HUMBOLDT BAY
EELGRASS COMPREHENSIVE MANAGEMENT PLAN

Prepared for :
Humboldt Bay Harbor, Recreation, and Conservation District
601 Startare Dr.
Eureka, CA 95501

United States Environmental Protection Agency

Prepared by:
Merkel & Associates, Inc.
1670 Chester Ave
Arcata, CA 95521
Whelan A. Gilkerson, Senior Biologist
(707) 407-7469
Keith W. Merkel, Principal Consultant
(858) 560-5465

PREFACE

Background

Humboldt Bay is California's second largest estuary, encompassing roughly 62.4 square kilometers (about 15,400 acres) and supporting more extensive eelgrass resources than any other system in the state. Eelgrass is a highly productive seagrass that contributes to ecosystem functions at multiple levels as a primary and secondary producer, as a habitat structuring element, as a substrate for epiphytes and epifauna, and as a sediment stabilizer and nutrient cycling facilitator. In Humboldt Bay, eelgrass provides foraging habitat or cover for a variety of fish, bird and invertebrate species, including species that have important cultural, commercial, and recreational values to the region as well as species that are listed under the federal or state Endangered Species Act. Eelgrass is one of the most abundant habitats in Humboldt Bay, and its contribution to the ecosystem stability and character cannot be overstated.

The importance of eelgrass both ecologically and economically, coupled with ongoing human pressure and potentially increasing degradation and losses associated with climate change, highlight the need to protect, maintain, and where feasible, enhance eelgrass habitat. Based on this need, NOAA's National Marine Fisheries Service (NMFS) promulgated and adopted the California Eelgrass Mitigation Policy and Implementing Guidelines (CEMP) in October 2014. The CEMP has subsequently been embraced by a number of state and federal resource and regulatory agencies. While the precursor Southern California Eelgrass Mitigation Policy (SCEMP) had been in effect since 1991 (NMFS 1991, as amended), the expansion to a statewide policy and integrating prescriptive transplant ratios based on regional eelgrass restoration failure history increases the cost and complexity of addressing eelgrass from that which has been the case in prior times. The northern portion of the state, while having been exposed to the same underpinning resource conservation principles of impact avoidance, minimization, and mitigation as encapsulated in the SCEMP has not previously been subject to the same rigorous standards that have been in place in southern California. Similarly, absent consistent conditions relating to eelgrass, there has been more inconsistent implementation and regulatory enforcement of conditions than is the case in southern California where greater anthropogenic pressures on eelgrass have existed for a longer period of time and a solid understanding of expectations on all parties has resulted in substantially enhanced success with eelgrass management, monitoring, and mitigation practices.

While the CEMP seeks to provide statewide uniformity in governing standards and resource management principles with respect to eelgrass, and furthers consistency and certainty with respect to how agencies will address eelgrass, there are a number of considerations that vary geographically. In response to public concerns over the potential impacts of a "one size fits all" approach to managing eelgrass in the State, the CEMP included opportunity for the development of Comprehensive Management Plans (CMPs) to address system-specific alternative means to accomplish the objectives of the CEMP. A CMP allows for development of region or system specific means to achieve the objectives of the CEMP that may vary from the prescriptive structure of the CEMP while still achieving the overarching goals and objectives.

Within Humboldt Bay, eelgrass distribution, abundance and overall health is affected by many factors including climate change (e.g., sea level rise, ocean acidification) and human activities within the bay (e.g., mariculture, dredging, dock and wharf construction, shoreline protection, boating) and watershed (e.g., urbanization and development, agricultural and forestry practices). Unlike other Humboldt Bay habitats which have been part of larger-scale restoration projects, most eelgrass conservation actions have been undertaken as mitigation for human activities that affect eelgrass and are implemented on a "project-by-project" basis. This has not resulted in an efficient use of resources, including funding and agency staff time, nor has it resulted in a high degree of success in achieving the intended goals. The adoption of the CEMP results in a structure that tightens obligations for success in compensatory mitigation of eelgrass impacts. It further establishes regional restoration targets that escalate in scale based on regional eelgrass restoration failure history. While this element of the CEMP is expected to assist in achieving a no-net loss of area or function goals for eelgrass, it also has the undesirable consequence of increasing the cost of compliance with the CEMP where a poor history of eelgrass restoration success exists. This is of tremendous concern in the economically depressed Humboldt Bay region where the restoration ratios under the CEMP are very high and little overall eelgrass restoration experience exists.

Concurrent with the recent changes within the eelgrass regulatory environment, there has been a developing appreciation for both the functions of eelgrass in environment as well as the threats eelgrass presently faces and is expected to face in years to come under scenarios of climate change and sea level rise. Collectively, these issues resulted in the development of the Humboldt Bay Eelgrass Workgroup, which consists of representatives from local, state and federal agencies, the Wiyot Tribe, and other stakeholders. This Workgroup convened a Humboldt Bay Eelgrass Management Workshop on October 6-7, 2014 in Eureka, CA. The workshop was well attended and during the workshop, development of an eelgrass management plan for the bay was identified as a high priority.

As an outcome of this workshop, the Humboldt Bay Harbor, Recreation, and Conservation District, with commitments by a number of collaborating partners, applied for funding from the U.S. Environmental Protection Agency Regional Wetlands Program Development Grant Program to support the development of a comprehensive eelgrass management plan for Humboldt Bay. The grant was approved in September 2015 and Merkel & Associates was retained in 2016 to assist the District and its partners in the preparation of the Humboldt Bay Eelgrass Comprehensive Management Plan.

Purpose

The Humboldt Bay Eelgrass Comprehensive Management Plan is intended to be an ecosystem-based management (EBM) plan. The goals of the plan identified in the EPA grant proposal are to:

- Ensure that the sum of individual eelgrass restoration and protection actions has the greatest benefit to eelgrass and eelgrass functions,
- Facilitate more efficient regulatory processes for projects in the bay; for example, by pre-identifying high priority eelgrass mitigation/conservation options, and

- Provide a long term eelgrass habitat conservation strategy that allows for sea level rise adaptation, dredging and economic development in Humboldt Bay.

Additional objectives have been developed through partnership meetings and public workshops. These have included the following in no particular hierarchical order:

- Identify data gaps and means to fill these;
- Review eelgrass projects performed around the bay to identify what has been successful and what has not and why projects were successes or failures as a learning experience;
- Efforts to identify eelgrass mitigation and management opportunities to facilitate waterfront and harbor maintenance needs;
- Identify the purpose of the plan with respect to ongoing impacts affecting eelgrass and driving projects behind plan actions;
- Recommendation of a process to avoid common and avoidable pitfalls with respect to eelgrass management issues within the environmental review and regulatory process;
- Outline standards for surveys to facilitate project review, including baseline surveys being done;
- Recommendation for methods to streamline regulatory process and address the high cost and effort of mitigation for eelgrass impacts, and;
- Identification of the types of impacts to be addressed within the plan.

There were different thoughts expressed by partners with respect to the reach of the plan with some recommendations for the plan to address a narrow scope and others expressing that the plan should be broader in scope. As a compromise the plan addresses a broad scope relative to the eelgrass resources in the Bay ecosystem, but proposes a narrower scope with respect to how the plan would function within the regulatory forums. Nothing in the plan replaces existing regulatory programs; however, it is intended that conformance with the Humboldt Bay Eelgrass CMP would be considered compliant with the requirements of the CEMP. This is applicable to projects of a nature specifically addressed within the regulatory framework sections of the plan.

Finally, the plan has also been developed to be a living document that will necessarily be revised from time to time.

Process

Planning efforts regarding eelgrass in Humboldt Bay date back to the 1980s initially commencing with aligning interests between parties concerned about the health of Humboldt Bay and a growing realization as to the magnitude of importance eelgrass has in the bay system. Planning efforts continued with an expanding involvement of Humboldt State University and California Sea Grant in the investigation of eelgrass and ecological linkages in the bay that tended to converge in the eelgrass beds. From 2001-2009 the Humboldt Bay Cooperative Eelgrass Project was an operative collaboration to develop a baseline understanding of eelgrass resource dynamics in Humboldt Bay. The program terminated when the HBHRCD began participating in the SeagrassNet Monitoring that displaced this local effort. In 2006 initial funding was provided by the California State Coastal Conservancy to initiate an ecosystem-based management approach for Humboldt Bay under the Humboldt Bay Ecosystem Program. As an outgrowth of this precursor effort, the Humboldt Bay

Initiative (HBI) was born as a collaborative effort working towards an ecosystem-based management (EBM) approach for Humboldt Bay. EBM emphasizes collaborative, science-based management, sustainability, ecological health and inclusion of humans in the ecosystem.

In 2011 the Coastal Ecosystems Institute of Northern California (CEINC) was established to foster the HBI efforts. One of the undertakings of CEINC has been the Humboldt Bay Sea Level Rise (SLR) Vulnerability and Adaptation Planning effort. This effort has provided some keen insights into how Humboldt Bay may be affected by SLR in the future. It has also provided valuable tools for the assessment of how eelgrass and other bay resources may be affected by SLR.

As a culmination of local data and management planning developments and the public process underway on adoption of the California Eelgrass Mitigation Policy, the HBHRCD and others in the Humboldt Bay community initiated efforts to host the October 2014 Humboldt Bay Eelgrass Management Workshop that continued and, to some degree coalesced many conversations about the future of Humboldt Bay with respect to eelgrass and eelgrass management. The outgrowth effort from this meeting was the EPA grant application and award to the HBHRCD for development of the Humboldt Bay Comprehensive Management Plan. This process established a format for the present stakeholder and public coordination. This format includes the following:

- At least 5 partner meetings on the plan development and review
- Two field tours of the bay with partners
- Hosting of initial and final public workshops
- Development of and hosting of a project website

ACKNOWLEDGEMENTS

This Eelgrass Comprehensive management plan has been developed with funding provided to the Humboldt Bay Harbor, Recreation, and Conservation District from the USEPA Regional Wetlands Program Development Grant Program.

Partners

A number of partners have been involved in the development of this plan and have committed time, meeting facility resources, consultant time, and other in lieu contributions for the development of this plan. In total, the partners in the development of the Humboldt Bay Eelgrass Comprehensive Management Plant have committed 624 hours to the development of the plan. The partners in the effort include:

California Coastal Conservancy
California Coastal Commission
City of Eureka
City of Arcata
Hog Island Oyster Company
Humboldt Baykeeper
Humboldt Bay Harbor, Recreation, and Conservation District
Humboldt County
NOAA National Marine Fisheries Service
University of California, Sea Grant Extension Program
Wiyot Tribe

In addition to the original partners under the EPA Grant, several other entities have committed significant time and effort to the program, bringing enhanced benefit to the planning efforts. These include:

Audubon Society Redwood Region
California Department of Fish & Wildlife
GHD Consulting Services
North Coast Regional Water Quality Control Board
PlanWest Partners
SHN Consulting Engineers & Geologists
Stillwater Sciences
Trinity Associates
U.S. Army Corps of Engineers
U.S. Fish & Wildlife Service

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Humboldt Bay Eelgrass
Comprehensive Management Plan

1.0 INTRODUCTION

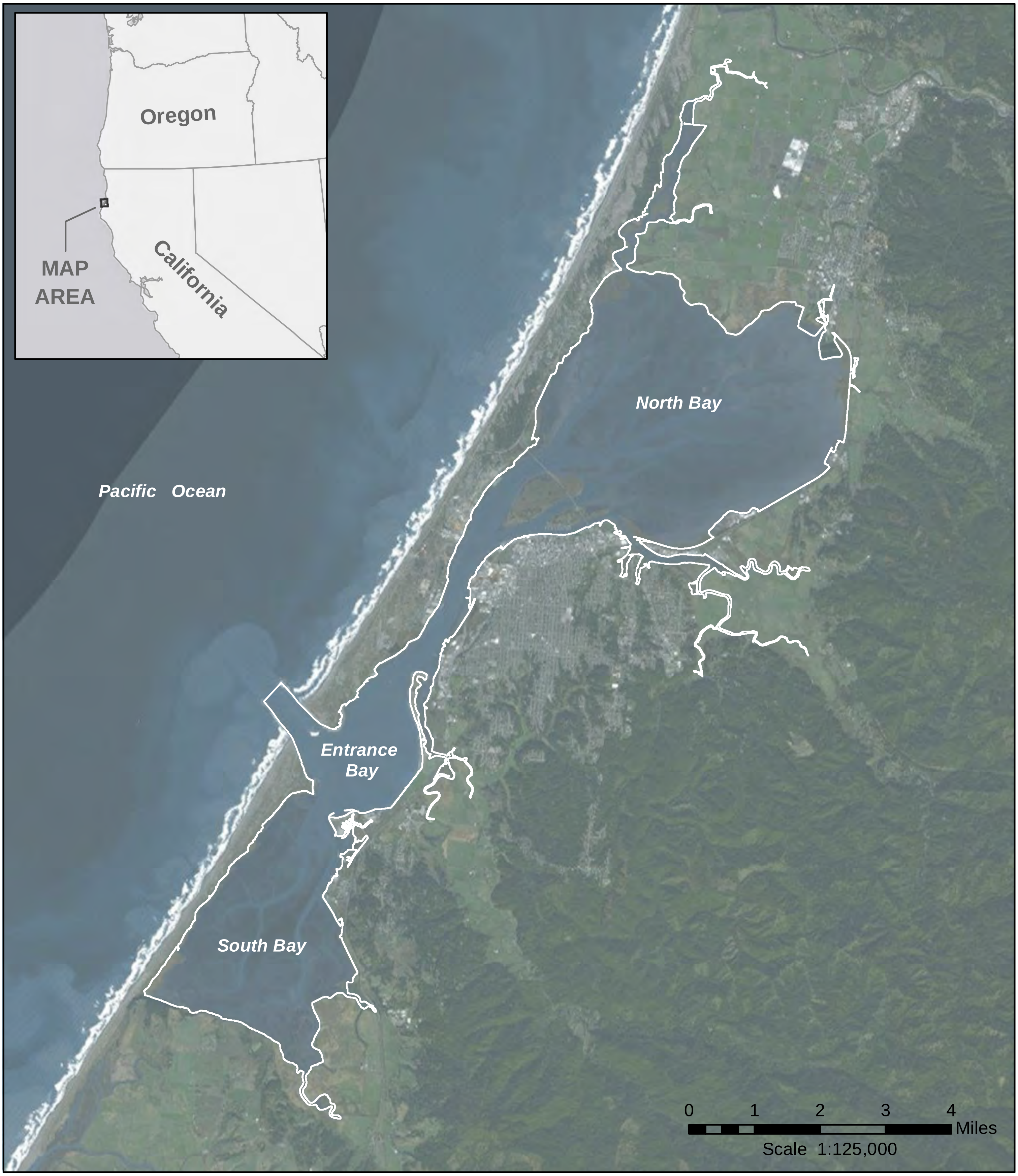
1.1. HUMBOLDT BAY

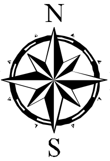
Humboldt Bay is California's second largest enclosed bay and the largest protected coastal embayment on the U.S. West Coast between San Francisco Bay and Willapa Bay, Washington, covering approximately 62.4 km^2 (24.1 mi^2) at mean high tide and 28.0 km^2 (10.8 mi^2) at mean low tide (Proctor et al. 1980 in Barnhart et al. 1992). The bay is comprised of three distinct sub-basins, North (Arcata) Bay, Entrance Bay, and South Bay (Figure 1). Both North Bay and South Bay consist of extensive intertidal mudflats interspersed with drainage channels (Barnhart et al. 1992). Entrance Bay has a maximum depth of approximately 15 m in the dredged portion of the entrance channel and connects both North and South Bay to the Pacific Ocean. The total length of shoreline in Humboldt Bay is 164 km (102 miles), of which 75% is composed of artificial structures and 25% of which remains natural (Laird 2010).

Humboldt Bay provides abundant wildlife habitat and supports a diverse assemblage of resident and migratory shore birds, waterfowl, marine mammals, fish and invertebrate species that rely upon the bay's extensive, intertidal mudflat, eelgrass, salt marsh and wetland resources. In addition to its abundant natural resources and wildlife habitat value, Humboldt Bay supports the only deep water port and harbor facilities between San Francisco Bay and Coos Bay, Oregon making it a vital resource for the economy of the north coast region.

Historically, the timber industry on Humboldt Bay has been an economic engine in the region, providing facilities for processing and exporting timber products from the deep water port. Concurrently the bay historically supported a strong commercial fishing and mariculture industry. The bay has also been an important regional center for recreational fishing, hunting, and resource exploitive harvests such as crabbing and clamming.

With a U.S. decline in the timber industry and a sharp decline in the California timber industry, much of the Humboldt Bay working waterfront has fallen into a state of disrepair. Despite being a deep water port, aging shoreline infrastructure currently increases costs and limits the potential of bulk shipping, as well as cruise ship use of the bay. Further, railroad access was eliminated in the late 1990s due to storm damage, also limiting the potential for the harbor to function competitively in the shipping industry. Declines in commercial fishing in the region have further hurt the regional economy. The circumstances of the deteriorating Humboldt Bay waterfront infrastructure have created a negative feedback loop wherein lack of demand for the infrastructure has led to a decline in maintenance. The decline in maintenance has resulted in high costs to bring the shoreline infrastructure back-up to a functional level, which often exceeds the operating value of the facilities, making it difficult to attract potential users. Increasing regulation in the bay has further generated greater difficulty in attracting potential bay dependent business, thus facilities continue to spiral downward.





Humboldt Bay, California

Humboldt Bay Eelgrass Comprehensive Management Plan

Figure 1

As a matter of investing in the bay, maintenance and repair of the harbor infrastructure to revitalize the economy surrounding the bay has become a leading focus of the HBHRCD and is of high interest to Humboldt County and the cities of Eureka and Arcata. This focus has included improving specific facilities that would assist in sustaining deep harbor functions, enhancing water access and investments in changing demands on Humboldt Bay. Further efforts underway include pursuit of transition opportunities away from the heavy industrial nature the bay has historically supported to a more regionally and environmentally sustainable economic development model that embraces sustainable fisheries and mariculture, sustainable industrial, manufacturing, and commercial development, as well as expansion of visitor serving and niche business opportunities within the vacated waterfront lands.

