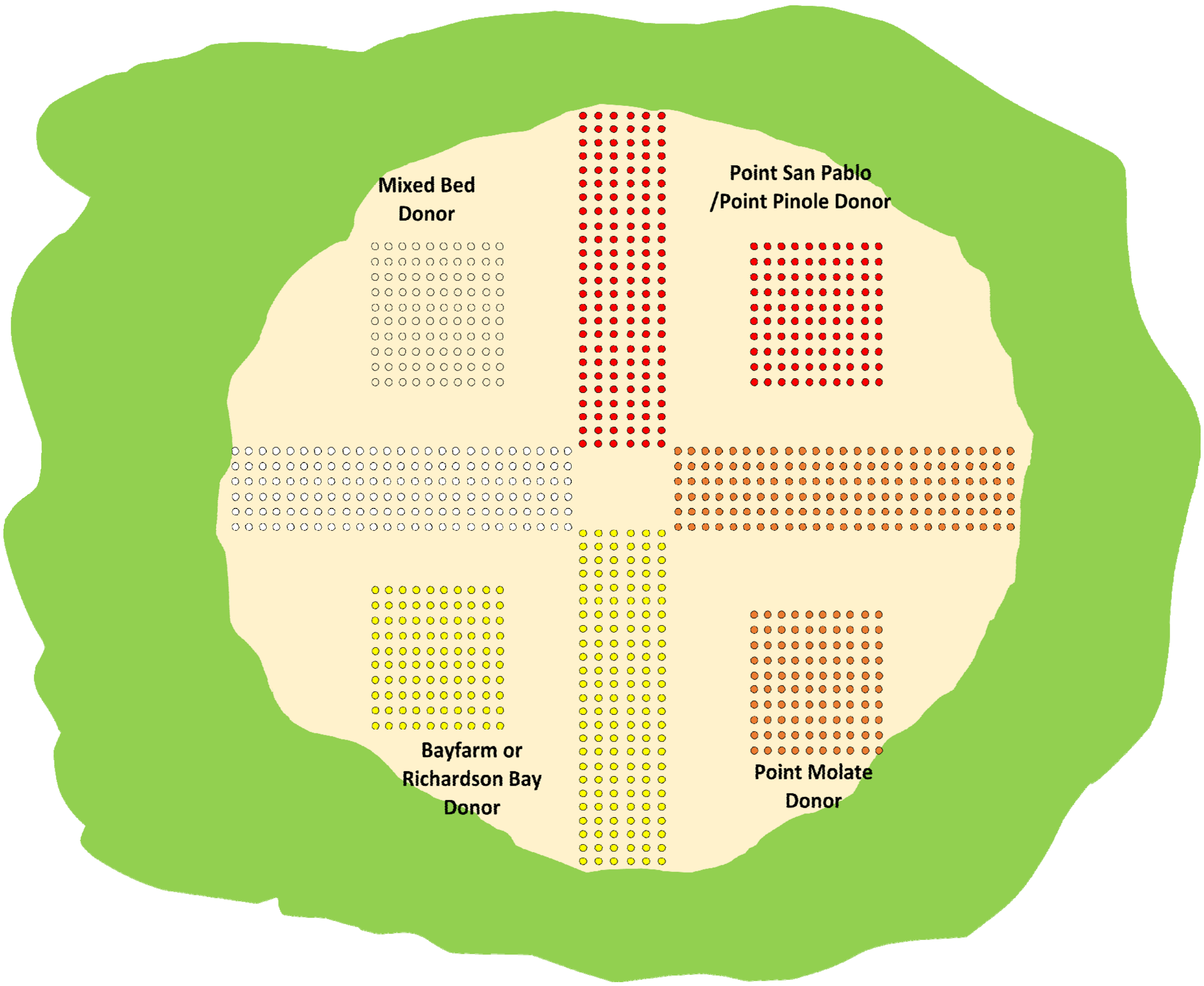


Figure 9. Typical Eelgrass Planting Plot Configuration within a Half-acre Mooring Scar

Eelgrass planting is to be guided by establishing temporary planting lines on the bottom that are set three meters apart by spooling weighted lines out from the center point. The center point of the planting plot is set by a real-time kinematic global positioning system (RTK GPS) and cardinal coordinate orientation is established for each of the planting lines. Lines are marked with uniquely identified buoys to allow for location, information management and surface-based retrieval after lines are planted. Eelgrass planting units are deployed in bundles on the individual lines. Using planting lines, the restoration sites are planted on 1-meter centers along the lines. Each guideline can be used to plant a planting area 3 meters wide. The use of planting lines facilitates tracking work progress and completion of quality control reviews throughout the planting process.

Planting Process

The plant materials will be planted by excavating a hole in the sediments with a small trowel or by hand. Each anchored bareroot planting unit will be planted in accordance with standard practices for the units. These are as follows:

- Planting Merkel Paper Stick Planting Units

For the Merkel paper stick planting units, planting is performed by burying the paper stick anchor units parallel to the sediment surface deep in the sediment such that the cotton string connecting the anchor to the rhizome bundle is tight with the rhizome bundle being installed approximately 3 cm below the sediment surface with the leaves of the unit extending vertically through the water column. When properly planted, the paper stick anchors are fully buried.