1.2. BIRTH OF THE HUMBOLDT BAY EELGRASS MANAGEMENT PLAN

Although a comprehensive statewide inventory of eelgrass habitat is lacking, a review of recent mapping efforts and ecological studies suggest that California may contain as little as 11,000-15,000 acres of eelgrass habitat at any given time (Merkel 2013, NOAA 2014). This estimate is being increased for open coastal and insular beds, but has been in a recent state of decline for beds within enclosed bays and estuaries (Merkel, unpublished, Merkel 2015). While eelgrass is widely distributed throughout many protected coastal embayments and estuaries spanning the state, it appears that over 80 percent of California's eelgrass habitat is associated with California's five largest bays (San Francisco, Humboldt, Tomales, San Diego, and Mission Bays). Based on a recent baywide inventory of eelgrass and other benthic habitats in Humboldt Bay and Eel River Estuary (Schlosser and Eicher, 2012), Humboldt Bay likely accounts for over 30 percent of California's eelgrass habitat overall and contains the largest eelgrass population in the state.

In Humboldt Bay, projects that impact or have the potential to impact eelgrass have historically been regulated under a loose set of compensatory mitigation standards that have resulted in varied mitigation requirements that have often resulted in poor mitigation success or uncertain functional replacement of lost resource values. Eelgrass mitigation has been identified as being historically challenging in northern California and particularly in Humboldt Bay due to lack of site opportunities as well as economic constraints associated with mitigation projects. Further, there has been a growing trend towards mitigation of convenience, without adequate consideration of the broader land and water uses in Humboldt Bay. This creates potential future conflicts in management and operations of waterfront facilities.

There has been a growing awareness of the implications of a changing regulatory approach brought on by the Army Corps' 2008 Compensatory Mitigation for Losses of Aquatic Resources; Final Rule and the recent adoption of the California Eelgrass Mitigation Policy and Implementing Guidelines (CEMP) (NOAA Fisheries, 2014). These both result in increased protections for eelgrass and higher standards for eelgrass mitigation. Concurrently there has been a building awareness of the importance of eelgrass to Humboldt Bay and the increasing vulnerability of eelgrass to global climate change predictions. With increasing scientific, management, and regulatory uncertainty, the HBHRCD convened the Humboldt Bay Eelgrass Management Workshop on October 6-7, 2014 to bring together eelgrass experts and regional stakeholders to discuss the regional issues related to eelgrass. The outcome of this effort was a recommendation for development of an eelgrass management plan tailored to the unique needs and circumstances of Humboldt Bay.

The workshop featured multiple presentations on eelgrass ecology, conservation, management, and regulatory policy; incorporated panel discussions that engaged agency, industry, and environmental stakeholders in productive dialog; and ultimately fostered a tremendous understanding of the needs for and challenges facing the development of an eelgrass management plan for Humboldt Bay. Although strong feelings were expressed on all sides of multiple complex issues associated with eelgrass management in Humboldt Bay, there was a general broadly held agency and stakeholder understanding that Humboldt Bay could not delay longer with respect to addressing eelgrass. By doing nothing, existing harbor facilities faced being shut down, lands were at risk of being inappropriately conserved for eelgrass in developed areas, and more beneficial eelgrass restoration opportunities that did not conflict with other bay uses were forgone.

As a result of the workshop, the HBHRCD gained valuable insight into the need for a comprehensive eelgrass management plan for Humboldt Bay and subsequently pursued and received funding for this plan through an EPA Wetland Program Development Grant in 2015. The overarching goal of the plan entails focusing on the ecosystem context of eelgrass with current infrastructure and operational needs being the catalyst for plan development and adoption. This approach to plan development recognizes a need to focus on areas of principal agreement in order to build a functional plan with broad agency and stakeholder support.

1.3. REGULATORY CONTEXT AND THE EELGRASS COMPREHENSIVE MANAGEMENT PLAN

The recently adopted CEMP supports the objectives of development of a comprehensive management plan and states "*NMFS supports the development of comprehensive management plans (CMPs) that protect eelgrass resources within the context of broader ecosystem needs and management objectives.*" Further, the CEMP was not adopted in a vacuum but was evaluated with the public and partnering agencies. During this vetting process, the CMP element received broad-based support with no negative feedback. As outlined in the CEMP, CMPs are intended to fit best in situations where actions result in incremental but recurrent impacts to a small portion of the local eelgrass population through time. Because of the expansive nature of eelgrass in Humboldt Bay, the CMP process can fit well within the context of management needs and system resources.

The poor history of eelgrass mitigation performance in northern California, including Humboldt Bay, has had the effect of driving up prescriptive transplanting ratios to mitigate for eelgrass impacts under the CEMP (75 percent failure rate; CEMP 2014). While the ultimate success criteria for eelgrass mitigation remains the establishment of eelgrass at a 1.2:1 ratio relative to area of eelgrass impacted, the CEMP requires an up-front planting ratio of 4.82:1 as a means of helping to ensure success. This high prescriptive planting ratio has had unintended consequences for entities such as the HBHRCD for a number of reasons. First, eelgrass is believed to be near carrying capacity in Humboldt Bay (Gilkerson 2008) which makes it difficult to identify potentially suitable locations to restore or mitigate for eelgrass impacts absent significant and costly habitat engineering. Secondly, the small scale of the northern California coastal economy, which already makes capital improvement projects and maintenance of waterfront infrastructure difficult to fund (e.g. rehabilitation of marinas, shoreline infrastructure, and maintenance dredging), is further challenged by the additional costs imposed by high prescriptive eelgrass transplant ratios. For these reasons and the challenges of addressing deferred maintenance with limited funding, the HBHRCD and larger Humboldt Bay community stand to benefit from a programmatic approach to addressing eelgrass resource management that improves regulatory efficiencies, makes eelgrass mitigation more cost-effective, and improves the outcome of mitigation and restoration efforts, while ultimately maintaining strong protection of eelgrass resources within the Humboldt Bay system.

To achieve the goals of improving regulatory efficiencies this plan does the following things:

1) Recommends protocols for completing eelgrass surveys and impact evaluation methods in support of projects in order to:
    a. Determine eelgrass status in the project area early in project planning in order to provide time for effective evaluation of opportunities for impact avoidance, minimization, and/or mitigation and to ensure impacts are addressed in project environmental disclosure documents;
    b. Ensure survey methods are adequate to detect potential impacts and evaluate potential project impacts at the scale of potential effects. This includes identification of an appropriate area of potential effect (APE), selection of survey methods to fit project scale and environment, developing bathymetric data, and identifying and surveying an appropriate reference site for tracking natural variability in the system, and;
    c. Identify when eelgrass surveys are warranted as: i) a planning baseline survey; ii) pre- and post-activity surveys, and; iii) post-construction surveys to determine if secondary impacts develop from the project implementation.

2) Recommends the use of combined regional mitigation sites to address small scale impacts to eelgrass in a manner that controls costs, uncertainty, and schedule for projects qualifying for the mitigation site uses.
    a. The plan identifies a number of potential eelgrass mitigation opportunities that may be explored for future implementation;
    b. The plan suggests the development of sites both ahead of mitigation need and opportunistically to control costs and reduce ultimate compensatory mitigation ratios consistent with the provisions of the CEMP, and;
    c. The plan provides conceptual planning information for one such site to be developed in association with maintenance dredging of the King Salmon channel.

3) Recommends regulatory and resource management structures for meeting eelgrass mitigation needs and capturing surplus eelgrass developed for application to future project needs. The document addresses the following:
    a. Potential and recommended structures for mitigating site development and management;
    b. Potential and recommended permitting structures to reduce complexity in implementing projects with eelgrass impacts or potential impacts, and;
    c. Means to integrate the use of the Humboldt Bay Eelgrass CMP into the regulatory process.

2.0 HUMBOLDT BAY EELGRASS

2.1 EELGRASS DISTRIBUTION AND ABUNDANCE

Broad Geographical Context

Common eelgrass (*Zostera marina*) is a vascular marine plant that occurs within protected and semi-protected environments within bays and estuaries and protected open coastal environments. Eelgrass can be a prolific species where suitable habitats occur and is widely distributed throughout the temperate regions of both the northern Pacific and Atlantic oceans.

Within the eastern Pacific, eelgrass is distributed from northern Alaska and the Aleutian Peninsula to Baja California and mainland Mexico in the Sea of Cortez. The majority of the eelgrass on the Pacific coast occurs in northern estuaries of Alaska, Canada, and the mainland of Washington State. Several large estuarine embayments located along the Pacific Coast of Baja California (San Quintin, Magdalena, San Ignacio, and Ojo de Liebre) have historically supported extensive eelgrass populations rivaling those of the far north; however, recent dramatic declines particularly in intertidal eelgrass abundance have been observed in these systems, likely as a result of thermal stress associated with climate change.

The overall abundance of eelgrass on the west coast is driven largely by physical geography, climate and hydrology. Southeastern Alaska supports the largest eelgrass systems in the world as a result of the presence of expansive, shallow low-gradient lagoons and coastal embayments characterized by moderate tidal regimes, relatively low freshwater inflows, and predominantly cool, overcast weather conditions throughout the growing season. With the exception of several large embayments in British Columbia, Washington State and Northern California that support several thousand acres of eelgrass habitat each (e.g. Boundary Bay, Padilla Bay, Willapa Bay and Humboldt Bay); throughout much of the coastal Pacific Northwest, smaller populations of eelgrass are commonly associated with coastal fjord and drowned river mouth estuaries fed by perennial coastal streams. Between Central California and Mexico, eelgrass distribution is associated with a broad array of physical environments that include the vast and dynamic San Francisco Bay estuary; numerous smaller coastal lagoon systems; the developed ports, harbors, and open coastal areas of the Southern California Bight; insular eelgrass of the Channel Islands; and the larger bay and lagoon systems situated along the Pacific Coast of Baja California.

In California, eelgrass distribution patterns are not as well documented as one would expect. However, the California Department of Fish & Wildlife (CDFW) and NOAA National Marine Fisheries Service (NMFS) have been working to fill knowledge gaps through completion of CDFW implemented and NOAA sponsored contract inventory and monitoring efforts, development of databases to house and disseminate eelgrass data (http://www.westcoast.fisheries.noaa.gov/maps_data/eelgrass_data.html), and the development and implementation of regional monitoring programs (Bernstein et al. 2011, Merkel & Associates 2009).

While inventories of eelgrass continue throughout California, at present it is estimated that only about 15,000 acres of eelgrass occur statewide. Humboldt Bay supports the greatest extent of eelgrass of any single system, holding an estimated 31 percent of all eelgrass (Table 1).

Table 1. Estimated eelgrass extent in California systems based on multiple survey sources.

System	Acreage	% Total
Humboldt Bay	~4,700	31%
San Francisco Bay	~3,000	20%
San Diego Bay	~2,100	14%
Tomales Bay	~1,300	9%
Mission Bay	~1,100	7%
All Other Systems	~3,000	19%
Total	**~14,900**	**100%**

General distribution of eelgrass in California with the relative extent of eelgrass in each system indicated by size of location marker. Systems with less than one acre of eelgrass are not shown. (Merkel & Associates unpublished data)

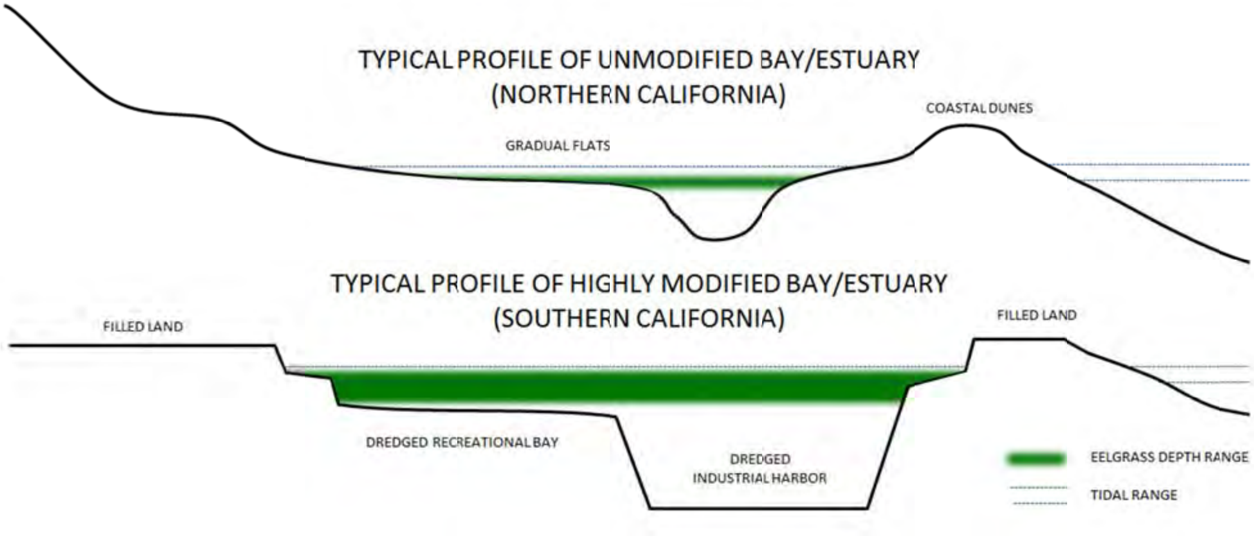
Notably, only five systems account for an estimated 81 percent of all eelgrass. The extent of eelgrass in other systems ranges from a high of approximately 670 acres within Bodega Bay, down to a low of a few scattered individual plants, in some cases occurring only intermittently within some of the smaller drainages scattered along the coast. One segment of the states' eelgrass distribution that remains very poorly documented is the extent of eelgrass present on offshore islands and protected open coastal waters. At present, only a portion of the southern California Channel Islands and some of the nearshore waters have been surveyed. This has revealed considerable eelgrass in southern California, although the representation of eelgrass on the open coast is expected to diminish with increasing energy in a northward progression up the state.

Throughout its California range, eelgrass has been found to grow within a range of tidal elevations. Within enclosed bays and estuaries, eelgrass is known to grow as deep as -7.3 m to as high as +1.5 m relative to Mean Lower Low Water (MLLW), although both extremes of this distribution occur under peculiar conditions of ultra-clear water at depth and perched pooling at higher elevation ranges. Within the clear offshore waters of San Clemente Island in the Channel Islands, insular eelgrass has been documented to grow as deep as -21 meters MLLW (Merkel & Associates 2017a).

In general, eelgrass extends to deeper depths and extends less into the intertidal environment in southern California and exhibits a shallower depth limit and greater intertidal range in northern portions of the state. This latitudinal generalization relates to the typically dominant controlling factors on eelgrass depth distribution of light limitations at depth and desiccation stress at the upper bed margins. Because of higher fluvial discharges, greater nutrient upwelling, lower sun angle, lower air temperatures, and greater coastal cloud cover in the northern portion of the state over the southern portion of the state, most of the depth distribution pattern differences are attributable to natural environmental controls. However, anthropogenic factors also play a role, particularly with respect to water quality and availability of natural shoreline gradients.

Within northern portions of the state, agricultural land-uses and more regular drainage discharge events generate greater nutrient and sediment loading into bays and estuaries than typically occurs in more developed and drier climates of the southern portion of the state. As a result, nutrient loading and associated micro and macroalgal blooms, as well as suspended sediment is more prolific in north coast systems than south coast systems and eelgrass typically does not extend as deep in northern California systems as southern California systems. Conversely, persistently stronger economic conditions and greater urbanization in southern California have resulted in greater historic losses of coastal wetlands and shallow embayments than has occurred in northern portions of the state. As a result, most of southern California bays lack gradual sloping transitions in elevation from the bays to the surrounding uplands. Rather, bays and estuaries have been historically dredged and adjacent shoreline margins have been filled to create excessively abrupt transition zones between subtidal waters and non-tidal uplands. These patterns of shoreline margin transition lead to differing depth distribution patterns for eelgrass, with portions of the natural environmental depth range either missing or underrepresented in many systems.

These shoreline configurations and normal vertical ranges in eelgrass play very important roles in how the systems are likely to respond under various sea level rise, climate change, and anthropogenic stressor scenarios. In tightly bounded highly modified systems, sea level rise would be expected to result in significant losses of eelgrass, while in systems where increased sea level would expand the inundation area of the bay, eelgrass would be expected to expand outward from existing limits. However, in the face of changing atmospheric conditions, such as a reduction in the frequency or extent of coastal stratus, intertidal eelgrass is exposed to higher risk of injury than subtidal eelgrass.

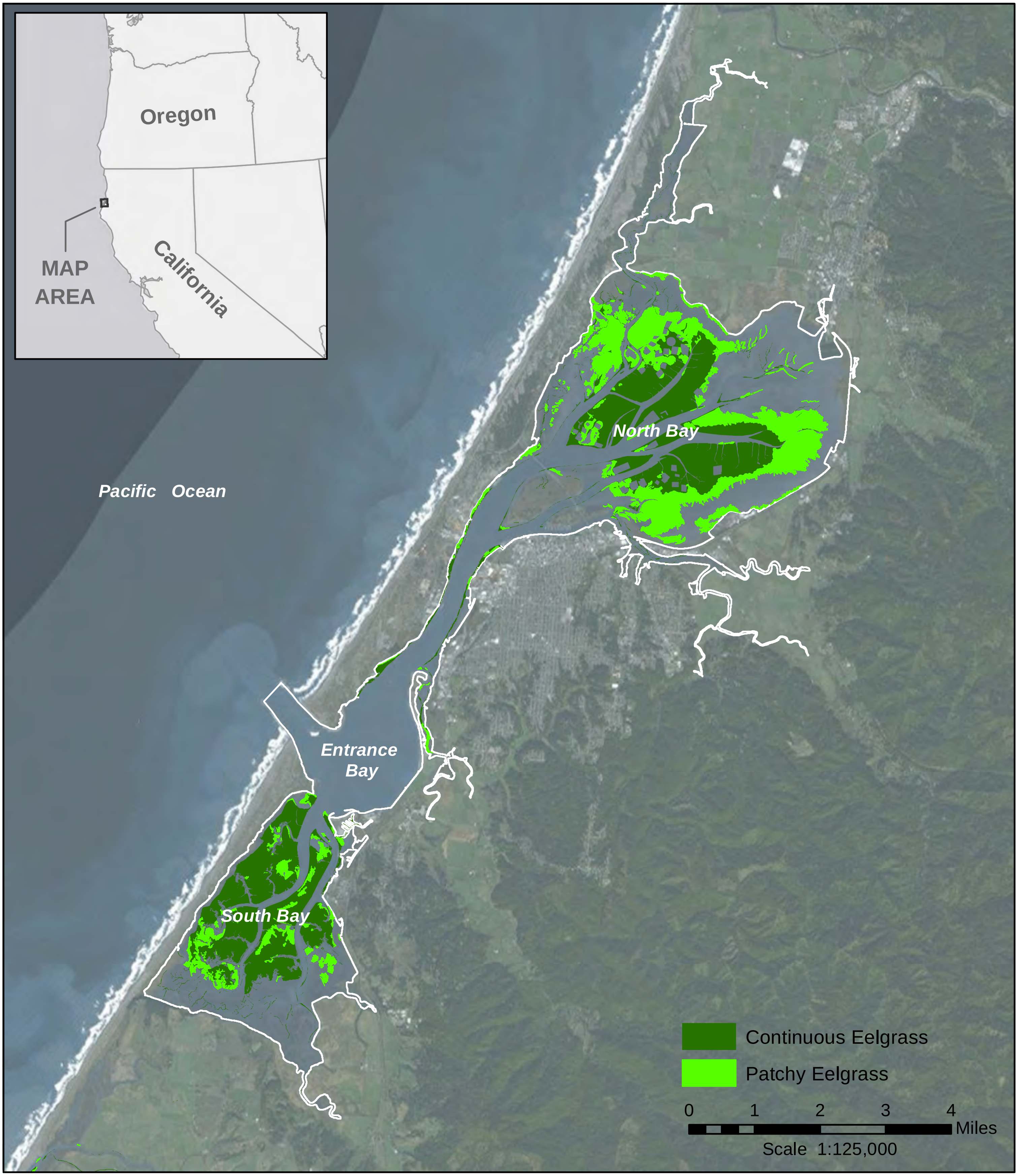


Typical profiles of unmodified bays and estuaries in northern California and highly modified bays of southern California illustrate differences in eelgrass distribution patterns relative to tidal range. Patterns also illustrate potential issues associated with eelgrass distribution under influence of sea level rise scenarios.