- Planting Kiriakopolos Bamboo Stake Planting Units

For the Kiriakopolos bamboo stake units, the stake is buried vertically with approximately three-fourths of its length in the sediment and the remainder of the stake extending vertically above the sediment surface. The burlap wrapped rhizomes of the planting unit are again buried approximately 3 cm below the sediment surface with the leaf bundles extending above the sediment surface adjacent to the bamboo stake. The protruding vertical bamboo can then be relocated within the transplants to identify the initial location of planting.

Example of eelgrass grid planting for illustrative purposes. Clarity in San Francisco Bay does not occur to this level.

For planting, a planting "T" is used to control the spacing of planting units along the planting lines. This planting "T" has three 1-meter long legs. Plants are installed at the center point of the "T" and at the ends of each of the arms. The "T" is then advanced until the center leg end reaches the plant that was installed along the top of the "T". The diver then advances to the new top of "T" and plants three more plants. The line is shifted over when the diver completes the planting of three rows. In the photograph it is possible to see the diver working along the line with a "T". Above the diver are two fids loaded with bareroot paper stick anchor planting units. In the background are three sticks of eelgrass floating up from the line weight. These sticks will be planted on the next line move made by the diver.

The photographs on the following page depict planting conducted by the Merkel and Boyer eelgrass team for the San Franciso Bay Eelgrass Restoration Program using funding derived from Cosco Busan DARP and SFOBB eelgrass restoration programs.

Eelgrass planting at Corte Madera Bay, Marin Rod & Gun Club, and Richardson Bay Audubon Sanctuary. Planting varied from subtidal planting by divers to intertidal planting by wading. Temporary guidelines and corner stakes were set prior to planting and removed following the planting efforts.

NON-PLANTING RESTORATION ACTIONS

NON-VESSEL MARINE DEBRIS REMOVAL

Need for Debris Removal

Debris on the bottom can adversely affect eelgrass habitat development through both physical barriers to substrate, and by growing invasive species that compete with eelgrass for canopy space. Most particularly this includes the seaweed *Sargassum muticum*.

Example from San Diego Bay of debris collected by divers and waders that is loaded into baskets or direct rigged to be winch lifted onto a deck boat (top). This material is then be amassed for loading into dumpsters for disposal (bottom).

Approach to Debris Removal

Past experience diving within the mooring scars has documented the presence of considerable debris discharged from moored vessels either intentionally or unintentionally. This includes among other items, buckets, carts, batteries, rope and cable, televisions, fuel cans, outboard motors, tires, steel boxes, plastic, and small dinghys. Most, but not all of the discarded debris can be lifted from the bottom by divers. However, other material will require a winch lift.

To remove debris, several steps are to be undertaken. The first is that interferometric sidescan sonar surveys to map the sea floor for eelgrass and unvegetated areas will be used to detect and map debris aggregation. In addition, data will be collected from mooring planting efforts where debris accumulations resulted in an abandonment of planting the site for a given season. These data sources will be used to identify aggregations of debris requiring removal.

In order to remove debris, sites identified will be visited by a restoration crew working off a flat deck boat with an A-frame and winch. The team will dive and/or wade to identify and remove debris. To locate debris in poor visibility, a weighted leadline will be anchored at one end and swung around in a radius at multiple overlapping points. When debris is encountered by the line, the radius changes dramatically, and the diver will follow the line back to whatever it snagged on. Eelgrass encountered by the line will lay down and spring back up after the line passes over.

Divers working in teams will load large baskets with debris from the bottom and the pontoon boat will crane lift these to the deck for disposal. The boat will carry a spill response kit, including petroleum absorbent pads and booms as sometimes removal of debris such as fuel tanks, motors, and spray cans can release contents. A containment pool for leaky objects will also be present on the boat decks.

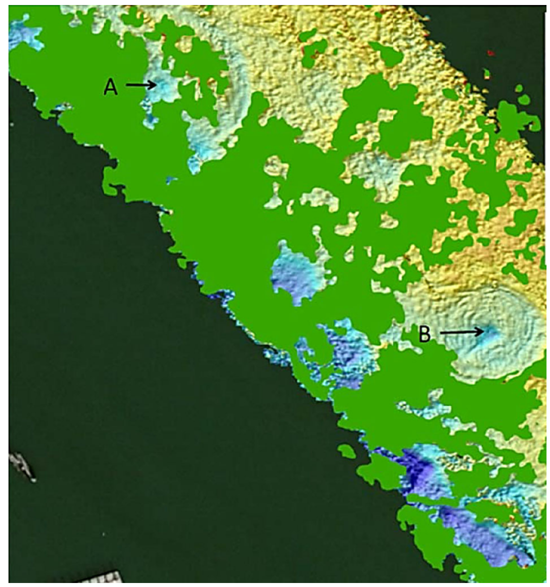
Once debris is loaded on the pontoon boat, it will be transported to the Army Corps ramp as Sausalito where the boat will be unloaded and debris will be placed into dumpsters for disposal. This material will be disposed of within the RBRA waste stream for vessel marine debris.

The debris removal will be documented by photographs and a ledger of material removed. As the material will enter the vessel debris waste stream it will not be individually accounted for by weight or volume.