Humboldt Bay Eelgrass

Eelgrass is the dominant macrophyte of the lower intertidal and shallow subtidal zones of Humboldt Bay and grows in a wide range of unconsolidated sediments primarily within the spectrum of fine gravel to clay. Gilkerson (2008) established the depth range capable of supporting eelgrass in Humboldt Bay and found substantial variation with respect to the maximum depth distribution of eelgrass on the basis of location and upper limits of continuous versus patchy eelgrass habitat distribution. The maximum depths capable of supporting eelgrass were substantially shallower in North Bay relative to South Bay, -1.3 m MLLW vs -2.1 m MLLW, respectively (Gilkerson 2008). Generally, maximum depths were shallowest in areas closest to sources of freshwater runoff where high-suspended sediment loads entered the bay (e.g. Eureka Slough and Salmon Creek). Based on a combination of field surveys and classification of aerial imagery (Judd 2006; Gilkerson 2008) the upper limits capable of supporting continuous eelgrass habitat were estimated to range from approximately 0.3 to 0.4 m MLLW, while patchy eelgrass associated with pool forming depressions and intertidal channels capable of retaining water during low-tide was found to extend up to +1.4 m MLLW. Recently, additional observations were made that reported observations of eelgrass up to +1.5 m MLLW (G. O'Connell, pers. comm.). In all cases, these higher occurrences of eelgrass have been related to perched pooling environments.

In terms of the distribution of eelgrass within Humboldt Bay, the majority of eelgrass habitat by area is found in North Bay and South Bay, where expansive, low-gradient intertidal and shallow subtidal mudflats support extensive eelgrass meadows. Based on classification of high-resolution multispectral imagery collected in June 2009, 3,644 acres of continuous eelgrass habitat and 2,043 acres of patchy eelgrass habitat (defined as 15-84% cover) were identified in Humboldt Bay (Schlosser and Eicher, 2012; Figure 2). The characterization of patchy eelgrass, often referred to as leopard spot distribution, creates some degree of complexity with respect to mapping as well as management issues. This is because most of this patchy eelgrass distribution within the bay is not a reflection of sparse occupancy of suitable eelgrass habitat, but rather a reflection of variable occupancy of sparse and fluctuating suitable habitat. To facilitate making broad comparisons in overall eelgrass habitat extent in Humboldt Bay relative to other systems supporting eelgrass in California, it was assumed that patchy eelgrass habitat occupies, on average, approximately 50 percent coverage relative to continuous habitat, leading to a baywide estimate of approximately 4,700 acres (Table 1).



Eelgrass Distribution (NOAA, 2009)

Humboldt Bay Eelgrass Comprehensive Management Plan

Figure 2

Landscape characteristics of continuous (near channel margins) and patchy eelgrass and close up view of patchy eelgrass in north Humboldt Bay depicting the affinity of eelgrass at higher intertidal elevations for pooling areas in basins and along micro channels.

Much of the patchy eelgrass occurs in perched pool forming depressions within the intertidal mudflats and small tidal drainage channels that convey water on and off the flats. As such, this patchy eelgrass typically occurs under conditions of atypically higher inundation frequency for the tidal elevation at which the eelgrass occurs. The complex mosaic of channels and pooling basins on the flats is common within mud and sand flats built by non-fluvial sediment deposition processes. These patterns are believed to be the result of bioturbation and concurrent physical processes of erosion and deposition. The result is an expansive landscape of non-draining pools linked by slow draining shallow channels.

Humboldt Bay Historic Review

A comprehensive topographic and bathymetric record for Humboldt Bay dates back to the 1870 Office of Coast Survey, which has been reviewed and digitized as a component of the Humboldt Bay and Eel River Historical Atlas (Laird 2008). This record set provides a detailed view of how the bay's physical geography and surrounding wetland resources have changed through time. Understanding the current distribution of eelgrass relative to present and historic conditions of the surrounding bay environs does allow some degree of interpretation to be made with respect to the likely historic distribution of eelgrass. Although the early nautical charts do not explicitly map eelgrass distribution, historic accounts as well as the depiction of the bay's shoreline, channel network and fringing salt marshes suggest that the majority

Historic bathymetry of Humboldt Bay depicts a complex network of sand shoals and shallow tidal channels present within Entrance Bay.
Image Credit: USC&GS, 1894.

of the area in both the north and south bay basins that presently support the majority of Humboldt Bay's eelgrass habitat have remained largely stable through time. This observation stands in contrast to the changes observed in Entrance Bay resulting from the construction of the jetties, armoring of the shoreline, dredging of the entrance channel and associated development of the King Salmon peninsula from dredge spoil material disposal. Within Entrance Bay, these changes likely had a negative effect on eelgrass distribution, by allowing ocean-wave energy to propagate much further into the bay, which ultimately led to erosion of Red Bluff and the complex network of sand shoals and shallow, interconnected tidal channels that would have likely supported eelgrass. However, within the northeastern portion of South Bay, creation of the King Salmon peninsula during the 1940's created more wave-sheltered conditions, which likely promoted an increase in eelgrass habitat of approximately 15-20 acres between King Salmon and Field's Landing since Entrance Bay reconfiguration occurred, although the extent of eelgrass loss in Entrance Bay is unknown.

Expansion of the King Salmon Peninsula during the early 1940's reduced the effects of wave energy in South Humboldt Bay and likely promoted expansion of eelgrass habitat along the peninsula and shoreline of Field's Landing to the south.
Image credits: *Humboldt Couty 1941; NOAA 2009*

Although information on the historic configuration of the bay and surrounding salt marsh distribution extends well into the past, efforts to map Humboldt Bay's eelgrass habitat did not commence until 1959 (Schlosser and Eicher, 2012). Early estimates of eelgrass distribution and abundance suggested that South Humboldt Bay contained approximately 78-95 percent of the eelgrass biomass within the bay (Harding and Butler, 1979), which has in turn been used to help explain historic observations of proportional black brant use within Humboldt Bay (Moore et al. 2004). More recently, geospatial modeling efforts integrating eelgrass biometric and habitat distribution data have resulted in a re-evaluation of the relative abundance of eelgrass in North and South Humboldt Bay. While eelgrass biomass per unit area in South Humboldt Bay is nearly double that in North Humboldt Bay (Stillman et al. 2015), the larger overall footprint of continuous eelgrass habitat in North Bay nearly offsets this discrepancy. Extrapolating the results of this recent modeling effort to project total eelgrass biomass for North and South Humboldt Bay suggests that North Bay may account for as much as 48.5 percent of eelgrass biomass in Humboldt Bay. These results suggest that the abundance of eelgrass in North Humboldt Bay may have increased in recent years although differences in surveying and habitat characterization methods make direct comparison difficult.

While it is known that eelgrass resources in Humboldt Bay have been extensive based on historic and anecdotal information including records regarding brant migration, the first known effort to map eelgrass distribution in the bay was conducted in 1959 (Schlosser et al 2005). Since that time a number of mapping efforts have been conducted using a wide range of methods including aerial photography and photointerpretation, field mapping by boat and on foot, dive surveys using GPS, and spectral classification of aerial imagery. Table 2 adapted from Schlosser and Eicher (2012) details the history of eelgrass surveying efforts in Humboldt Bay.

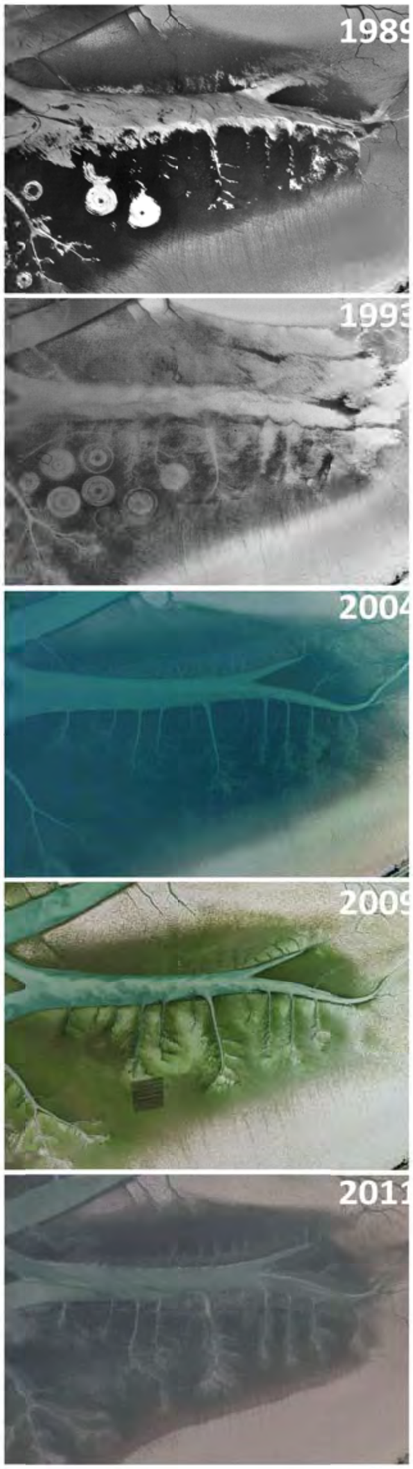
Table 2. History of eelgrass surveying and mapping efforts in Humboldt Bay (derived from Schlosser and Eicher, 2012).

Location	Acres	Year	Survey Method	Source
North Bay	840	1959	Aerial photography (1958), walking and boat field surveys, planimetry to outline eelgrass beds, noted algal beds not distinguishable from eelgrass in photos	(Keller 1963)
	1,670	1961	Aerial photography AT 4800 feet (April 1, 1961), no field surveys	(Waddell 1964)
	2,600	1962	US Coast and Geodetic Survey Chart 5832 used to map by boat and on foot with landmarks and channels as reference points. Mapped continuous eelgrass areas, not patches or discontinuous eelgrass beds.	(Waddell 1964)
	1,275	1963	Same as 1962	(Waddell 1964)
	1,075	1972	US Coast and Geodetic Survey Chart 5832 used to map by boat, on foot and with light aircraft. Eelgrass beds were outlined with a plane planimeter.	(Harding and Butler 1979)
	1,035	1979	Aerial photography (Nov. and Dec. 1978, March 1979) utilizing color infrared to map eelgrass distribution at 1:24000. Ground verification conducted but no details stated. Compensating polar planimeter used to outline eelgrass	(Shapiro and Associates 1980)
	1,011	1992	Aerial photography, ground verification, and planimetry.	(Ecoscan Resource Data 1992)
	2,562	2000	Aerial photography (Dec, 1997), ARC GIS 3.0, photointerpretation of continuous eelgrass beds.	(Mello 2000)

Location	Acres	Year	Survey Method	Source
	3,104	2004	High resolution bathymetric data (LIDAR), multibeam sonar and single beam sonar imagery (2002-2005) used to model eelgrass habitat. Intertidal (low tide) and subtidal (diving) DGPS field surveys used for ground verification.	(Gilkerson 2008)
	3,577.11	2009	Aerial imagery (June 2009, low tide) See Ch. 3 for methods.	(Schlosser & Eicher, 2012)
Entrance Bay	128	2000	See North Bay above	(Mello 2000)
	122.83	2009	See North Bay above	(Schlosser & Eicher, 2012)
South Bay	1,999	1959	See North Bay above	(Keller 1963)
	1,378	1966	Same as Keller 1963	(Keller and Harris 1966)
	1,942	1972	See North Bay above	(Harding and Butler 1979)
	1,900	1979	See North Bay above	(Shapiro and Associates 1980)
	1,979	2000	See North Bay above	(Mello 2000)
	2,582	2002	Kriging to interpolate eelgrass distribution from samples collected in 1999 and 2000 using a 1 ha grid.	(Moore et al. 2004)
	2,338	2004	See North Bay above	(Gilkerson 2008)
	1,947	2005	Hyperspectral, aerial imagery (Oct. 2004,high tide) , bathymetric LIDAR (2002) and tide gauge data used to classify submerged eelgrass distribution with ArcGIS 9.1.	(Judd 2006)
	1,948.08	2009	See North Bay above	(Schlosser & Eicher, 2012)
Entire Humboldt Bay Area	2,839	1959	See North Bay above	(Keller 1963)
	2,017	1972	See North Bay above	(Harding and Butler 1979)
	2,935	1979	See North Bay above	(Shapiro and Associates 1980)
	4,670	2000	See North Bay above	(Mello 2000)
	5,441	2004	See North Bay above	(Gilkerson 2008)
	5,642.02	2009	See North Bay above	(Schlosser & Eicher, 2012)

Estimates of eelgrass areal extent have varied between surveys, particularly within North Bay where there has been a general trend of increased eelgrass abundance through time. It is difficult to know to what extent this variation reflects differences associated with surveying methods versus actual changes in eelgrass area. The larger degree of variation in eelgrass extent between surveys within North Bay relative to South Bay may at least be partially a result of North Bay being more affected by freshwater inflows during periods of high precipitation, or changes in the intensity of legacy shellfish bottom culture activities over time. It may also relate to the complication of how patchy eelgrass has been handled in various surveys. With the much longer residence time and lower tidal flushing rate in conjunction with much more expansive shallow gradient intertidal mudflats in North Bay relative to South Bay, it is likely that North Bay eelgrass is episodically subjected to greater thermal stress than eelgrass in South Bay. This would lead to greater interannual or multi-year fluctuations in bed extent along the upper margins of eelgrass habitat.

In the 1980s through 2010, Susan Schlosser, Marine Advisor at the Eureka SeaGrant Extension office invested considerable effort in understanding eelgrass dynamics, and reached the conclusion that at the highest level, eelgrass within Humboldt Bay has likely been relatively stable overall through time. While there is a general sense that eelgrass distribution in Humboldt Bay has been relatively stable, much of this belief is related to the scale at which the bay is viewed, the portion of the beds that have been inventoried, as well as the period of time at which these thoughts were formulated. It is clear from all of the data available that at a landscape level eelgrass in Humboldt Bay has been geographically distributed in similar locations through recent time. However, at a finer scale, eelgrass in Humboldt Bay is believed to be fairly dynamic in certain areas. Perhaps the area of greatest variability is the upper margins of the beds where continuous eelgrass transitions to patchy eelgrass. Secondarily, it is generally the case that deeper margins of subtidal eelgrass are more dynamic than core areas of the beds. Because subtidal eelgrass in Humboldt Bay has never been comprehensively inventoried given the survey technologies applied, the extent of eelgrass and its variability along the deeper margins remains largely unknown. However, given the bay morphology, it is not anticipated that unmapped subtidal eelgrass is a major component of the overall eelgrass extent within Humboldt Bay.



East lobe of North Bay displaying relative stability in broad spatial eelgrass distribution over time. Notable is the variable width halo around the continuous eelgrass that reflects the patchy eelgrass. Photos also reveal impact recovery from historic oyster bottom culture.

The 2009 NOAA multispectral imagery and 2010 Coastal Conservancy LiDAR data sets together, provide the most comprehensive view of the bay's ecological resources that have been collected to date (Figure 2). Recent advances in geospatial technology have facilitated an enhanced capacity to delve into management and academic questions relating to eelgrass distribution patterns in the bay and ecosystem functions. Most specifically, the coupling of elevation data directly with eelgrass data has provided critical insights into how eelgrass is distributed in the bay, both horizontally and vertically, as well as how this distribution may affect the ecosystem and be affected by natural and anthropogenic stressors.

One important note should be made regarding the relative stability of Humboldt Bay eelgrass through time. That is that eelgrass along the entire eastern Pacific has become much more variable over the past decade than it has been leading up to the present period. Eelgrass in Humboldt Bay has not been immune to significant declines and perturbations that are likely attributable to recent variation in climatic conditions. In Humboldt Bay, changes in eelgrass have been most apparent in the upper margins of the beds within the patchy eelgrass and higher elevation eelgrass fringes where declines have been observed since about 2012. In addition, in 2013 eelgrass wasting disease was noted to have hit Humboldt Bay (V. Frey, pers. comm.). Insights gained from several pilot studies involving collection of high resolution aerial imagery of eelgrass habitat in Humboldt Bay during 2016, suggest that Humboldt Bay was likely impacted by thermal stress associated with the historically-unprecedented positive temperature anomalies observed across much of the eastern Pacific Ocean between 2013-2016 (Di Lorenzo and Mantua, 2016).