MOORING SCAR BACKFILL

Problems with Mooring Scars

Mooring ground tackle and vessel grounding drags stir up bottom sediment that is subsequently transported by waves and currents. While a single pass of an anchor chain may result in minor turbidity and mechanical damage to eelgrass plants, over time chronic dragging on the bottom results in excavation of the bottom and export of the sediment to surrounding areas, or out of the area. This creates depressions at the moorings that can be a few inches to several feet deeper than the surrounding bay floor. Further, the chronic generation of turbidity at the mooring center can result in an elevated turbidity level in adjacent areas and the loss of eelgrass beyond the moorings due to plant smothering and light limitation.



Examples of mooring scar excavation pits in central Richardson Bay. (A) illustrates a central mooring tackle excavation pit with a partial keel drag excavation to the southeast. (B) illustrates a ground tackle drag excavation to the outer extent of the mooring scar.

The effects of the scoured depressions around moorings can be multifold. First, the depressions support a lowered light level than the surrounding bottom because they are deeper and light must pass through more water column. This can reduce the amount of photosynthetically active radiation (PAR) reaching plants within these depressions. Second, depressions in the bay floor accumulate drift detritus and particularly drift algae such as *Gracilaria* and *Ulva*. The accumulation of algae creates a barrier to seed reaching the sediment, and a barrier to seedlings and vegetative shoots extending through the debris layer. This impedes recruitment and growth of eelgrass within internally draining depressions on the bay floor. Finally, depressions create scarps on the bottom that may promote bat ray foraging due to energetic efficiencies of foraging in pre-excavated pits. It is often observed that bat ray foraging pits grow significantly over time and it is believed that this is due to an energetic benefit associated with foraging along the margins of established pits pulling food out of the sidewalls of the foraging pits, over the effort it takes to excavate a new pit. This is especially true in eelgrass beds due to the difficulty of excavating through an established rhizome mat, relative to undermining the edge of a mat on an existing pit. If this is the case, then it is possible that mooring scars may also provide enhanced foraging opportunities where rays can expand the scars by working along the margins of the scoured pits. This question is being explored by the Boyer Laboratory.

Need for Backfill

While there are known and potential impacts of scour pits on eelgrass restoration and natural recovery, there is also an expectation of a generally rapid rate of natural sediment accretion in these depressions given the sediment rich waters of San Francisco Bay. The expectation is based on a number of observations of scarred bottom environments in the Bay and tracking the timeframes to infill.

Over multiple years, surveys of the Richardson Bay mooring area have revealed a broad range of timeframes associated with healing of excavation damage associated with mooring tackle dragging on the bottom. In some instances, recovery has been noted within a year to two, while in other cases, recovery of the mooring excavation has not occurred after as much as five years has passed. Unfortunately, the uncertainty as to when moorings have been removed or vacated, coupled with the wide range of scar depths, bathymetric depths, and distance from the main channel make it difficult to draw specific conclusions regarding recovery rates from mooring scars and there are no good surrogate, well documented sediment accretion studies on the flats in Richardson Bay. As such, this monitoring effort has recently been initiated by the Merkel and Boyer restoration team.

However, there are examples elsewhere from which to draw on. Deep scouring damage within eelgrass beds at the Berkeley Shoal occurs relatively frequently due to vessel grounding. These scars typically remain over one or two years before they fill with sediment and are over-grown by eelgrass. As these troughs are typically shallow (0.5-1 foot) in depth and typically occur within the intertidal top of the shoal it is not known to what extent scar healing is driven by suspended sediment infill of the trough, bedload transport by surrounding surface scour, or eelgrass growing through the depressed terrain. A second example of similar conditions occurred within Keil Cove on the Tiburon Peninsula where, following the Cosco Busan Spill, an oil spill response vessel cut two trenches through soft bottom terrain supporting a dense eelgrass bed in January 2008. The scars were defined by trenches ranging from 0.5 to 2 feet in depth and were excavated by hull grounding and propeller wash by the twin propeller response vessel. Multiple surveys conducted in 2008 and 2009 showed approximately 50 percent partial healing of the scar occurring by 16-month post-injury. A subsequent July 2013 survey occurring 66-months post-injury failed to detect any residual trough or damage to eelgrass (Merkel & Associates 2013). As a result, it was determined that the bed damage, including the sediment infill of the excavated trench, recovered fully somewhere between 16- and 66-months following damage. Based on the level of recovery after 16 months, it is likely the scar fully healed closer to two years after impact than 5.5 years after impact. Finally, at the recently removed Point Orient Pier structure, sediment accretion has been noted to be occurring very quickly with one area of scour near the head of the pier exhibiting over 10 feet of infill within the first year following pier removal. Other areas showed less, but several feet of accretion (Merkel & Associates 2023, unpubl. data). While all of these examples and mooring removals that have been conducted in Tomales Bay suggest that mooring scars will self-heal, the rate of this process remains unknown.

Should mooring scars remain over multiple years and eelgrass not be successfully introduced into the scars, it would be worth evaluating the potential for backfill of the scars to bring them to grade with the surrounding bottom. However, this should not be undertaken immediately for several reasons. First, in their current state, mooring scar depressions are depositional zones and effectively reduce suspended sediment within the flats of Richardson Bay as they trap and sequester sediment. This results in some degree of water clarity improvement, although it is anticipated that this may be negligible in scale. Second, sediment placement is messy work and can generate considerable short-term turbidity while being placed. Further, depending on the nature of the sediment placed and the wave scour reaching the placement, turbidity may be elevated for an extended period of time around the placement site. This is contrary to the overall restoration goals but may be a worthwhile balance to consider at some point during the restoration process. This should not be considered for at least the first three years following a mooring removal.

Adaptive Approach to Mooring Scar Backfill

Should mooring scar infill be determined a suitable action to undertake, it will be necessary to carefully place material that is suited to supporting eelgrass and has limited risk of prolonged turbidity generation. In general, this would dictate placement of sandy sediment via either mechanical or hydraulic placement means. Alternatively, mechanically placed fine sediments such as may be derived from a maintenance dredging project, might be mechanically placed, but these would still need to be capped with a more stable sandy material.

Backfilling the scar depressions by pumping clean washed sand into the scar from a shoreline or barge-based hopper to bring the elevations up to the grade of adjacent areas may be practical. The sand fill should be derived from in-bay rinsed sources such as Presidio Shoals or Angel Island sand deposits that are commercially mined, as this material is fairly course, clean of fines, and can be controllably placed by hydraulic pumping without the risk of damage to adjacent areas. A mechanical placement might be possible; however, the shallow locations of the mooring scars would limit some equipment access for fills, and the limited volume of material expected to be required may make this an impractical method of placement.

The beneficial reuse of dredged sediment may be considered for use in backfilling scar depressions. However, it will be necessary to consider the chemical suitability of the material, whether the material is coarse enough to limit on-going resuspension of the placed sediment, and whether the material can be placed and flattened. In most cases, sediment derived from maintenance dredging (e.g., local marinas and/or navigation channels) will be too fine for use in backfilling the mooring scars in Richardson Bay, which require coarser, sandier sediment. However, as noted above, these fine sediments may be suitable for beneficial reuse if they are capped with stable, sandy material. Beneficial reuse of dredge sediment is overall valuable for the San Francisco Bay system, but will need to be considered on a scar-by-scar basis for any backfilling in Richardson Bay.

Regulatory Considerations

Placement of sediment to backfill mooring scars will require a separate permit from the Army Corps of Engineers issued under section 10 of the Rivers & Harbors Act, and section 404 of the Clean Water Act (CWA). A state water quality certification issued by the Regional Water Quality Control Board under section 401 of the CWA would be required. A permit would also be required from the BCDC. Supporting these permit actions, it is expected that section 7 Endangered Species Act (ESA) consultation may be required for steelhead depending on timing of work, and a section 2081 permit may be required from the California Department of Fish & Wildlife for longfin smelt should hydraulic placement methods be pursued.

MONITORNG AND ADAPTIVE MANAGEMENT

MONITORING METHODS

Monitored Metrics

For eelgrass restoration, the metrics include spatial metrics associated with the bed and plant metrics associated with individual plant properties within the restoration areas. Specific eelgrass metrics monitored for this restoration project include the following (* CEMP metrics):

Eelgrass Bed Spatial Characteristics

- Area created and/or enhanced, expanded
  **Areal extent*
  **Spatial distribution*
- **Percent vegetated cover*
- Elevation range of established eelgrass

Eelgrass Plant Characteristics

- **Shoot density*
- Plant height
- Flowering
- Evidence of disease or herbivory
- Herring spawning in restored eelgrass

In addition to the eelgrass metric monitoring identified above, the surveys will include three other elements for tracking site performance. The first is bathymetric surveys conducted of representative mooring scars on a recurrent semi-annual basis. Should funding allow, the second is completion of bathymetric surveys of the project site during Years 5 and 10 of the monitoring program. The final element is annual spring season mapping of vessels on moorings within the eelgrass beds. These data are necessary to plan each season's planting activities.

Spatial Distribution Surveys and Mapping

Surveys will be undertaken twice per year within the mooring field. The first event will occur during the spring (April-May) and the second will occur at the end of the growing season (September-October). Surveys will be conducted using a combination of remote sensing tools. These are Interferometric sidescan sonar and aerial photography using a UAV platform.

Interferometric Sidescan Sonar Mapping

Sonographic surveys will be undertaken using an interferometric sidescan sonar system. The interferometric sidescan system consists of a dual channel hull mounted sonar operating at 468 or 450 kHz depending on the specific unit employed. The equipment integrates a vessel motion sensor to correct for vessel pitch, heave, and roll; a sound velocity sensor that corrects for speed of sound in water related to density differences resulting from changes in temperature and salinity; and a dual antenna RTK GPS that provides precision vessel positioning and correction for vessel yaw. Because the position of the interferometric sidescan sonar head is rigidly fixed to the vessel, the positional error is dramatically reduced from that associated with other mapping methodologies, including traditional towed sidescan sonar. Further, the system greatly reduces the complications of vegetation and other features that can foul towed sonar systems and limit survey coverage. With the survey system utilized in this effort, absolute positional error for eelgrass mapping is approximately ±1 meter. The relative positional error is estimated at ±0.25 meter as the positional error is substantially nullified across short distances represented within sonar mosaics.

For the present mapping work, the interferometric sidescan will be set to 31 meters on the port and starboard channels such that the full swath was 62 meters wide. At this swath width, the generated digital image is comprised of pixels that are approximately 6 cm x 6 cm with the pixel intensity being generated by the average reflective conditions of the surfaces within the pixel. Because eelgrass is acoustically highly reflective due to air in the lacunae of the leaves, even a few leaves can generate an acoustic signature separating the eelgrass from the low reflectivity soft sediment. Reflectivity of debris can also often be separated from eelgrass by shape and shadow density. This allows for mapping of debris when it is encountered in the surveys.