Eelgrass can be a fairly prolific species under the correct environmental conditions. Under good conditions, plants spread both by vegetative growth of individual clones as well as by seedling recruitment. Seedling recruitment is a critical factor in occupying extensive space in an unstable environment. However, eelgrass typically takes between one and three years to mature to a sexually reproductive condition from seedlings. As a result, highly variable environments tend to not support extensive eelgrass; however, in areas of high suitability, eelgrass is very resilient to transitory disturbances. Conversely, eelgrass is not particularly susceptible to minor pulsed disturbance events. These properties make eelgrass an ideal candidate to serve as an indicator species for overall system health. In effect, it serves as a pre-deployed environmental integrating multiprobe with ancillary habitat benefits.

2.2 EELGRASS ECOSYSTEM FUNCTIONS

Ecosystem Functions Overview

Seagrasses are recognized as one of the most productive ecosystems on Earth and eelgrass is the most abundant seagrass species in the northern hemisphere and among the most productive species of seagrasses. Eelgrass is often referred to with terms such as "foundation species" or "habitat architect" due to its role as a habitat forming species. Eelgrass performs a multitude of ecosystem services (Orth et al. 2012, Waycott et al. 2009, Cole and Moksnes 2015). This recognition is derived from its multiple functions and ecosystem contributions at multiple levels. Eelgrass provides significant physical, chemical, and biological services. Eelgrass is recognized as an ecosystem engineer, providing protection against coastal erosion, increasing water clarity through the reduction of wave energy, trapping of particulates, and stabilizing of sediments (Orth et al. 2012).

Dense rhizome mats of eelgrass meadows stabilize sediments near channel banks against surficial slides, while the leaf canopy dampens wave energy, traps sediment, and stabilizes sediment against wave resuspension. These functions result in clarifying the water column and reducing shoreline and mudflat erosion. Conversely, the effects of eelgrass also serve to facilitate the development and routing of tidal channels within the flats by concentrating flows around beds, while building sediment elevation within beds. In many senses eelgrass provides a similar function within the marine system as does soil stabilizing vegetation in the terrestrial environment.

From a chemical standpoint, eelgrass provides a high degree of function in nutrient uptake and cycling and influences multiple water column properties including dissolved oxygen, temperature, turbidity, total dissolve solids, and pH. It is also serves a role in nutrient trapping and cycling (McGlathery et al. 2012), sequestration of atmospheric carbon (Duarte et al. 2005, Fourqurean et al. 2012), and buffering against the effects of ocean acidification (Shaughnessy and Tyburczy; in progress).

Eelgrass also supports a rich detrital food web and complex multi-tier trophic structure. It provides structure and nursery habitat for a diverse range of fish and invertebrates including commercially-important species. Eelgrass provides a critical food source for migratory waterfowl such as black brant that feed almost exclusively on the plants and it is a supporting forage resource for a number of other species that make a diet of both eelgrass and the epiphytic growth that occurs on the leaves.

Besides the critical resource values and ecosystem functions of eelgrass, it is uniquely suited to serve as a sentinel indicator of overall ecosystem condition. Eelgrass is an easily and repeatably monitored widely distributed integrator of environmental conditions that responds to natural and anthropogenic stressors that are chronic in nature. Eelgrass is robust with respect to short-term environmental fluctuations within normal or near normal environmental ranges, but is vulnerable to stressors manifesting over longer time frames, such as persistently elevated water temperature and/or turbidity (e.g. ENSO events).

Humboldt Bay Functions

While all of the ecosystem services attributed to eelgrass are represented within Humboldt Bay, the sheer extent and proportion of the bay occupied by eelgrass is unique. The degree to which Humboldt Bay is dominated by eelgrass is significant in the context of shaping bay physical processes and morphology, water chemistry, and biotic systems in the bay and even within the nearshore coastal region. Eelgrass is considered the most important contributor to primary productivity within Humboldt Bay. As a result, eelgrass provides functions that generate a uniqueness to the Bay that is not widely duplicated on the California coast.

Physical and Chemical Functions

Within Humboldt Bay, eelgrass is likely responsible for much of the nature of bay morphology with stabilized flats and intervening deep channels. The extensive eelgrass in the system is constrained by desiccation at upper margins. As such, during periods of sea level rise, eelgrass would trap sediment allowing flats to build upward. During periods of falling sea level, eelgrass would be lost to desiccation and flats would be eroded with material exported to the coast or transported to marshland development. This physical role is expected to be critical in the future as sea level rise is predicted to accelerate. Based on the dominance of the bay area by eelgrass, functions of nutrient cycling and pH buffering are expected to be more highly developed in Humboldt Bay than most coastal systems. This has implications for native shellfish and mariculture operations in light of increasing ocean acidification trends as discussed later.

Dungeness crab in eelgrass beds. Eelgrass habitat is a supporting habitat for adult crabs, and provides important nursery habitat for juvenile crabs.

Fisheries Support Functions

Eelgrass in Humboldt Bay is recognized as a major contributor to the local fisheries by providing important particulate organic material (POM) to the regional coastline, and serving as a critical nursery area supporting such resources as the Dungeness crab fishery. It is also recognized as a nursery area for a number of marine game fish including species of rockfish and lingcod. Herring spawn on eelgrass within Humboldt Bay, however the extent of spawning has remained very low compared to the degree of spawning occurring in San Francisco Bay.

Pacific herring eggs on common eelgrass.
Photo credit: Ryan Bartling, CDFW

Coho salmon smolts leaving the Freshwater Creek watershed for Humboldt Bay were observed during a two-year telemetry study (Pinnix et al. 2012). Young coho migrated through the Freshwater Creek Estuary in 10 to 12 days and remained in the deeper channels of Humboldt Bay for an average of 22 days. While coho smolts did not use eelgrass beds, they were frequently detected in association with floating eelgrass mats (Pinnix et al 2012). In the Pacific Northwest, eelgrass use by anadromous fish has been identified although the relative importance of this use remains poorly understood. More research is still required in California to understand the extent to which anadromous fish make use of eelgrass or whether there are any important relationships between eelgrass and anadromous runs.

Brant foraging at the margins of eelgrass in Morro Bay shown moving away from survey boat as eelgrass investigations are completed in adjacent channels.

Black Brant Migration

In the context of the Pacific flyway, Humboldt Bay is the most important spring staging site in California and is the fourth most important stop-over site for migratory black brant during the spring staging period in terms of peak brant numbers (Moore et al. 2004). Based on a study by Lee and others (2007), as much as 58 percent of the flyway population of brant staged in Humboldt Bay in 2001. This represents a significant proportion of the overall population. Since brant feed almost exclusively on eelgrass, maintaining the productivity of eelgrass in Humboldt Bay may be critical to maintaining a sustainable population of brant within the Pacific flyway. Additionally, recent declines observed in eelgrass habitat at other estuaries that represent important wintering and spring staging sites along the flyway including Morro Bay (Morro Bay National Estuary Program 2012) and San Quintin Bay (Ward et al. 2003) suggest that Humboldt Bay may become increasingly important to brant if current trends continue.

The relationship between eelgrass and black brant in Humboldt Bay has been well studied and the more detailed the examination, the greater the importance of Humboldt Bay to brant becomes known. Several investigators have noted the unique aspects of Humboldt Bay that support the systems' value to brant and the risks brant face within the system (Moore et al. 2004, Ward et al 2005, Moore and Black 2006, Shaughnessy et al 2012). Humboldt Bay has many characteristics that make it critically important to brant along the Pacific flyway. These include the system's extensive and predictable eelgrass habitat, its generally shallow depth distribution and therefore, prolonged accessibility as a foraging resources, the presence of upper mudflat pooling environments that support eelgrass at higher elevations than would occur otherwise, the relatively low intensity of human activity on the bay and thus reduced avian disturbance levels relative to most California systems, and the availability of favorable gritting sites.

Detrital Export

While there is a general tendency to focus mostly on direct linkages when considering functions, the indirect pathways are often more important even if they are harder to trace. The tremendous eelgrass productivity in the Bay is seasonally manifested by leaf shed and export of wrack both to the bay margins and out the mouth of the bay to the coastal beaches. In these areas, wrack serves many functions as a nutrient and carbon source to marshes, dunes, and marine environments. Exported eelgrass provides a food for direct grazers and organisms such as amphipods that consume rotting plant matter and are themselves consumed by shorebirds and fish. In addition, wrack provides an important wave protection benefit at the margins of the bay and on the coastal shoreline where it reduces impact of waves on the shorelines as it dampens energy and retains sand and soil. This is especially obvious when one walks the upper beach margin and can see dried eelgrass woven through the beach sand in a tight mat of sand and plant fiber.

Early fall conditions for eelgrass wrack on Samoa Beach approximately 7 miles north of the Humboldt Bay entrance. The generation and export of eelgrass to the coastal waters feeds a detrital based trophic web both on the beach and in the water. The wrack also contributes to back beach stability by binding the sand at the wrack zone in a manner that reduces erosion.

2.3 THREATS TO EELGRASS IN HUMBOLDT BAY

Current Threats and Stressors of Eelgrass

Eelgrass can be impacted by both natural and anthropogenic factors. The levels of risks and scales of potential impacts vary with the types of threats and can even vary with time (Short and Wyllie-Echeverria 1996). In some instances, factors that are negative under certain conditions may be positive under others. This makes the evaluation of the likely outcome of various stressors on eelgrass a sometimes complicated process. In this section, several of the key threats to eelgrass that presently affect Humboldt Bay or may affect the bay in the future are discussed. Because threats are often situation specific, these factors should be viewed as generalizations rather than specific assessment of a given site condition.

Bernstein et al (2011) developed a working summary of stressors on eelgrass in the Southern California Bight and then coupled the stressors with general indicators suggestive of the stressor influence on eelgrass. In general, this summary pertains to Humboldt Bay equally well as it does for southern California, although the magnitude of stressor influence often differs for Humboldt Bay from that expressed in the Southern California Bight. Table 3 below has been adapted from Bernstein et al (2011). The table separates stressors into physical, chemical, and biological categories, however, it can quickly be seen that some stressors that have been classified in one category may span multiple categories, such as the classification of animal grazing and bioturbation in the physical stressor category rather than biological stressor category where it would be equally appropriate. For the purposes of this management plan, it is useful to consider the coupling of detectible monitoring indicators with stressors as outlined by Bernstein. However, for organization purposes this section is arranged sequentially by the most directly controllable threats to those for which local actions have lesser capacity to influence the threat, but for which response to the threat may be possible to mitigate potential harm of the uncontrolled changes to the ecosystem.

Table 3. Eelgrass stressors in Humboldt Bay and indicator useful in measuring their effects.

STRESSORS	*GENERAL INDICATORS*
Physical Stressors	
o **Wave and current energy**	short and narrow leaved growth form; exposed turions at patch margins; coarse sand with ripples outside of bed; limited to no detritus accumulation
o **Sediment burial, instability**	leaf sheath buried below sediment surface; upwardly migrating turions where burial is occurring; free rhizomes and water roots in erosive areas
o **Dredging**	steep active slumping of adjacent side slopes; frequently, sliding eelgrass on slopes adjacent to cuts; uneven bottom due to recent cuts by dredging
o **Wake scour and prop scars**	undercut rhizomes at patch margins; loose or free eelgrass plants with water roots; linear cuts in bed with loose sediment in trough
o **Shading and circulation patterns**	loss of eelgrass under structures and adjacent thinning of turion densities increased sediment loading compared to nearby beds
o **Animal grazing and bioturbation**	apparent random pattern of rhizome exposure; forage pits in beds (rays); clipped leaves, rasping or chewed tissues, waste and prints (waterfowl), invert. herbivores
Chemical Stressors	
o **Sediment toxicity**	Variable to unknown
o **Water contamination**	Variable to unknown
o **Oiling and other chemical fouling**	oils on leaves and soil; bleaching of leaves
Biological Stressors	
o **Metabolic Stressors**	
• Photosynthetic limitation and light competition	
➢ Turbidity	low transparency in water; Sedimentation on plants; declining leaf density and chlorotic tissues
➢ Phytoplankton bloom	red tides or green water
➢ Macroalgal blooms	accumulation of sheet and tube alga (typically *Ulva*, *Enteromorpha*, *Porphyra*, and *Gracilaria* species); thinning of eelgrass beds in matted algae
➢ Epiphytic loading	heavy growth of epiphytes on leaves; high silt loading on plants
➢ Ambient water transparency	Gradual reduction in eelgrass cover over bottom; reduction in shoot density within patches at depth
• Heat and desiccation	bleaching of leaves at upper shore; loss of turgor in leaves mottled light and dark splotches on leaves
• Osmotic regulation and other salinity stresses	loss of turgor in leaves; decline of bed in regions of prolonged elevated or depressed salinities
o **Disease and infection**	pronounced decline of eelgrass in dense beds areas; black mottling and rot on leaves
o Invasive species	presence of invasive species in areas of eelgrass, displacement patterns along margins or within beds

Anthropogenic Threats to Eelgrass

Dredging, Filling, and Bay Coverage

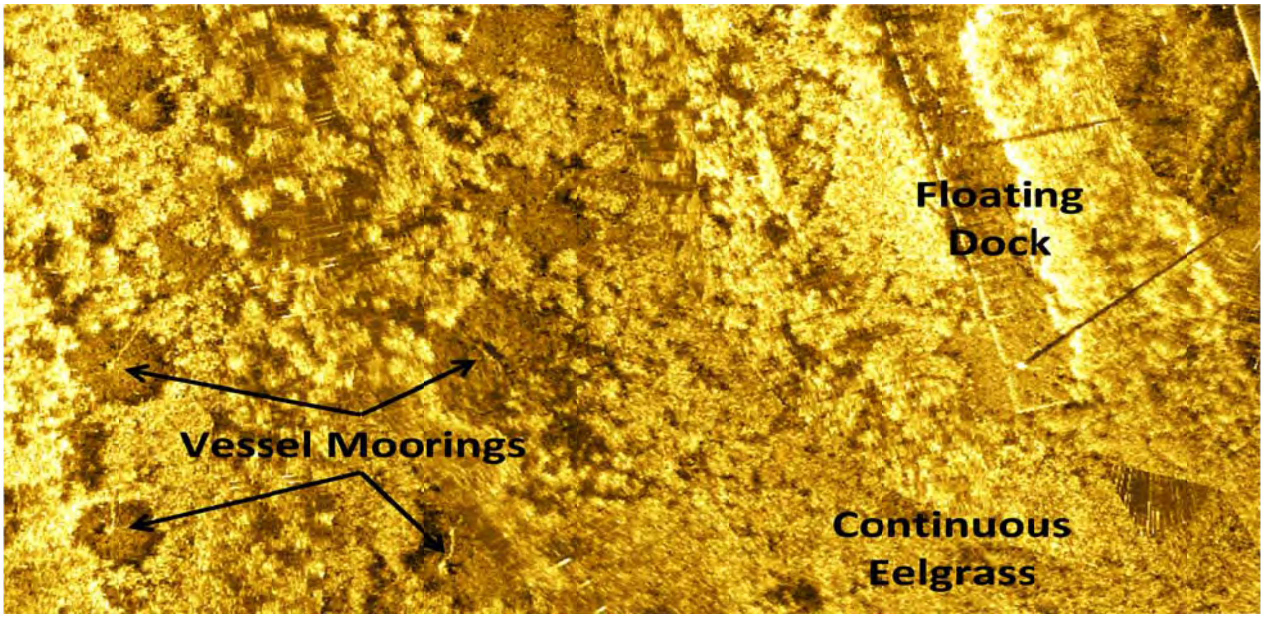
Eelgrass is directly affected by actions that physically displace it such as dredging or placement of fill material. Or eelgrass can be displaced by activities that alter suitability of habitat, such as through the shading of over water structures such as docks and piers. Moorings placed in eelgrass can result in loss of eelgrass due to ground tackle dragging, vessel grounding, and to a lesser extent, shading.

In the cases of project activities such as development of new structures, fills or dredging, impacts are typically discrete and can be reasonably predicted for small scale projects. These impacts are generally evaluated and regulated under existing environmental review frameworks and permitting programs.

However, as projects grow larger in scale, the complexity of effects becomes more challenging and the potential for unanticipated impacts increases. Large marinas, breakwaters, new channel systems, expansion or reduction of tidal prism and other such alterations within

Marinas, piers, wharfs mooring, training walls and breakwaters are overwater structures that tend to result in discrete impacts to eelgrass.

Dredging can result in direct losses of eelgrass and indirect losses associated with temporary and prolonged elevation of turbidity levels as disturbed areas stabilize at both dredging and disposal areas.



An example of bottom disturbance to eelgrass beds can be seen within this Interferometric sidescan sonar mosaic from Mission Bay that illuminates impacts of vessel moorings and dock structures when placed in eelgrass habitats.

the system can result in gains or losses of eelgrass that are in excess and potentially even spatially removed from the project activities themselves. In general, more expansive projects (typically those in excess of an acre or more, or those with the potential to change wind or tidal circulation patterns) require a greater degree of analysis and consideration than do smaller projects. Some of the factors that may require evaluation are effects of the project on circulation patterns, sediment deposition and scour patterns, water quality and debris and wrack transit and accumulation patterns.

Dredging has been conducted within various areas of the Humboldt Bay to establish navigation channels and to support marine development including marinas and vessel berths at industrial wharfs and piers. There is no doubt that historic dredging in Entrance Bay to remove the extensive shoaling and establish the deep water port removed considerable eelgrass habitat, however what is less clear is whether the enhanced circulation through Entrance Bay and the major channel systems had resulted in a net positive or negative effect on eelgrass in the system overall. There are many examples on smaller scale systems (e.g., Mission Bay, San Dieguito Lagoon, Batiquitos Lagoon, Agua Hedionda Lagoon, Huntington Beach Wetlands, Bodega Harbor), where shoal removal at ocean inlets results in improved water quality within the embayment and expansion of eelgrass further into the system where increased flushing enhances suitability to support eelgrass. The benefits and detriments of dredging within Humboldt Bay have also been previously contemplated (Schlosser and Eicher 2012).

Intermittent maintenance dredging of existing channels and basins would be expected to result in minor impacts to eelgrass when done on a regular basis, and more expansive impacts to eelgrass when maintenance is deferred. However, intermittent presence of eelgrass in maintained channels and basins does provide function during the period of time eelgrass is allowed to persist between maintenance cycles. Therefore, how frequently maintenance is performed influences both the extent of eelgrass functions that are developed and the duration over which the functions persist.