Following completion of the field surveys, sonar traces will be downloaded and processed into rectified mosaic images in a GeoTiff format using Chesapeake Technologies, Inc. Sonar Wiz. The planting plots will be digitally overlain on the sidescan mosaic to assess the individual plot performance.

Aerial Photographic Mapping

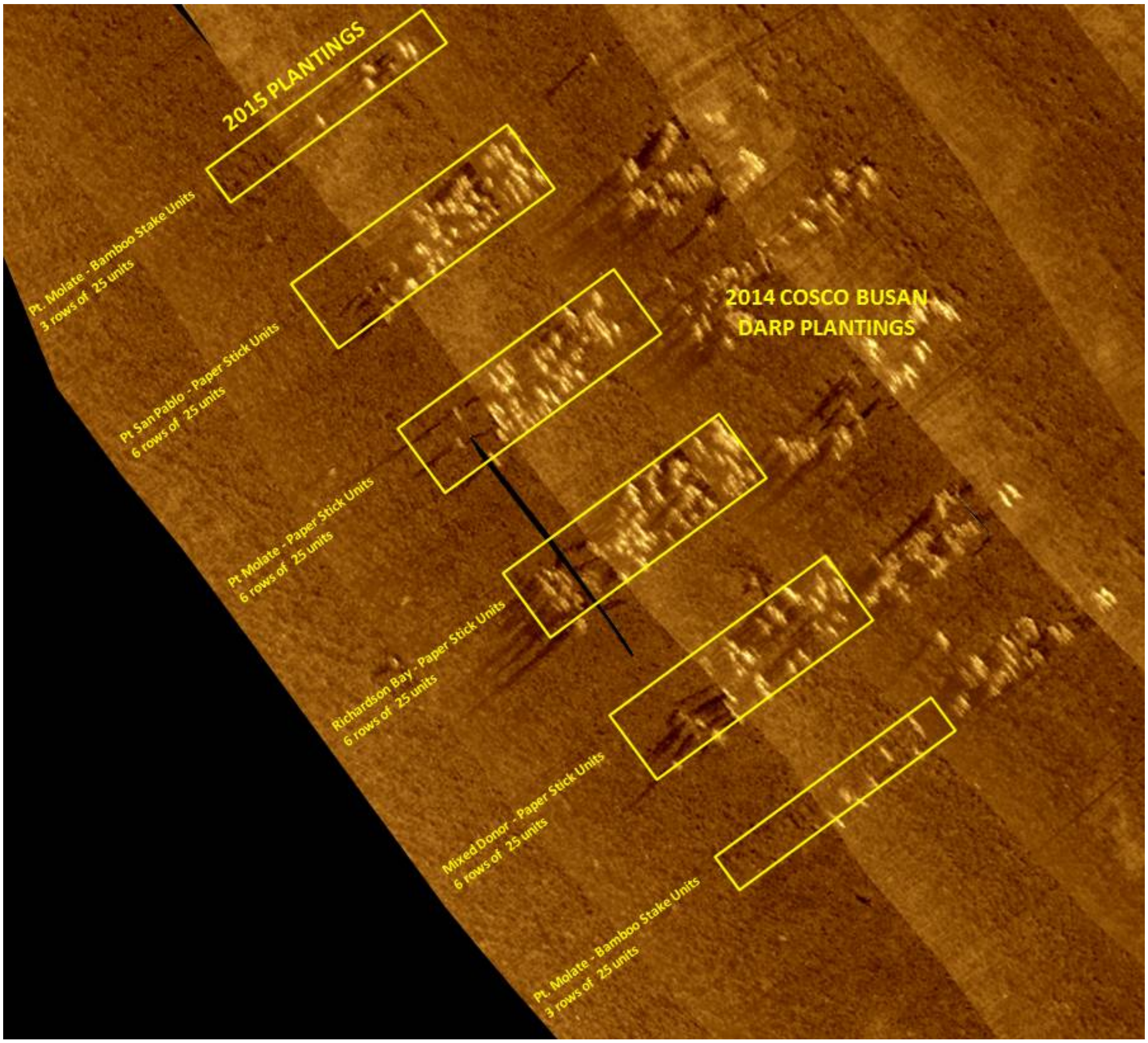
To support this approach, unmanned aerial vehicles (UAV) equipped with high resolution digital cameras will be flown at low altitude during minus low tide conditions to capture overlapping still imagery of the entirety of the project area. This imagery will then be processed into rectified orthomosaic images and classified to delineate eelgrass habitat throughout the Project Area. A DJI Phantom 4 Pro or Mavic 3E UAVs with 20 mega-pixel (MP) cameras will provide the primary aerial imaging platforms for the Project. Flights will be conducted from land or vessel positions in close proximity to the Project Area. Automated flight control software will be used to ensure the imagery capture is performed in a consistent manner with respect to flight altitude (250-350 ft) above ground level (AGL), front lap (75%) and sidelap (75%). Incorporating a higher image overlap ratio facilitates improved image alignment, and an enhanced ability to resolve partially or wholly submerged features that may be obscured by sun-glint, glare or reflections off the water surface; these factors tend to reduce the useable extent of each image, therefore having the ability to mask out problem areas without sacrificing necessary overlap between adjacent images produces higher quality orthomosaics.

Aerial imagery will be processed, color-corrected for exposure variation, mosaicked and orthorectified into a series of orthomosaics covering the Project Area using Structure from Motion (SfM) photogrammetry software (Agisoft Photoscan Professional).

Spatial Data Processing

Moored vessels and eelgrass will be mapped by manually digitizing from registered sidescan mosaics and aerial photographs using ESRI ArcGIS software. Mapping techniques and areal coverage determination will be made using of a mix of analytical techniques developed and employed in prior eelgrass surveys. For each area of the sidescan sonar mosaic that supported eelgrass, the spatial extent and bottom cover of eelgrass will be determined following metrics established in the California Eelgrass Mitigation Policy (CEMP, NMFS 21014).

Patterns of restoration site performance will be investigated by comparing eelgrass distribution and extent of bottom coverage across the multiple post-planting surveys. In addition, features such as bottom disturbance by biogenic agents (*e.g.*, bat rays, burrowing organisms) as well as anthropogenic agents (*e.g.*, propeller scarring) will be noted from the image interpretation. An example of the sonographic imagery to be collected is shown in the image below.



April 2016 interferometric sidescan mosaic illustrating an example of successful eelgrass transplant plot from 2014 Cosco Busan DARP and 2015 SFOBB plantings. The mosaic identifies the donor areas and types of planting units initially installed during the transplants. Because images are spatially rectified, they can be overlaid in ArcGIS to interpret patterns of change including areas of the bed that have experienced high growth or mortality. By evaluation of multiple images, the overall bed dynamics may be partially explored.

The area of eelgrass beds and percent bottom cover within reference plots and within each transplanted plot will be determined by interferometric sidescan sonar survey of the transplant areas. The surveys produce spatially accurate acoustic maps of the eelgrass habitat. Transplant plot metrics of eelgrass cover area and percent bottom cover will be produced for use in the interpretation of performance of the initial plantings. The interferometric sidescan sonar survey, mapping, and GIS spatial analyses will be conducted by M&A, coincident with monitoring reference plots that have been established to evaluate natural variability as a factor influencing transplant performance.

Direct Field Observations

Direct observations of plants will be undertaken once a season during the fall in order to collect data on plant conditions. Transplant and reference site reviews will include an assessment of: 1) the presence or absence of eelgrass within the planting plot; 2) the mean density ± 1 standard deviation of shoots present within the surviving plants; 3) measurement of plant heights; 4) reproductive status of plants. In addition, plants will be assessed for overall vigor as well as any identifiable biotic or abiotic stressors including signs of disease, evidence of herbivory, percent epiphytic loading, color, and leaf turgor. These qualitative and quantitative metrics provide insights into site conditions and potential stressors on the native and transplanted eelgrass.

To assess these parameters, the transplant plots will be sampled individually by initial restoration treatments. Flowering frequency and inflorescence development will be assessed following de Cock (1980), and overall non-destructive plant vigor assessment based on leaf color, turgor, epiphytic loading, macroalgal bed loading, tissue blemishes, herbivore grazing, as well as leaf tip erosion and new leaf development will be evaluated.

For shoot density, sampling will be conducted using 0.5m x 0.5m (0.25 m^2) quadrats placed over randomly selected plants within native and transplant plots. Under the CEMP, shoot density is a plant metric rather than a bed metric, as a result all samples must include vegetation and no zero values can occur. The sampling will include collection of a minimum of 40 quadrat counts for transplant plots and 40 counts for natural reference sites. This count is anticipated to be an adequate number to meet CEMP objectives for assessing a difference between reference and restoration areas with statistical power of 90 percent and $\alpha=0.10$ and $\beta=0.10$ (CEMP, NMFS 2014). Quadrats are to be widely distributed across the transplant and reference plots.

Biotic and abiotic stressors will be evaluated through observations of the site conditions and plants during each field investigation. While not always obvious with point sampling, efforts will be made during all sampling efforts to identify any plant conditions, substrate characteristics, site disturbance, water temperature, elevated turbidity, depressed salinity, or biological activities that may have adversely affected plot performance.

Discrete Investigations

Concurrent with the restoration program, there are plans to continue to conduct discrete studies and pilot investigations to aid in the development of restoration science. These efforts derive funding from various sources and are typically undertaken as master's degree research efforts by students in the SFSU Boyer Lab. In other instances, the research provides discrete information for restoration planning and may provide future assessment tools. One such discrete investigation presently planned relates to determining planting unit expansion rates across years and seasons. This will be accomplished by measuring radial growth from the initially planted location of bamboo stakes in order to determine the rate of coverage until plants ultimately coalesce with adjacent planting units. This will require high frequency visits during a few years and thus is a discrete study action separate from the annual monitoring set to occur during the fall in each year.

Other discrete data collection efforts will include monitoring of temperatures across elevation and geographic gradients within Richardson Bay and relating these temperatures to fluctuations in bed extent over the restoration period. The goal of this effort will be to further assist in calibrating numeric models in shallow water environments, and to assist in the assessment of thermal stress in shallow water eelgrass habitats.

Early morning low tide monitoring conducted in Richardson Bay. Plant survival, growth, and height are being assessed.

Consideration of Reference Sites

For the present work, there are three types of references being used. The first is natural reference sites, the second is vacated unrestored mooring scars, and the third is occupied mooring scars.