Mariculture

Within Humboldt Bay the most extensive anthropogenic influence on eelgrass is associated with intertidal mariculture practices and even remnants of past mariculture practices. Over time, mariculture within Humboldt Bay, principally oyster culture, has shifted from activities of greater direct impact on eelgrass to activities with substantially lower impact levels. Historically, oyster mariculture was dominated by ground culture for which substrates were modified and harvesting was performed by surface dredging. This resulted in loss of eelgrass within the oyster growing areas, alteration and coarsening of sediment through deposition of shell debris, and changes in sediment elevation within the dredged beds. Since the middle 1990s, bottom culture in Humboldt Bay has been phased out and oyster growing has moved to a variety of off-bottom cultivation methods including rack and bag, cultch on suspended lines, and a more recent addition of suspended baskets on lines. All of the off-bottom growing methods are generally believed to result in lesser impacts to eelgrass than the historic bottom culture farming.

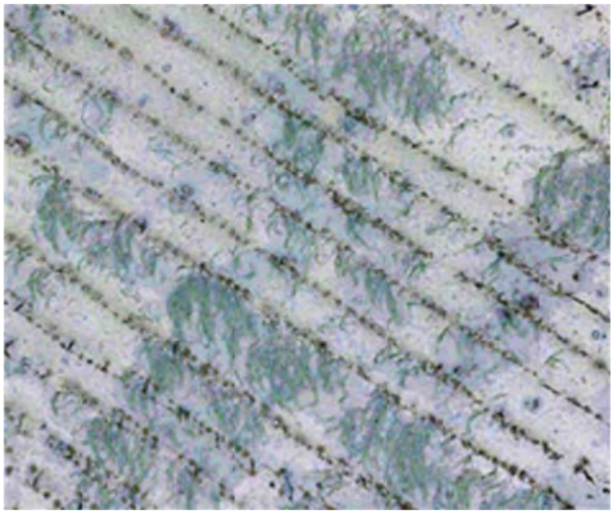
There is a large amount of debate and controversy around the extent of mariculture in Humboldt Bay and potential for expansion of mariculture in the bay. There is an equal amount of controversy regarding the extent to which mariculture practices have an impact on eelgrass, both present and in the past. However, there is strong evidence that mariculture in Humboldt Bay has both positive and negative effects on eelgrass depending to a large degree on the specific circumstances existing at the sites and times of operations. What is far less clear is the net magnitude of eelgrass impacts of the culture activity when considered both spatially and temporally within a variable environment.

While it is generally easy to detect and accept negative impacts of mariculture on eelgrass habitat, is generally less readily accepted that mariculture can have positive influences on eelgrass as well and that eelgrass can similarly have positive influences on mariculture. In some circumstances, present and past mariculture practices have a modifying influence on the intertidal environment that promote expansion of eelgrass into areas that otherwise would not support eelgrass. While in other circumstances, mariculture appears to have negative or neutral influence on eelgrass distribution patterns.

Generally, negative effects that mariculture may have on eelgrass include increased deposition rates, alteration of substrate character by increased shell accumulation, accumulation of wrack and smothering within beds, expansion of marine debris, alteration of circulation patterns, mechanical leaf abrasion on gear and damage of rhizome mats during harvest, enhancement of water column nutrient loading and increased epiphytic loading rates. Positive effects mariculture can have on eelgrass may include scour protection, enhancement of pooling at intertidal elevations, shading and other thermal protection benefits, enhanced water clarity, reduction in eutrophication potential and reduction of herbivore pressures.

While mariculture plots are generally thought of as supporting a lesser extent of eelgrass than similar areas outside of active mariculture, a striking observation was made at some of the North Bay intertidal oyster culture plots during

Eelgrass within oyster mariculture operations in northern Humboldt Bay illustrating the distribution of plants between and under suspended lines. ...



Eelgrass within oyster mariculture operations viewed from above. The plot shows typical patterns of patchy eelgrass distribution, generally associated with low-lying pooling environments. The density of beds within the patchy mosaic may be reduced by a combination of factors including mechanical damage and modification of energy regimes (higher energy environments typically promote shorter leaves and denser more compact leaf shoots, but not necessarily higher biomass).

Submerged eelgrass below basket on line mariculture. The spacing of lines and frequency and nature of basket grounding may affect the extent of eelgrass damage from this type of culture activity.

the most recent period of prolonged drought, high atmospheric temperatures, and low coastal cloud cover. Eelgrass disappeared from prior dense beds on unaltered flats surrounding aquaculture and was prolific within culture beds. While it is not known for sure why this was the case, it is speculated that the benefits of hanging culture served many roles to protect eelgrass from desiccation and thermal stresses. The lines provide diffuse shading at elevations where eelgrass is not light limited and thus shading provides a cooling benefit without photosynthetic detriment. Further, when exposed, the oysters and epiphytes on the mariculture gear are subject to high rates of moisture evaporation and thus cooling above the underlying eelgrass. Finally, the suspended gear reduces air circulation and thus reduces desiccation below the lines. As a result, it is believed that the internal portions of the mariculture beds provided a refuge against the stresses of exceptionally warm conditions.

In many circumstances, mariculture operators note the expansion of eelgrass into locations that were devoid of eelgrass at the time of operations establishment. This would be expected to occur, although not yet rigorously tested, in areas that are controlled by desiccation or thermal stress on a regular basis.

The issue of how much impact mariculture activities have on eelgrass is extremely complex and often times driven by perspectives and differential valuation of ecosystem functions. Overall, it can safely be stated that there are good and bad mariculture practices with respect to eelgrass resources. There are means to promote reduction in conflict between eelgrass and mariculture where effort is expended to understand the needs of both including ecological, physiological, and economic.

Example of eelgrass within dense cultch on line plot where eelgrass is held up by lines. Under some circumstances, the support of leaves on lines can result in greater abrasion damage than normally found outside of culture beds. It also increases the desiccation stress on plants over the natural low-tide prostrate layering on mudflats or suspension in the falling tide water column.

Vessel Grounding and Wake Damage

Eelgrass can be adversely impacted by generally difficult to regulate vessel activities. The most commonly considered impact of vessels on eelgrass is vessel grounding in shallow waters. However, other damaging vessel impacts are associated with wake damage propagating outward from navigation channels into shallows supporting eelgrass. Vessel wakes can exert tremendous energy that can result in bottom scour to the extent of lowering the bottom to unsuitable elevations, or washing fine sediment fractions from the bottom and

Vessel grounded at low tide in San Francisco Bay trying to free itself causes propeller damage to eelgrass beds. Other propeller scaring from a vessel running through the bed can be seen in the photo foreground.

creating an increasingly unsuitable bottom dominated by coarse material of pebble and shell hash. In other instances the passing of vessels generates an increase in sediment resuspension and elevated local turbidity levels.

Vessel damage to eelgrass is typically driven by the number, size, speed, and operator experience levels. As a result, high degrees of eelgrass damage from vessels are less common in non-recreational boating environments where users of the water are experienced operators. Damage is also lower, where navigational aids are well laid out and maintained.

Invasive Species

Although Humboldt Bay appears to be less affected than many other bays subject to port development and associated shipping activities, 95 exotic species covering a wide range of taxa have been documented within the bay (Boyd et al. 2002). Of these species, two invasive flowering plants, dense flowered cordgrass (*Spartina densiflora*) and Japanese eelgrass (*Zostera japonica*) may have the potential to negatively affect Humboldt Bay's native eelgrass population.

Eradication of invasive Spartina in Humboldt Bay salt-marsh. Photo credit: U.S. Fish & Wildlife Service.

In the case of *Spartina densiflora*, a salt marsh species which typically occurs at elevations above those capable of supporting native eelgrass, *Spartina* has shown the ability to colonize lower elevation intertidal mudflats and convert these areas to salt marsh through facilitated deposition of fine sediment. *Spartina* also has the immediate effect of displacing native salt marsh species and reducing important foraging habitat for shorebirds. Over longer timeframes, *Spartina* has the capacity to impact eelgrass habitat by reducing the tidal prism and raising the elevation of intertidal mudflats, which could eventually result in reduced circulation and a loss of potential accommodation space for eelgrass to transgress shoreward in response to sea level rise. The U.S. Fish and Wildlife Service in cooperation with other regional land management entities, is currently spearheading a coordinated response to *Spartina* that includes active and ongoing eradication and monitoring efforts throughout Humboldt Bay. *Spartina* is not considered to have a major, direct impact on eelgrass, but may further develop as a constraining stressor in the future.

Invasive dwarf and native common eelgrass.
Photo credit: A. Eicher UC ANR.

Japanese or dwarf eelgrass (*Zostera japonica*), was first discovered in Humboldt Bay in 2002 by researchers surveying native eelgrass in support of the Humboldt Bay Cooperative Eelgrass Project. Although dwarf eelgrass has since been found in the Lower Eel River Estuary, these discoveries represent the southern range extent of the species in the Eastern North Pacific.

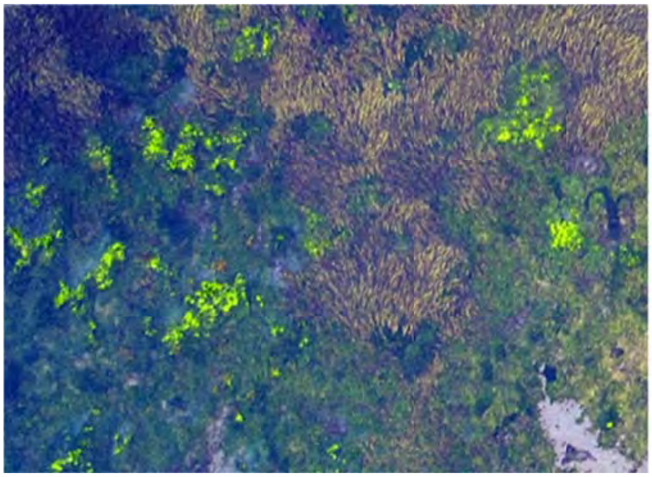
Japanese eelgrass can be distinguished from native eelgrass by the narrow width of its blades and annual life history. It has the potential to compete with native eelgrass along the upper margins of native eelgrass habitat and in a manner similar to *Spartina*. Like *Spartina*, *Z. japonica*, has the ability to colonize previously unvegetated intertidal mudflats. Since 2003, a volunteer effort coordinated by local U.C. Sea Grant and CDFW staff has conducted annual monitoring and eradication efforts to control the spread of dwarf eelgrass in both Humboldt Bay and Eel River Estuary.

Ampithoe valida out of tube.

Photo credit: Image courtesy of Matthieu Leray, Smithsonian Institution, boldsystem.org.

Another invasive species that pose a threat to eelgrass in Humboldt Bay is the tube building amphipod, *Ampithoe valida* that has been identified in the bay at many locations (Boyd et al. 2002). This species is not exclusively associated with eelgrass beds, but is found in many areas within the bay. In recent years, *A. valida* has been documented to be the source of considerable flower and seed herbivory within many eelgrass beds in San Francisco Bay, to the extent that amphipods may affect recruitment potential within some of the eelgrass beds. (K. Reynolds et al. 2012). At present, it is not known how active *A. valida* may be with respect to eelgrass seed herbivory within Humboldt Bay, nor what conditions may favor greater or lesser concern over activities of this invasive species.

Eutrophication and Nutrient Enrichment



Ephemeral macroalgal bloom displacing eelgrass within intertidal sites by smothering plants. Areas of heavy smothering are generally opened up as bare patches when algae dies off. Blooms are fostered by watershed discharges of nutrients during winter runoff and coastal upwelling during spring and summer. As water temperatures warm and day length increases during the spring and summer, nutrients stimulate responsive growth in macroalgae.

Eelgrass is a highly efficient consumer of sediment nutrients and a relatively poor consumer of water column nutrients. Conversely, ephemeral macroalgae (predominantly green algae including *Ulva* and *Enteromorpha*, but also including some reds such as various *Gracilaria* and *Ceramium*) are highly responsive to plentiful water column nutrients as evidenced through prolific blooms. These blooms result in substantial diurnal oxygen fluctuations. However, with exhaustion of water column nutrients, algae dies off creating a significant biological oxygen demand in the areas of the die-off.

Because eelgrass increases bottom roughness and reduces wave energy at the sediment surface, eelgrass effectively traps sediments providing for nutrient extraction from sequestered sediments to build both above ground and underground plant structure. This trapping of sediment and development of persistent below ground tissues fosters effective carbon cycling and sequestering in the sediment, irrespective of seasonal leaf loss. Conversely, algae die-off immediately returns carbon to the water column.

While eelgrass traps and extracts nutrients from the sediment, excessive nutrient loading into bays and estuaries can result in a more abundant supply of nutrients than can be utilized by eelgrass and a more rapid seasonal release. This results in algal blooms, fluctuating DO levels, and competitive decline of eelgrass beds. Loss of eelgrass then provides for an increased exposure of sediments to resuspension and greater turbidity and sediment nutrient release. These factors can result in development of adverse feedback loops contrary to eelgrass and supportive of algal dominated conditions.

Factors favoring the development and advancement of this type of stressor include:

- Nutrient loading in the watershed (e.g., fertilizer rich agriculture, dairy, and other heavy ranching practices)
- Prolonged drought followed by wet winters
- Depressed salinities and warm water following wet winters

In Humboldt Bay, nutrients including nitrate, ammonium and phosphate, derived from terrestrial sources enter the bay as a result of freshwater runoff primarily during the winter wet season, whereas oceanic nutrients principally enter the bay during the spring and summer upwelling periods (Tennant, 2006). In a recent study, Swanson (2015) determined that Humboldt Bay is a nitrogen limited system, and that watershed and wastewater contributions of phosphorus and nitrate to the system are small when compared to nutrient loading originating from the ocean. Further, Swanson postulated that anthropogenic nutrient contributions to potential eutrophication in Humboldt Bay are minimal in comparison to influences resulting from upwelling in the nearshore ocean. From this perspective, Humboldt Bay may be somewhat unique relative to many other estuarine systems in California, where anthropogenic nutrient sources have been implicated as the principal driver of eutrophication.

When contemplating the potential ramifications of relative sea level rise on Humboldt Bay with respect to nutrient inputs to the system, it is possible that some of the nutrient uptake capacity inherent to the extensive herbaceous pasture land and riparian corridors associated with low-gradient tributaries conveying runoff to the bay will be lost as a result of inundation and conversion of these lands to intertidal mudflat. It is unknown to what extent an expansion of intertidal mudflat and to a lesser degree saltmarsh surrounding the bay could offset or fully replace this potential loss of nutrient uptake potential, however; to some degree, conversion of these areas to tidal habitats may also diminish local agricultural contributions to nutrient loading in the bay.

Bioturbation and Herbivory

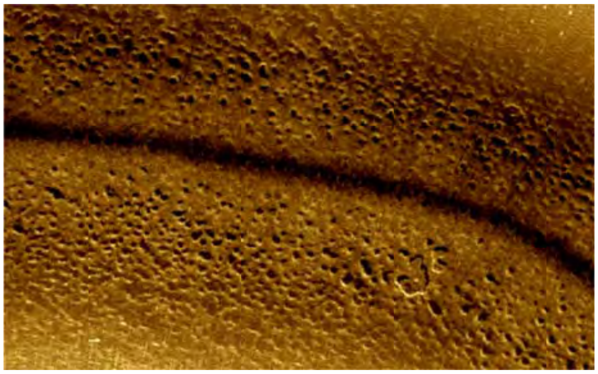
Marine Organisms

Eelgrass losses can occur from the effects of marine organism burrowing and foraging. However, it is more often the case that the loss of eelgrass provides an opportunity for site impact by marine organisms that retard the recovery of eelgrass following the initial perturbation. The rhizome mat of eelgrass often impairs invasion by displacing marine organisms and thus damage to beds when it does occur, often commences on a bed margin.

Burrowing organisms can develop a complex bottom relief and active sediment disturbance processes that prevents establishment of seedlings due both to the loss of seed into deep burrows as well as disturbance of seedlings at early stages of establishment. The most extensive damage is derived from mud and ghost shrimp.

Bat rays use their snouts to dig shallow pits in sand and mud bottom environments to expose clams and other prey species. It is believed that foraging pits are expanded through time as the rays continue to dig along the margins preferentially over excavating new pits. Some pits can grow to hundreds of square meters in size. This digging behavior can lead to localized impacts to eelgrass beds, however; at higher elevations within the intertidal zone, bat ray foraging pits impound and retain tidal water, creating microhabitat conditions that can allow eelgrass to persist at locally higher elevations. It is believed that the patchy 'leopard skin' eelgrass habitat common throughout the intertidal mudflats of Humboldt Bay is largely a result of historic bat ray foraging over time.

In Humboldt Bay localized damage to eelgrass has been noted within harbor seal haul-out locations. The habitual use of these areas is presumed to result in mechanical damage to the plants and ultimate denuding of the haul out locations.



Heavy bioturbation of the bay bottom by burrowing organism such as ghost and mud shrimp (regular pockmarks) and foraging pits by bat rays (larger depressions) is seen in this interferometric sidescan sonar image collected in Richardson Bay in San Francisco Bay in 2017. The top to bottom distance illustrated in the image is approximately 30 meters.

Bat ray damage within an eelgrass bed at the edge of a foraging pit in Morro Bay. Rays preferentially forage outward along the margins of foraging pits to access infauna. This leads to large depressions in beds that may persist for years in some cases.

Harbor seal haul-outs are habitual use areas of the mudflats where eelgrass is removed, presumably by mechanical damage.

Sand dollar damage to eelgrass beds in Morro Bay following major sand dollar recruitment event after eelgrass declines had started. Sand dollars were so dense in some areas as to effect vegetative expansion and seedling recruitment potential.

Other biogenic damage that has been observed in eelgrass beds includes damage by heavy sand dollar recruitment events and plant consumption by yellow shore crabs. In both of these circumstances, observations of damage to eelgrass have been made in the aftermath of massive die-offs of eelgrass within Morro Bay and periods of ecological instability in the bay.

One of the most exceptional observations of herbivory on eelgrass was made during the August 2014 Morro Bay eelgrass recovery program planting effort. During this period highly aggressive herbivory by the yellow shore crab (*Hemigrapsus oregonensis*) of new eelgrass planting units was observed and documented on video within portions of the mid-bay This shore crab is primarily known to consume green algae and diatoms and principally forages at night. The species is a facultative omnivore, specializing on algae but eating meat when presented. Yellow shore crabs have not previously been identified as a consumer of eelgrass. Yellow shore crabs were noted to leave *Gracilaria* and voraciously attack newly planted eelgrass. In some instances, eelgrass planting units were torn apart by crab chelipeds within minutes of their being planted by dozens of crabs on a single planting unit that would compete for leaves or position on the plant and were even noted to move onto planting units being carried by divers. The crabs were little deterred by the movements of divers; and while they would temporarily retreat when approached by a diver's hand or the camera, they would immediately return to the planting units even with the continued presence of the threat.

This odd behavior of shore crabs with eelgrass planting units was only noted in a few locations and appeared to be mediated by the presence of *Gracilaria* in the vicinity that hosted abundant crabs. It is postulated that yellow shore crab populations exploded with a shift in dominance of the system by green algae and Gracilaria following the collapse of eelgrass and that the collapse in green algae biomass in 2014 left a food deficit and crabs living on the less desirable *Gracilaria* that persisted. Eelgrass planting units were then introduced into a population of starving crabs. It is believed the crab herbivory may have been a substantial source of planting unit losses in 2014 with crabs consuming whole planting units within hours of planting (Merkel &Associates, 2015).

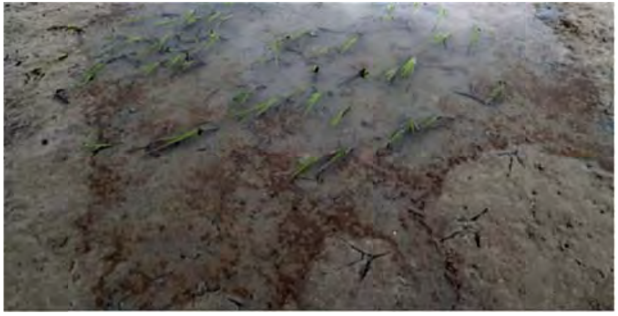
Photographs captured from video taken within minutes of planting illustrating hordes of yellow shore crabs exiting the cover of Gracilaria and converging on installed eelgrass planting units where they commence cutting and consuming the green leaf tissues during the Morro Bay 2014 eelgrass recovery planting efforts.

Canada Goose and Black Brant

The damage to eelgrass associated with avian foraging can vary substantially based on food abundance and foraging behavior of birds. The most tightly coupled trophic link between eelgrass and avifauna is with black brant. A species that has coevolved with eelgrass in a manner that some have argued is symbiotic with brant clipping leaves and providing fertilization of plants. Others believe the relationship is more one sided, but has evolved in a manner that does not result in undue harm to eelgrass beds that are strung out sporadically along long migratory routes.


Black brant clipping eelgrass
Photo by Len Blumin, Audubon Society


Canada goose pulling eelgrass rhizomes
Photo by Renee Takesue, USGS


Eelgrass in intertidal ponds within north Humboldt Bay showing typical signs of foraging by brant where eelgrass is clipped above the meristematic tissue leaving the rhizome mat and viable shoots intact.

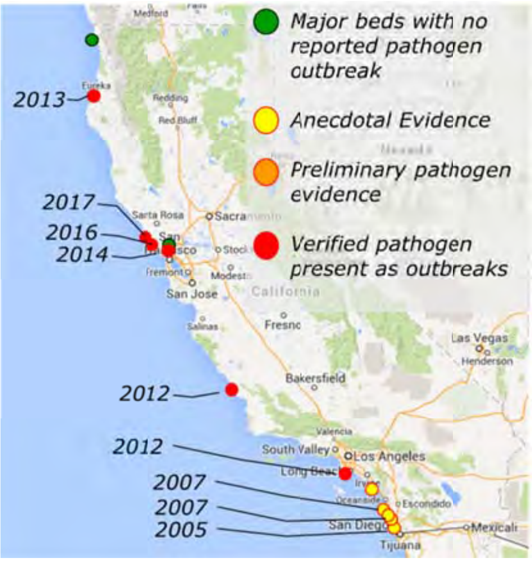
Conversely, the Canada goose is more of a generalist than brant and has no specific evolutionary ties to a particular food supply. Canada geese tend to be opportunistic and may heavily forage on resources to the extent of over-exploitation. Further, Canada geese tend not to clip eelgrass, but rather pull and consume eelgrass leaves, meristems, and even rhizomes. The result of Canada goose foraging can be denuding of eelgrass beds in an area. Further, because several flocks of Canada geese have developed non-migratory patterns around humans, foraging on lawns in parks and sports fields, the timing of goose foraging has become asynchronous with normal phenology of eelgrass thus placing some eelgrass at risk of being mowed down prior to setting seed. The results of heavy Canada goose foraging pressure has been implicated in the loss of eelgrass in some areas around Vancouver BC. It has also been identified as the reason for annual bed expression at Crown Beach in San Francisco Bay where it has been demonstrated through cage exclusion experiments that absent goose foraging, apparent annual plants exhibit perennial survival and growth characteristics (S. Kiriakopolos 2013). Further, within North Basin on the Berkeley shoreline of San Francisco Bay, Canada geese have been noted to harvest recently planted eelgrass planting units during low tides immediately after planting (K. Merkel, pers. obs.). While it cannot be fully determined when Canada geese will become a nuisance species damaging eelgrass, it is generally obvious when the potential exists. More often than not, Canada geese that pose threats to eelgrass are non-migratory lawn ornaments that have become habituated to humans, rather than migratory geese. There are no present threats to eelgrass by Canada goose foraging in Humboldt Bay.

While brant typically do not result in the same type of damage caused by Canada geese, it should be noted that with the significant declines in eelgrass within Morro Bay, greater plant damage was noted as a result of brant than typically occurs. It is believed that this was due to the lack of food availability and thus atypical grazing pressure.

Eelgrass Disease

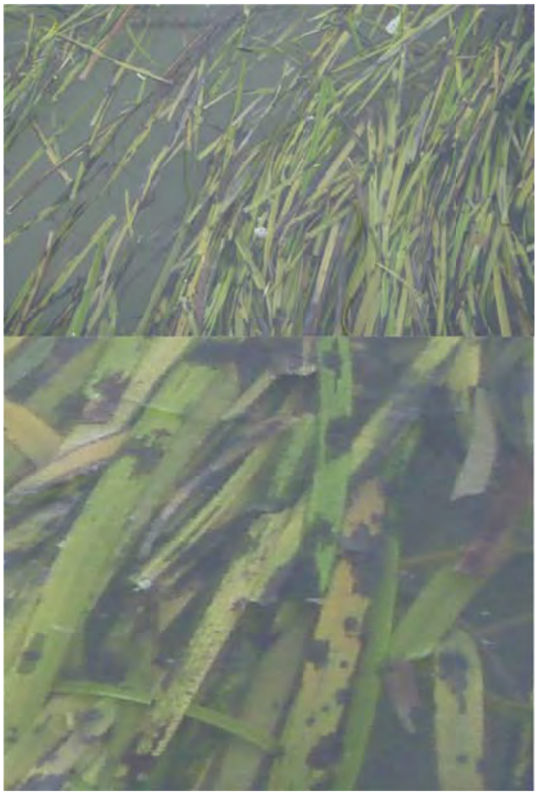
Eelgrass is susceptible to a number of physical stressors that influence plant metabolism and can also be adversely impacted by chemical stressors. However, perhaps one of the most complex and devastating concerns is a biological malady known as wasting disease. Wasting disease is the result of a virulent condition within the naturally occurring protist *Labyrinthula zosterae*. This species is believed to have resulted in the devastating losses of an estimated 90 percent of all of the eelgrass in the north Atlantic along North American and European coast in the early 1930s (Muehstein 1989). The impact of the decline resulted in consequences that extended far afield including impacts to fisheries, waterfowl migratory patterns and population levels, and water quality. The decline was also linked to expanded coastal erosion and waterway maintenance needs (Muehstein 1989).

What is less well known is that similar less devastating declines have occurred at other times and other locations throughout recent history. Presumed wasting disease losses occurred in 1893-1894, also along both north Atlantic coastlines. Declines were identified in the 1920s in England, and within the late 1930s declines on the Pacific coast of North America were noted with reports along the California coast specifically identifying Tomales Bay, Drakes Bay, Bolinas Bay, Morro Bay, and Mission Bay as disease based declines with other systems showing declines but not explicitly coupled to disease (Moffitt and Cottam 1941). In 1984 disease was noted along the coast of Maine, New Hampshire, and Massachusetts (Short et al. 1986). Die-offs were also noted in Washington State in the 1980's.



Wasting disease progression in California. Data are based on anecdotal evidence, generally related to large scale losses of eelgrass from core areas of expansive, historically stable beds as well as direct verification by observed disease proliferation and leaf drop.

Merkel & Associates, unpubl. data



August 2013 shed leaf wrack and diseased eelgrass in Humboldt Bay.

Photos provided by Vicky Frey, CDFW

Since the 1980's outbreaks a heightened awareness has developed within the scientific community. In 2005, evidence of disease began showing up in eelgrass within San Diego Bay and other systems in southern California (Merkel & Associates 2008). A progressive spread of diseased systems was noted northward along the California coast (Merkel & Associates 2013). Concurrent development of wasting disease has also been noted in Puget Sound, Washington (Short 2014).

The hardest hit by wasting disease in California was Morro Bay. Between 2007 and 2012, Morro Bay lost 96 percent of its eelgrass. This decline has persisted through 2017, with the beginnings of eelgrass recovery commencing in 2016 (Merkel & Associate 2017). Within Humboldt Bay, wasting disease was first noticed in August 2013 when considerable non-seasonal eelgrass wrack was noted on the surface of the bay. While the shed leaves were a clear indication of tremendous disease impact, the precise areas of the bay where the disease outbreak occurred were not identified.

Morro Bay mid-bay flats Morro Bay National Estuary Program monitoring station photo plots taken in 2009 (left) and 2010 (right). Plots reveal the transition from dense eelgrass dominance to loss of eelgrass and development of mudflat and Gracilaria dominant cover. Photo credit: Annie Gillespie, MBNEP 2010

L. zosterae is common and widespread in eelgrass habitats. However, under most circumstances, only senescent eelgrass tissues are affected by the organism. What exactly spurs the virulence of *L. zosterae* has been a subject of much investigation, yet the precise cause of an outbreak remains a matter of speculation. What is known is that wasting disease spreads by direct contact of diseased plant tissues with other eelgrass; virulence is enhanced with increasing salinity and nitrogen enrichment (Short 2014). The pathogen is impaired by lowered salinities (Burdick et al. 1993, McCone and Tanner 2009). There is also ancillary evidence that wasting disease spreads more effectively when eelgrass is weakened by elevated temperatures. However, it is often difficult to separate temperature from increasing salinity within coastal embayments.

Because wasting disease is spread by direct contact between infected plant tissues and non-infected tissues, it spreads in a predictable epidemiological pattern. Dense populations are more susceptible to rapid spread of the disease than less dense populations and other factors that enhance exposure and distribution of disease can be used to predict how an outbreak may spread.

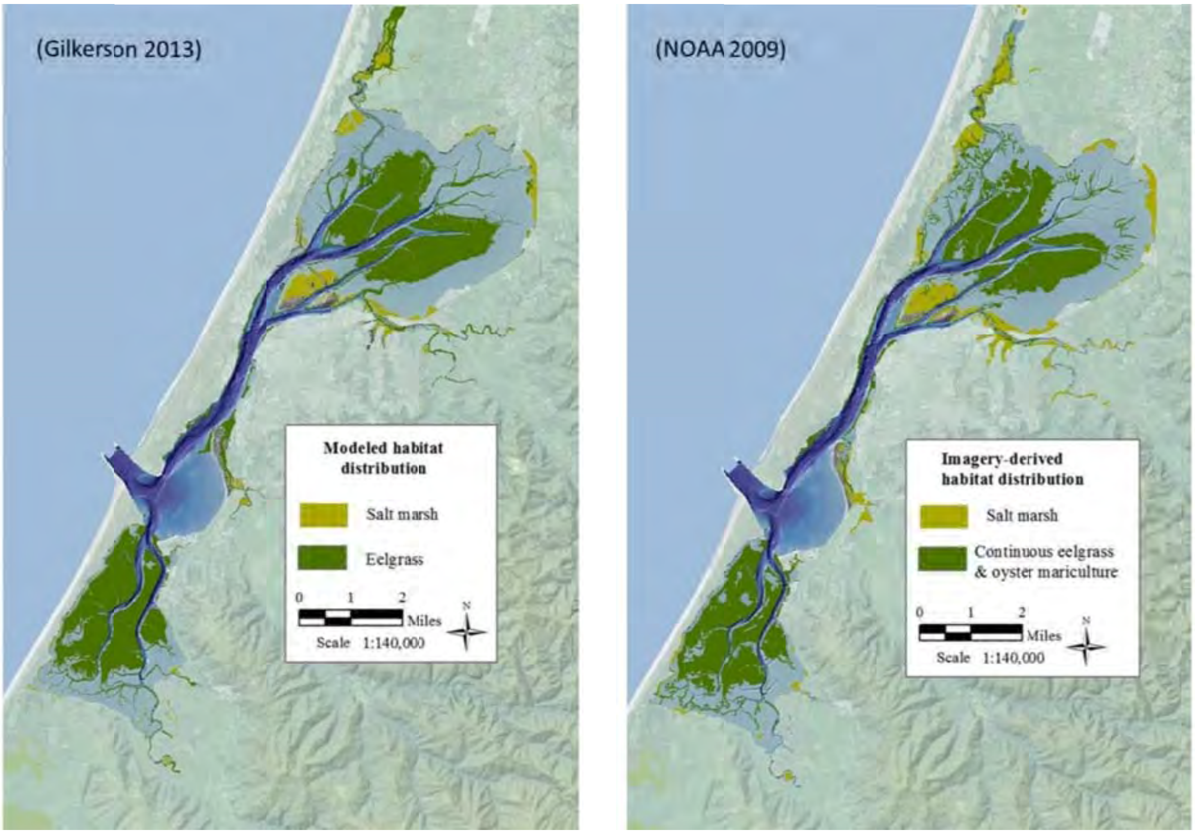
As infected leaves are shed by plants they float to the surface and drift with the tides and wind. As a result intertidal eelgrass that reaches the surface is subject to greater potential for exposure than subtidal beds. Further, during periods of increased temperatures, eelgrass in shallow flats may be more stressed than eelgrass within deeper waters. This may result in a lower immunity of intertidal beds. The result of these two factors would be a greater susceptibility of intertidal plants in warm water and elevated salinities to losses from wasting disease. Indeed, the pattern of eelgrass loss within Morro Bay was from the highest intertidal elevations and the densest beds in the southern most portion of the bay to the subtidal bed in the north bay with the deepest and northernmost beds being the only survivors of the losses (Merkel & Associates 2015). It is not clear what the initial stressor was that triggered eelgrass declines in Morro Bay. However, the precipitous declines from 2007 through 2013 were likely supported by the significant drought that persisted since 2011. High water temperatures and drought conditions likely both contributed to plant stress and stimulate virulence and population expansion of *Labyrinthula*.

For several reasons, the concerns about wasting disease in Humboldt Bay cannot be over emphasized and potential for significant losses of eelgrass due to disease in the system are high. The conditions favoring a major wasting disease impact on the system include:

1) a wasting disease outbreak as recently as 2013;
2) shallow flats with dense eelgrass that enhance potential for disease spread, reduce water circulation, increase water temperature, and increase potential for increased salinity;
3) a trend of reducing cloud cover on the north coast (Johnstone and Dawson, 2010);
4) a small local watershed area that reduces capacity to seasonally dilute rising salinity levels;
5) a source of increased nitrogen through upwelling that does not concurrently reduce salinity (Tennant 2006, Swanson 2015), and;
6) extensive eelgrass beds with a high coupling of ecosystem functions of Humboldt Bay to the eelgrass resources.

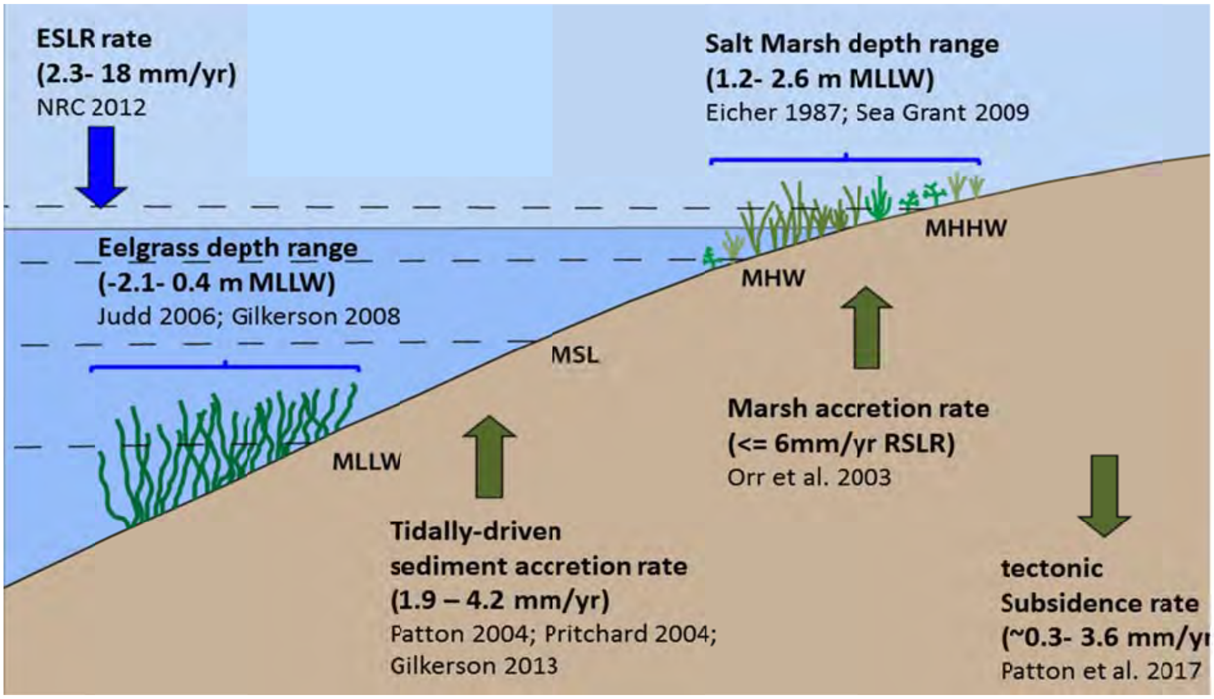
Eelgrass and Sea Level Rise in Humboldt Bay

In order to evaluate the influence of large-scale stressors in controlling the distribution of eelgrass and other broadly distributed habitat features within any system, spatial-numeric modeling is often beneficial. Such modeling is performed by identifying a number of environmental parameters that control the distribution of eelgrass and utilizing eelgrass response to these variables to predict where eelgrass is likely to occur. For Humboldt Bay, such modeling was the focus of W. Gilkerson's thesis work at Humboldt State University and the result was the development of a relatively robust model of eelgrass for Humboldt Bay (Gilkerson 2008). Over time this model has been modified and adjusted for application to many ecological "what if" questions involving eelgrass, salt marsh, and resources such as brant that are dependent upon eelgrass (Shaughnessy et al. 2012, Gilkerson 2013, and Stillman et al. 2015). The current version of the model was evaluated for its predictive capacity by comparing modeling predictions with the continuous eelgrass distribution observed during the NOAA 2009 survey. This evaluation demonstrated a high degree of similarity between the model and the measured conditions, providing a good sense that model predictions based on changing the incorporated model parameters would provide a good estimate of how the system may change in response to predictable shifts in the input parameters (Gilkerson 2013).