Natural Reference Sites

In order to evaluate how a restoration site is performing it is necessary to have a basis for expectations of performance. This is established by use of natural reference sites against which the observed performance of the transplants can be evaluated. Natural reference sites for this project consist of four half-acre plots in Richardson Bay, distributed across depth and geographic gradients on the central bay eelgrass beds within portions of the beds that do not suggest past damage has occurred as a result of vessel mooring. These natural beds are to be used for comparison of shoot density measurements and changes in percent bottom cover year after year. Because the restoration plots are anticipated to be widely distributed across the eelgrass beds where moorings have been removed reference sites are also to be widely distributed. The references will be pooled for analysis with the pooled data from restoration plots.

Removed Mooring Scar Reference Plots

While not used in restoration plot performance assessment, it is valuable to understand how active restoration performs relative to passive restoration activities, such as removing the moored vessels and associated mooring tackle and letting the damaged areas recover without intervention. This allows for a more direct assessment of the benefit of directed action. To investigate these questions, unplanted but vacated mooring scars are to be identified and monitored in parallel with planted scars. These unplanted plots will be added throughout the restoration program as it is most valuable to have plots that track with recently planted sites to evaluate temporal response to restoration fairly across the same windows of time.

Active Mooring Reference Plots

Mooring reference plots, like the scar reference plots are not used for direct assessment of restoration performance against natural conditions, but rather serve to evaluate how passive and active restoration differs from taking no corrective actions with respect to moorings. It is planned that these mooring reference plots will be used as a no-action baseline against which the restoration may be evaluated. These reference plots will also be used in assessment of influence on physical parameters in surrounding beds and other research interests associated with the restoration.

PERFORMANCE ASSESSMENT

Because the Richardson Bay eelgrass restoration is a restoration project rather than a mitigation project and overall ecological gains are anticipated to occur, the restoration is not subject to specific performance objectives under the CEMP. However, the omission of compensatory mitigation requirements does not negate the benefits of establishing higher goals for the restoration and using the CEMP metrics to track project performance. This has been done for this restoration program.

This RAMP establishes a goal of restoring approximately 75 acres of eelgrass through passive and active restoration within the Richardson Bay Eelgrass Protection Zone where eelgrass has been damaged by anchors, chains, and other mooring-related ground tackle by 2031. This is to be met through ongoing and future removal of vessels from within the EPZ, active replanting of eelgrass within mooring scars, and restoration of eelgrass in other areas damaged by vessel activities and debris discharges. The approximately 75 acres is inclusive of mooring scar planting that was completed before the adoption of this RAMP as part of the prior Cosco Busan eelgrass restoration and private entity planting conducted within a mooring scar. However, this goal does not include other restoration completed outside of the EPZ, such as that of the Cosco Busan and SFOBB restoration that has occurred predominantly within the Richardson Bay Audubon Sanctuary. As a result of these previous efforts, 6.75 acres have been planted and are presently being monitored to assess eelgrass restoration gains.

Should restoration funding sources be provided to implement the restoration of eelgrass, the restoration plots funded as compensatory mitigation will be subject to compliance with full CEMP metrics as may be associated with the regulatory obligations for the requiring project actions.

ESTABLISHMENT MONITORING

Under the CEMP, a monitoring program is typically initiated to evaluate restoration success by assessing the project at regular milestones over a period of 60 months (5 years). However, this works best for discrete restoration actions that are then tracked for establishment to meet a mitigation requirement. In the present case and as has been the case over the past 9 years for the Cosco Busan and SFOBB restoration, planting has been conducted over multiple years through an adaptive process, with some years having no planting and other years having significant planting activities. This makes it difficult to assess the whole of the restoration against discrete interval milestones. As a result, all of the plots will be monitored during all of the program years and assessed against CEMP metrics for each year. This will result in early planting plots being monitored for a period of 10 years, while the last planting plots may be monitored for a much shorter period of time. Individual planting plots will be assessed following CEMP spatial metrics including eelgrass spatial distribution, areal extent, and percent vegetated cover. If RBRA or other project partners wish to extend restoration and adaptive management efforts beyond the 10-year time frame of this plan, continued monitoring of all restored eelgrass, with a priority placed on the last planting plots, is recommended.

The collective of planting plots will be assessed against the collective natural reference for shoot density. Eelgrass shoot densities will be compared between restoration and reference plots to control variance to a level suitable to detect a 25 percent difference between reference and transplant sites with statistical power of 90 percent and $\alpha=0.10$ and $\beta=0.10$ (CEMP, NMFS 2014).

Restoration Success Criteria

Restoration will be deemed successful when damage to the eelgrass within the RBRA waters associated with moorings has been eliminated such that natural bed dynamics take over and no detectable pattern of past mooring damage remains within completed eelgrass surveys.

While not strictly applicable to the restoration program, the eelgrass development within planted plots will be tracked under the provisions of the CEMP to evaluate whether the restoration meets or exceeds the broader expansion objects discussed previously. Criteria for determination of transplant performance will be based upon a comparison of bed areal extent, percent vegetated cover and density (shoots per square meter) between the reference sites and the transplant sites. Specific performance metrics include the areal extent as defined where eelgrass is present and where gaps in coverage are less than one meter between individual turion clusters. Density of turions (shoots) is identified as the number of turions per square meter, as measured from representative areas within the control or transplanted beds.