Geospatial modeling efforts relating eelgrass and salt marsh distribution to tidal elevation, wave exposure, and substrate suitability compare favorably to 2009 imagery data and provide a foundation for modeling the effects of relative sea level rise on the distribution of these critically important habitats in Humboldt Bay (Gilkerson, 2013).

Relative sea level rise (RSLR) in Humboldt Bay is affected by eustatic sea level changes, tectonic vertical land level changes, and sediment accretion. Recent and ongoing efforts to gain a better understanding of RSLR throughout the Pacific Northwest indicate that portions of Humboldt Bay are experiencing the most rapid rates of RSLR anywhere on the west coast of the continental U.S. (Burgette 2012 and Patton et al. 2017). Eelgrass will be affected by relative sea level rise in Humboldt Bay due to its sensitivity to changes in water level and relatively limited depth distribution. All of the recent modeling efforts in Humboldt Bay suggest that eelgrass habitat is likely to expand particularly in North Humboldt Bay over the course of at least the next 100 years (Shaughnessy et al. 2012, Gilkerson 2013, and Stillman et al. 2015). The most robust estimates suggest that continuous eelgrass may expand by as much as 74 percent by 2113, with the majority of eelgrass gains occurring at the expense of patchy eelgrass, unvegetated mudflat, and coastal salt marsh where expansive low-gradient flats provide for shoreward transgression of eelgrass habitat.



Conceptual diagram of primary factors influencing eelgrass and salt marsh response to projected relative sea level rise in Humboldt Bay (Gilkerson 2013).

However, with changing climatic conditions also comes changes in fluvial discharge variability that may be expected to take away some of the predicted gains. In contrast, saltmarsh habitat, which has already experienced dramatic declines in spatial extent as a result of the construction of levees and transportation corridors around the bay will continue to lose ground absent concerted efforts to restore former tidelands. As eelgrass migrates shoreward and occupies a larger proportion of the intertidal mudflats around the bay, it will likely reduce the potential for wind-waves to resuspend fine sediment, thereby decreasing turbidity and increasing light levels in the bay. The overall effect of this is likely to be that as eelgrass expands shoreward in response to sea level rise, it may have the effect of improving the light environment such that eelgrass is then able to further colonize subtidal areas of the bay and increase its overall depth distribution.

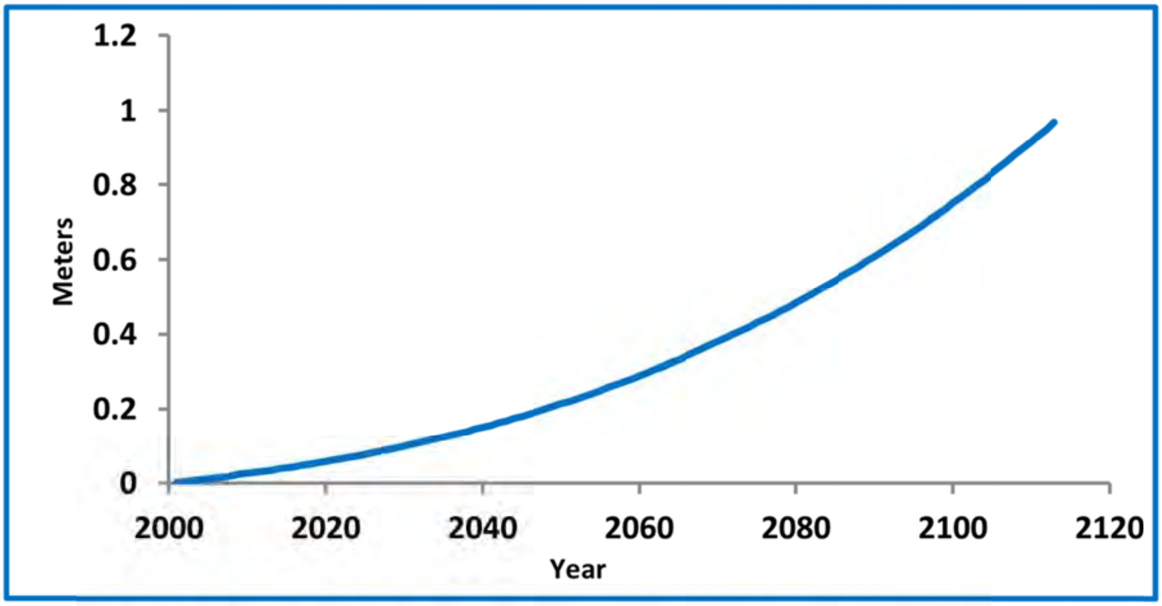
The predictions for sea level rise positively impacting eelgrass in Humboldt Bay are of keen interest in that most of the systems in California that support eelgrass are anticipated to suffer substantial losses of eelgrass under sea level rise scenarios. This relates to the differing profile of broad intertidal flats and deeply incised channels within Humboldt Bay and a few others such as Bodega Bay, Drakes Estero, Bolinas Lagoon, and Morro Bay where slope and current velocities likely limit eelgrass rather than light, as is the case in most other embayments in California. Considering such factors (see previously presented profiles), it is easy to see that sea level rise may result in a number of systems losing significant eelgrass while a few systems gain eelgrass.

There are multiple ways of viewing the influence of sea level rise on eelgrass in Humboldt Bay. At a local scale, sea level rise results in a costly loss of salt marsh and mudflat for gains in a resource that is already well represented in the system. Impacts to mudflats and marshlands are perhaps more of an ecological detriment than is the benefit provided by expanding eelgrass. This is especially true if you are a resource dependent upon the habitats reduced such as small shorebirds.

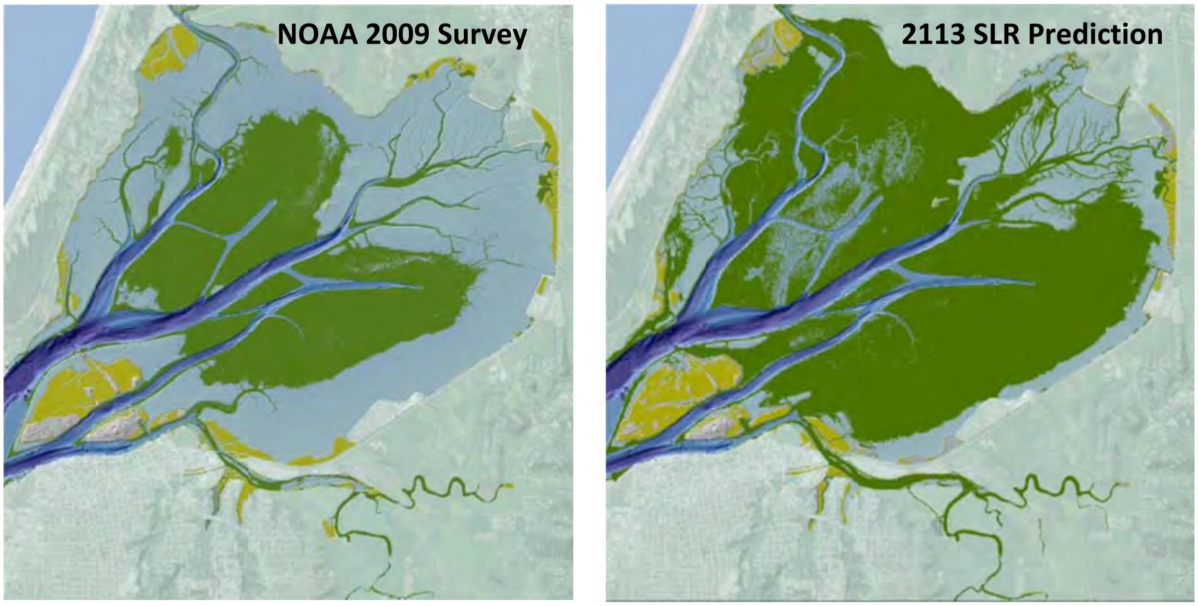
From a broader worldwide, coastwide, or even California perspective, sea level rise is predicted to have devastating consequences on eelgrass and other seagrasses. While detailed analyses have not been completed on a comprehensive basis, even at a state wide level, it is presently anticipated that the losses will outpace gains. For this reason systems that are predicted to support eelgrass gains are of particular importance to long-term ecosystem and environmental planning.

The outlook from sea level rise for Humboldt Bay is not all good. Not all eelgrass serves the same function and the results of sea level rise would be expected to result in an increase in subtidal eelgrass and a potential decrease in intertidal eelgrass as the tides are constrained by surrounding infrastructure and steeper uplands. This may result in a reduction in availability for species such as brant that are dependent upon low tides to access eelgrass, even though the resource itself is increased.

While the sea level rise modeling conducted to date presents a fairly deterministic result for eelgrass and marshlands, it is important to note that the models were constrained by existing features and hard boundaries for the model runs. They similarly do not adequately address some of the hydrodynamic, water quality, and sedimentation processes that would accompany sea level rise. Further, the models have not integrated some of the opportunities for shoreward tidal marsh transgression that are already underway in planning, engineering and even implementation phases. Such efforts as the lower Elk River restoration project, breaching levees to reconnect historically diked tidelands and regrading low elevation bottom lands could provide opportunities for reclaiming lost marshlands. Further, such projects would also result in expanding the bay’s tidal prism, a factor critical to achieving the extent of eelgrass gains predicted in the modeling efforts, where such predicted eelgrass returns occur in confined sloughs, tidal creeks, and protected basins where wind and tidal circulation are most impaired.



Current ESLR rate ~2.3 mm/yr Pacific Ocean (Burgette and Weldon, 2009)
NRC projection = 9.9 cm by 2030, 21.4 cm by 2050, and 75.1 cm by 2100



"Moderate" eustatic sea level rise projections for Humboldt Bay (NRC, 2012) depicting significant increase in inundation over the next 100 years. This translates into expanded inundation frequency over the shallow flats of Humboldt Bay that results in predictions of substantial expansion of eelgrass due to sea level rise at the expense of mudflats and marshlands (Gilkerson, 2013).

Ocean Acidification

Seagrasses including eelgrass are carbon-limited and recent research suggests that eelgrass is likely to experience increased photosynthetic and growth rates in response to elevated dissolved CO_2 associated with climate change (Palacios and Zimmerman 2007; Koch et al. 2013). The capacity of eelgrass to remove carbon from seawater may also have the potential to buffer Humboldt Bay from the effects of ocean acidification. Based on the distribution and abundance of eelgrass relative to basin size and tidal exchange rate, North Humboldt Bay may offer favorable conditions with respect to pH buffering in Humboldt Bay. More research is needed to evaluate this phenomenon locally, as the potential buffering effect of eelgrass in Humboldt Bay could have dramatic and positive implications for native shell-forming invertebrates as well as the shellfish mariculture industry in Humboldt Bay, especially for environmentally sensitive seed oysters and clam production.

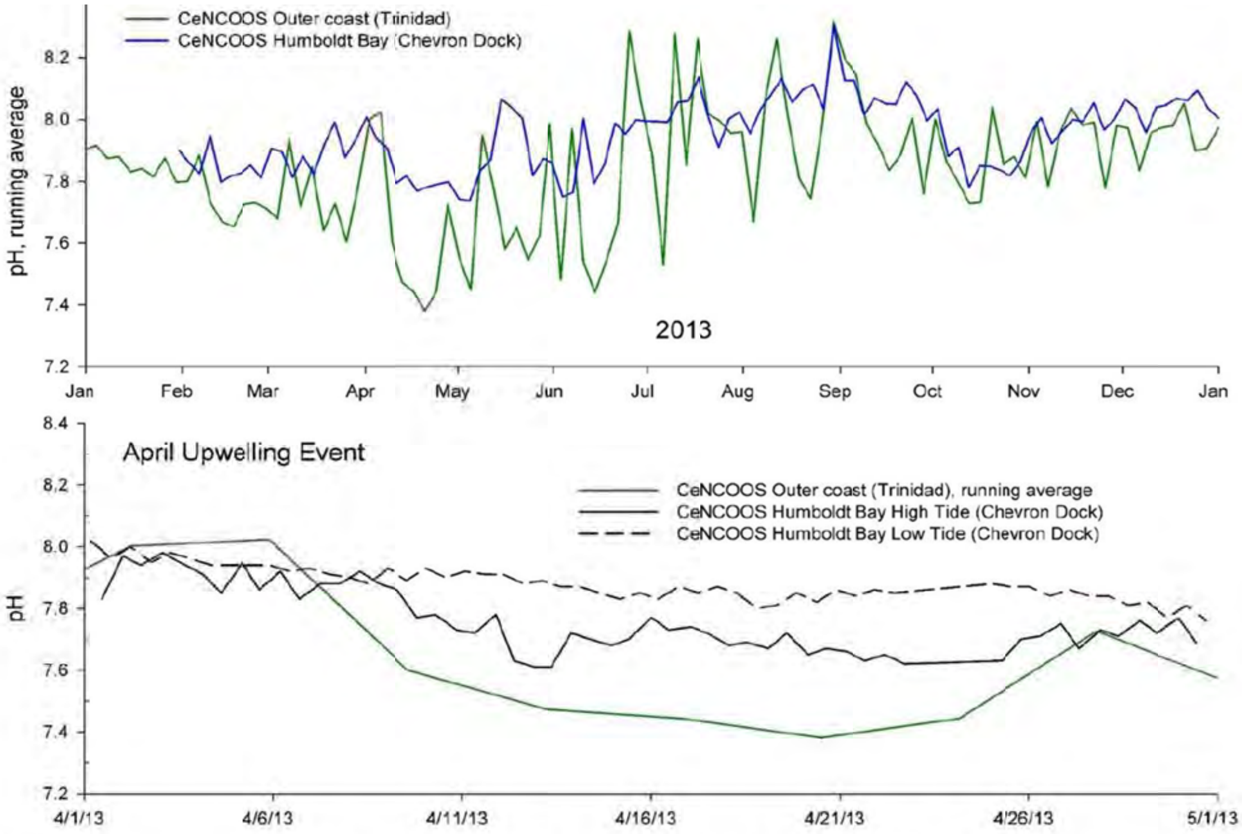


Figure by Shaughnessy (2013), illustrating potential buffering effect of eelgrass in North Humboldt Bay.

Other Climate Concerns

Beyond sea level rise and ocean acidification, a recent study of the redwood region of northern California revealed a 33 percent decrease in summer fog extent since the beginning of the 20th century (Johnstone and Dawson, 2010). In more recent years, Di Lorenso and Mantua (2016) documented the multi-year persistence of the 2014-2015 heatwave implicated in large scale losses of eelgrass along the west Coast of North America. While it is not yet clear whether the observed trends are indicative of long term climate change or variation in climatic conditions over shorter time scales, if these trends continue or become more frequent, they may have highly deleterious effects on eelgrass within the high intertidal and both positive light and negative metabolic demand effect on eelgrass in the subtidal. Overall, the results of such climate change patterns would be expected to be very deleterious to eelgrass in Humboldt Bay considering the overwhelming difference in eelgrass distribution between intertidal and subtidal depths and the likelihood that eelgrass in the subtidal is more generally controlled by factors beyond just light.

Taken as a whole, these factors suggest that eelgrass habitat in Humboldt Bay is likely to expand over the course of the next 100 years. Some elements will result in gains and some losses. This represents a dramatic contrast to the other four California systems that support 80 percent of the state’s eelgrass resources.

3.0 COMPREHENSIVE MANAGEMENT PLAN FRAMEWORK

Eelgrass is a unique and challenging resource to manage. Unlike saltmarsh and other terrestrial wetland systems, eelgrass is typically spatially restricted by naturally variable physical climate driven conditions. It is also essentially a monoculture, which makes it more vulnerable to potential collapse as a result of singular or multiple stressors. Despite the abundance of the resource locally in Humboldt Bay, the fact that eelgrass, and sea grasses in general, are extremely valuable ecologically and physically and have experienced dramatic declines globally and regionally (e.g. Morro Bay) has led to strong protective policies. In Humboldt Bay, eelgrass exists across a moderate bathymetric range compared to other systems within California. It has an overwhelmingly dominant intertidal component and a lesser subtidal component. As with most systems in California the distribution of eelgrass within Humboldt Bay is driven substantially by desiccation stress along the upper margins of the beds and available photosynthetically active radiation (PAR) at the lower limits of the beds along with steep slope conditions. The overall spatial occurrence of eelgrass in the Bay is defined by the manifestation of these limits across the bay topography and the influence of various physical and biological factors that interplay in manners that generate increased variability in bed distribution patterns.

Because the eelgrass population in Humboldt Bay is extensive and robust, and the cumulative impacts anticipated for maintenance dredging, shoreline repairs and future development associated with the core focus activities identified in the plan are quite small relative to the system at large, the focus of management actions associated with the HBECMP is to a) promote/encourage opportunistic eelgrass mitigation and restoration activities when feasible to draw down initial mitigation ratios, b) develop a mechanism for capturing and tracking surplus mitigation credit, c) establish a regulatory framework that supports a market function for future eelgrass mitigation credit and needs, and d) streamline the permitting process for essential port-related maintenance and development projects within the bay.