Key success criteria are as follows:

- Month 0 – Monitoring should confirm the full coverage distribution of planting units over the initial restoration site as appropriate to the geographic region.
- Month 6 – Persistence and growth of eelgrass within the initial restoration area should be confirmed, and there should be a survival of at least 50 percent of the initial planting units with well-distributed coverage over the initial restoration site. The timing of this monitoring event should be flexible to ensure work is completed during the active growth period.
- Month 12 – The restoration site should achieve a minimum of 40 percent coverage of eelgrass and 20 percent density of reference site(s) over not less than 1.0 times the area of the impact site.
- Month 24 – The restoration site should achieve a minimum of 85 percent coverage of eelgrass and 70 percent density of reference site(s) over not less than 1.0 times the area of the impact site.
- Month 36 – The restoration site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.0 times the area of the impact site.

- Month 48 – The restoration site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.0 times the area of the impact site.
- Month 60 – The restoration site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.0 times the area of the impact site.

Areas that do not meet the above success criteria may be revegetated, and again monitored until the final no-net-loss goals are achieved. Should replanting of the areas at the project site fail to meet the success criteria, reconstruction of portions of one or more transplant sites may be required to carry out this revegetation. Should the reference areas fail or decline alongside the transplant areas the goals would be depressed to subtract out the natural bed declines.

REPORTING PROGRAM

By agreement between RBRA and BCDC, regular reporting is to occur on a monthly, quarterly, and annual basis. This reporting calls for information to be presented on progress in achieving eelgrass metrics among presenting on other metrics. However, as the eelgrass restoration and monitoring activities are punctuated events through the year, the reporting information will be refreshed as new data becomes available, milestone actions are conducted, or as planning is completed to prepare for the next cycle of work.

Monthly Reports

Under the monthly reporting, RBRA will be provided information as it becomes available in the course of implementing this RAMP that addresses the progress of eelgrass restoration and vessel and ground tackle and mooring removals to free up restoration opportunities. It is anticipated that this reporting will be limited to a brief memorandum format and will vary depending upon the cycle of work. The reporting will track eelgrass metrics including but not limited to: 1) the amount of ground tackle/moorings removed or left behind following vessel removal, 2) progress and results from restoration studies in the Eelgrass Protection Zone; 3) progress on completing and implementing the 10-year adaptive management plan and how it meets the minimum requirements of the CEMP (including goals, performance standards, monitoring performance milestones, and contingency plan.

Quarterly Reports

Under the quarterly reporting, RBRA will be provided an expanded discussion of the status of removal of vessels and associated ground tackle as it pertains to opportunities for eelgrass restoration as well as an expanded summary on eelgrass restoration metrics. In addition, this report will include a summary of funding acquisition, and discussion of how budget surplus and deficits will be addressed. In addition, quarterly reports will include discussion on potential beneficial reuse of dredge materials for expansion of eelgrass in the bay.

Annual Reports

An annual report will be prepared to provide an update on project activities associated with the implementation of this 10-year RAMP. The annual monitoring reports will include information from previous monitoring intervals, including numerical comparisons and graphical presentations of changing bed configurations. Graphical comparisons will include bathymetry. The monitoring report will include an analysis of any declines or expansions in eelgrass coverage based on physical conditions of the site, as well as any other significant observations. Finally, the monitoring report will provide a prognosis for the future of the eelgrass bed and will identify the timing for the next monitoring period.

A brief presentation of the annual report results will also be prepared for presentation to the BCDC Enforcement Committee or full Commission as desired. The report will include a discussion of past actions, status regarding progress towards meeting goals, any hindrances in achieving the goals, and a discussion of future year plans. The annual report will also summarize the results of the monthly and quarterly reports, and RBRA's progress towards implementing the RBRA/BCDC agreement.

PRELIMINARY PROGRAM SCHEDULE

The proposed work is outlined to be conducted in accordance with Table 1. It is anticipated that approximately 8 acres of eelgrass will be planted in 2024 using funding derived from EPA grants and Cosco Busan DARP funding. A strong El Nino has been forecast for 2024 and this could result in eelgrass impacts throughout San Francisco Bay. Should this occur, the goals for 2024 may be revised based on donor site conditions in the spring.

Restoration is planned to target 8 acres of planting per year. This will allow potential for variability in planting level each year while achieving not less than 15 acres of restoration under EPA funding by 2027 and 6 acres under Cosco Busan funding that supplements prior restoration conducted from 2014 to present by NMFS and the NOAA Restoration Center. Should additional sources of restoration funding be made available, the planting levels each year will be varied accordingly.

Table 1. Preliminary Program Schedule

ACTIVITIES	TIME PERIOD	STATUS
Prepare an Eelgrass Protection and Management Plan	Dec 15, 2021	Completed
Establish an Eelgrass Protection Zone (EPZ)	Jul 2021	Completed
Conduct initial 6.75 acres of planting	2021-2023	Completed
Prepare eelgrass Restoration and Adaptive Management Plan (RAMP)	Oct-Dec 2023	Draft
Conduct pre-season planning surveys	April 2024	Pending
Obtain CDFW scientific collecting permit amendment	Jan-May 2024	Pending
Conduct 2024 planting	May-Jul 2024	Pending
Conduct non-vessel marine debris removals	Jun-Aug 2024	Pending
Remove all vessels from EPZ	October 15, 2024	Pending
Conduct 2024 monitoring	October 2024	Pending
Conduct 2024 annual reporting	December 15, 2024	Pending
Conduct Recurrent Program 2025-2033	2025-2033	Pending

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