To do this, the following measures will be taken:

1) Develop understanding of eelgrass mitigation/restoration opportunities and system level capacity within Humboldt Bay;
2) Define a suite of regulatory core focus activities for the plan based on high-priority port maintenance and development needs encompassing a similar suite of project types and anticipated impacts to eelgrass;
3) Establish a web-based eelgrass mitigation tracking system by means of relational database;
4) Explore/evaluate/adopt programmatic/regulatory tools that support retention and capitalization of surplus eelgrass mitigation credit for core focus activities within the plan;
5) Improve the efficiency and consistency of the application of eelgrass regulatory policy within Humboldt Bay through establishment of multiagency agreement relating to pre-project guidance, acceptable eelgrass assessment/mitigation/restoration strategies and standards, and prioritization of restoration/mitigation opportunities;
6) Promote system level long-term monitoring to better understand interannual variability in eelgrass abundance and distribution as an indicator of overall system health and the effects of climate change on the Humboldt Bay Ecosystem.

3.1 EELGRASS POLICY STANDARDS

California Eelgrass Mitigation Policy

CEMP Overview

Eelgrass impact and mitigation policy within California is primarily structured under the California Eelgrass Mitigation Policy (CEMP) (NOAA Fisheries 2014). The CEMP was adopted by NOAA National Marine Fisheries Service through a process of partner agency review and input as well as formal public review and policy adoption. While the CEMP is explicitly drafted to guide and standardize input from NMFS and to provide the public with a better expectation of NMFS positions relative to eelgrass impacts and mitigation, the policy was adopted through much input and coordination with sister state and federal agencies in order to develop a generally unifying policy among agencies. As a result, agencies such as the Corps of Engineers, California Coastal Commission, Department of Fish & Wildlife, State Lands Commission, State Parks, and several Regional Boards have made use of the CEMP to establish standards for eelgrass.

It is important to recognize, that while the CEMP provides a good functional and consistent means of addressing eelgrass within California, it is not a regulatory document. Rather the CEMP is a framework document to establish standards and provide detailed expectations of performance. Regulatory control that enacts CEMP requirements is derived through regulatory agency action, typically Army Corps issued Clean Water Act and Rivers & Harbors Act permits, Coastal Commission or Harbor District issued Coastal Act permits, and/or Regional Board issued CWA State Water Quality Certifications, or Waste Discharge Requirements.

The CEMP unequivocally states that it is NMFS' policy to recommend no net loss of eelgrass habitat function in California. The CEMP incorporates a policy standard of seeking means to avoid and minimize impacts to eelgrass prior to mitigating losses and is congruous with the Clean Water Act guidelines under section 404(b)(1) (40 CFR 230) in this respect. Where impacts to eelgrass are found to be unavoidable the CEMP recommends mitigation measures and appropriate biologically based ratios to achieve full replacement of lost functions. While options for mitigation under the CEMP include out-of-kind mitigation under certain circumstances, there is a strong preference for in-kind (eelgrass for eelgrass) mitigation.

Comprehensive Management Plan (CMP) under the CEMP

The CEMP has been drafted as a statewide policy and thus it does not fit all circumstances equally. Rather, it provides over-arching objectives, recommended methodologies to achieve those objectives, and guidance to the field to facilitate success. It also includes multiple acknowledgements that some situations may exist where the standard structure of the CEMP does not address needs very well. As a result, the CEMP makes provisions for project specific coordination and is supportive of development of system-specific comprehensive management plans (CMPs) under the CEMP that protect eelgrass resources within the context of broader ecosystem needs and management objectives. A CMP is not an alternative to the CEMP but rather it is a tailored application of the CEMP to a situation with unique circumstances. Because the CEMP is not prescriptive, but rather advisory and organized under a broad set of unifying objectives, the CMP provides flexibility in achieving the objectives, but not a vacation of the objectives themselves.

The CEMP on Comprehensive Management Plans:

In general, it is anticipated that CMPs may be most appropriate in situations where a project or collection of similar projects will result in incremental but recurrent impacts to a small portion of local eelgrass populations through time (e.g., lagoon mouth maintenance dredging, maintenance dredging of channels and slips within established marinas, navigational hazard removal of recurrent shoals, shellfish farming, and restoration or enhancement actions).

Given several unique circumstances within Humboldt Bay, the most appropriate approach to addressing eelgrass is through development and implementation of a CMP as outlined within the CEMP. This CMP provides some local adaptations of standard methodologies outlined in the CEMP, but is not intended to fully supplant the recommendations of the broader CEMP. As a result, where the CMP is silent on an element, it is taken that standard provisions of the CEMP apply.

The CEMP indicates that in order to ensure that the CMPs provide adequate population-level and local resource distribution protections to eelgrass and that the plan is consistent with the overall conservation objectives of the CEMP, NMFS should be involved early in the plan's development.

For the Humboldt Bay Eelgrass Comprehensive Management Plan the CMP development process has engaged the NMFS, the Army Corps, California Coastal Commission, California Department of Fish & Wildlife, and the Regional Water Quality Control Board. In addition, the process has engaged other major stakeholders in the process as partners in plan development.

The CMP and Certainty:

The key to success for the Management Plan is if it leads to regulatory certainty and affordable mitigation costs. Regulatory certainty is not 100% certainty, but it means that applicants can be reasonably confident that following the plan is likely to lead to streamlined approvals from all regulatory agencies.

Hank Seemann, Humboldt County Public Works (Partner)

Partners in the Humboldt Bay Eelgrass CMP have expressed cautious optimism that the CMP will enhance eelgrass management benefits to the Bay, improve impact mitigation success, lessen costs and risks to the regulated community, and reduce agency workloads and improve effectiveness of management actions pertaining to eelgrass. To achieve these aspirations, it is essential that the plan be implemented as a whole, recognizing that it is the sum of the parts that provides plan function and that individual elements of the plan are bolstered by other elements that may be of greater or lesser importance to specific partners, the regulated community, or the public at large.

It is important to recognize the adaptive nature of the plan. The CMP is intended to provide an adaptation of the CEMP that best fits the needs of the Bay. However, it would be erroneous to assume that the Plan will work perfectly from the outset (the SCEMP was on Revision 11 upon its retirement in 2014). As a result, the plan is designed to provide for both an open information structure using web-based access where the public and partners may track the status of plan implementation. The web-portal also provides information on eelgrass status for the Bay derived from monitoring and eelgrass restoration and impact accounting. Finally, it is intended that the Plan be reviewed for potential modification needs on a recurrent cycle of approximately every 5-years in alignment with the CEMP review timing or permit renewals in reliance of this Plan. This review would be done by reconvening the plan partners to review status of implementation, functionality of the plan, and any elements that may require refinement to meet the Plan intent.

CEMP Updates and Adaptive Management:

NMFS will continue to explore the science of eelgrass habitat and improve our understanding of eelgrass habitat function, impacts, assessment techniques, and mitigation efficacy. Approximately every 5 years, NMFS intends to evaluate monitoring and survey data collected by federal agencies and action proponents per the recommendations of these guidelines. NMFS managers will determine if updates to these guidelines are appropriate based on information evaluated during the 5-year review. Updates to these guidelines and supporting technical information will be available on the NMFS website.

CEMP Implementing Guidelines

Impact Determinations

Under the CEMP, eelgrass impacts are determined to occur based on an assessment of change between pre-construction and post-construction surveys relative to the natural variability of reference site(s). This approach to determining impact is intended to achieve multiple purposes and is somewhat different from more numerically proscriptive structure of most impact evaluations and permitting for wetlands and upland resources. The primary purposes of applying this impact assessment methodology are:

1) eelgrass is highly dynamic in its distribution and naturally expands and contracts over time thus creating potential to over or under-estimate impacts based on static assessments;
2) marine construction activities are not as precise as terrestrial work and there are many ways for impacts to be expanded, or even reduced from pre-construction estimates during project construction;
3) secondary impacts that develop after a project is constructed may result in expansion of impacts beyond those initially anticipated and thus should be accounted for, and;
4) mitigation of impacts under the CEMP are explicitly intended to achieve functional replacement of impacts and thus the methodology for assessing impacts provides the best assurance that all impacts are identified and accounted for.

While final impact assessment is based on the pre-post comparisons, for planning, budgeting, environmental review, and regulatory purposes, it is critical that estimates of potential impacts be identified early and used to assess the project needs throughout all stages of work. This is the only means by which prudent project implementation may be undertaken.

As a result, this dictates a process of eelgrass planning that commences with identification of eelgrass within a proposed project area, based on understanding of the project activities desired to be undertaken. Surveys must generally be timed to correspond to the high growth period of eelgrass (May to September for northern California). It is likely that the larger and more complex the project, the greater extent of eelgrass investigation will be required.

Planning for projects that may affect eelgrass resources should integrate consideration of how the project may be adjusted to avoid or reduce impacts and how any residual impacts may be mitigated. One of the primary constraining elements associated with projects that will impact eelgrass is a lack of early integration of eelgrass issues into the project development process. This lack of early integration generally results in schedule delays, added expense, and complications within the environmental review and permitting phases of work. It also generates typically avoidable coordination issues and high cost uncertainties.

One major objective of this CMP is to facilitate reduction of these issues by identifying methods to ensure better communication and management of eelgrass issues and to lay a framework for managing impact mitigation.

Compensatory Mitigation

Under the CEMP eelgrass mitigation is required to achieve a 1.2:1 (mitigation to impact) areal exent replacement and 85 percent of the density of impacted beds within 3 years, while meeting intervening progress milestones. For pre-established mitigation that has been in place for over 3 years, eelgrass mitigation ratios are established at a 1:1 mitigation rate.

At the time of adoption of the CEMP, eelgrass success rates in northern California were low and continue to be low. As a result, the CEMP dictates a high initial restoration ratio of 4.82:1 with the ultimate need to achieve the required 1.2:1 mitigation ratio. While the restoration ratio is subject to revision approximately every 5 years based on changes in regional success rates, it establishes a relatively high bar at the present time.

To address this high obligation, the Humboldt Bay CMP is focused on development of an eelgrass mitigation surplus that would reduce failure risks and thus lower the obligatory mitigation ratios under the CEMP. The process of developing the mitigation reserve is to meet the initial restoration objectives of 4.82:1 outlined for the northern California region for early project impacts and to develop a surplus of restored eelgrass that will be applied as back-up to insure against shortfalls on future projects undertaken at a lower initial restoration rate. Concurrently, the District will seek to identify and undertake opportunistic eelgrass projects to fill out a reserve of potential mitigation lands for future project needs.

The development and retention of mitigation credits obliges both an acceptable system for credit management and exchange structure, and a tracking system to monitor the status of mitigation credits. This is discussed in a later section of this document.

An important element of the CEMP is the policy objective of achieving one-time mitigation for impacts. This is important in that it fosters actions by stewards of the waterways that enhance resource management integration with essential facility management and maintenance actions, rather than pitting the two against each other.

The CEMP guiding policy statement on one-time mitigation:

[F]or on-going projects, once mitigation has been successfully implemented to compensate for the loss of eelgrass habitat function within a specific footprint, NMFS should not recommend additional mitigation for subsequent loss of eelgrass habitat if 1) ongoing project activities result in subsequent loss of eelgrass habitat function within the same footprint for which mitigation was completed and 2) the project applicant can document that no new area of eelgrass habitat is impacted by the project activities.

This is more explicitly demonstrated by example. In the case of maintenance dredging, a port is economically and operationally well served to let sediment accumulate in navigation areas to a level at which dredging is needed to maintain operational clearances. However, in some instances this results in growth of eelgrass within the navigation areas and the need for mitigation of impacts to eelgrass. As a result, ports wishing to avoid the need for eelgrass mitigation may dredge more frequently than absolutely necessary for navigation in order to prevent eelgrass growth. Under the CEMP, once mitigation is completed for an area and it is documented that mitigation has been performed successfully, future dredging is not obligated to mitigate again for impacts from recurrence of eelgrass. This results in both more efficient and economical dredging, and the presence of greater net eelgrass functions within the system since services are provided by eelgrass in maintained areas between maintenance events.

Humboldt Bay travel lift is presently nearly non-operational due to accumulation of sediment in the ways. Dredging of the ways will impact eelgrass and require mitigation. Under the CEMP the dredging would require one time eelgrass mitigation provided the impact and mitigation are tracked. Subsequent maintenance that will be required would be without eelgrass mitigation requirements.

Regulatory Programs and the CEMP

Army Corps of Engineers – Clean Water Act and Rivers & Harbors Act

Section 404 of the Clean Water Act (1972) establishes a framework for regulating the discharge of dredged or fill material into waters of the United States. In tidal waters, such as Humboldt Bay, regulation under Section 404 extends to the Highest High Tide plus adjacent wetlands. Applicants pursuing Section 404 permits must demonstrate that efforts have been undertaken to avoid impacts to aquatic resources where feasible, minimize impacts that cannot be avoided, and mitigate for any outstanding impacts remaining. A permit review process is used to regulate proposed activities.

Section 10 of the Rivers and Harbors Act (1899) stipulates that development or maintenance activities conducted below the Ordinary High Water Mark (OHWM) of navigable waters of the United States (including tidal waters of Humboldt Bay) are subject to regulation under Section 10. Regulated activities include construction, placement, or removal of structures, dredging and disposal of dredged material; any placement of fill, excavation, or disturbance of soil; or any other modification of a navigable waterway. The San Francisco District of the U.S. Army Corps of Engineers (USACE) is charged with implementing Section 10 and Section 404 regulatory programs.

Permitting under Section 404 and Section 10 can be accomplished individually or through combined Section 404/Section 10 permitting process. The Corps regulatory process includes several consultation and coordination requirements between the Corps and state and federal agencies. These include, but may not be limited to the following:

- Fish & Wildlife Coordination Act Coordination (FWCA)
- Magnuson-Stevens Fisheries Conservation and Management Reauthorization Act (MSRA) under which Essential Fish Habitat (EFH) Consultation occurs
- Coastal Zone Management Act (CZMA) – Under which a CZMA Consistency Determination is required from the California Coastal Commission
- Clean Water Act Section 401 State Water Quality Certification
- National Historic Preservation Act (NHPA) - Section 106 Consultation
- USACE Tribal Consultation Policy under multiple authorities (as applicable)
- Endangered Species Act Section 7 Consultation (as applicable)

Permit action by the USACE is subject to the National Environmental Policy Act (NEPA). The form of permits may vary from an individual permit for an explicit discrete action occurring at a specified location, or programmatically through either a Regional General Permit (RGP) or a Nationwide Permit (NWP) depending upon the scale and context of the proposed action and where authorized activities do not either individually or collectively have more than a minimal impact on the aquatic environment. Programmatic permitting when feasible has numerous advantages over individual permitting such as substantial reduction in review time, minimizing both the regulatory staff burden and project delays.

Vegetated shallows that support eelgrass are considered to be special aquatic sites under the 404(b)(1) guidelines of the Clean Water Act (40 C.F.R. § 230.43). As such, these areas are given special status under the public interest review of the Corps and there is a regulatory presumption that non-water dependent projects may be located outside of special aquatic sites.

NOAA Fisheries (National Marine Fisheries Service) – Magnuson-Stevens Act/Endangered Species Act

NOAA Fisheries is the lead agency under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (M-SA). The USACE and other federal action agencies are charged with consulting with NOAA Fisheries on the effects of authorized actions on Essential Fish Habitat (EFH) regarding measures that can be taken to avoid or minimize adverse effects. All tidal waters within Humboldt Bay are designated as EFH. Eelgrass is also considered a Habitat Area of Particular Concern (HAPC) for various federally-managed fish species within the Pacific Coast Groundfish Fishery Management Plan (FMP) (PFMC 2008). An HAPC is a subset of EFH that is rare, particularly susceptible to human-induced degradation, especially ecologically important, and/or located in an environmentally stressed area. HAPC designations are used to provide additional focus for conservation efforts.

Under the auspices of the M-SA, NOAA Fisheries adopted the CEMP and implementing guidelines with partner agency and public input to serve as a "clear and transparent process for developing eelgrass mitigation recommendations" made by the agency. The CEMP establishes the framework for NOAA Fisheries recommendations regarding eelgrass management issues under authorities of the MSA, the FWCA, and NEPA as a responsible agency. NOAA Fisheries promulgated the CEMP with the goal of providing a guidance resulting in the achievement of 'no net loss' of eelgrass habitat function.

NMFS separately has responsibilities under the federal Endangered Species Act and may consult with a lead federal agency under Section 7 of the Endangered Species Act (ESA). At present there are no direct linkages known between ESA listed species and eelgrass within Humboldt Bay and thus no additional discussion of ESA consultations is provided here other than to note that consultation may be required distinct from eelgrass management issues.

California Coastal Commission – California Coastal Act

The California Coastal Act (1976) first passed by voters as a state ballot initiative in 1972 and later enacted permanently by the state legislature in 1976 was established in response to concerns about development, land-use planning and public access to the coastline. The California Coastal Commission was concurrently established with broad regulatory oversight and permit authority relating to land-use regulations, public access, recreation, marine and terrestrial habitat protection, water quality, energy development and resource extraction, visual resources, agricultural lands, transportation, public works and port activities occurring in the Coastal Zone. The Coastal Commission is the State's lead land-use authority within the Coastal Zone and is responsible for issuing Coastal Development Permits (CDP) for projects implemented in Humboldt Bay. CDPs issued by the Commission are one way of meeting the CZMA Consistency Determination requirements for the USACE permit action.

Regional Water Quality Control Board – Clean Water Act and Porter-Cologne Act

The State Water Resources Control Board (SWRCB) was established by the California State Legislature in 1967 and given dual authority over safeguarding waters of the state from degradation, while also providing oversight of water allocations to support beneficial uses of the state's water resources. Nine Regional Water Quality Control Boards operate under the SWRCB to both develop and enforce water quality objectives and implementation plans aimed at protecting beneficial uses that vary with respect to location across the state. The North Coast Regional Water Control Board is responsible for water quality regulations and issuance of 401 water quality certifications in Humboldt Bay.

Regional Boards are tasked with developing basin plans which establish beneficial uses and water quality objectives on the basis of hydrologic units, overseeing issuance of waste discharge requirements and associated permits, providing enforcement, and monitoring water quality conditions. The Boards have authorities derived under the federal Clean Water Act, Section 401, and the state Porter-Cologne Water Quality Control Act of 1969. The Regional Water Quality

Control Boards are tasked with certifying that a federal permit or license, which may result in a discharge of pollutants into waters of the United States, complies with all applicable water quality standards, limitations, and restrictions of the State. This is addressed by a CWA Section 401 water quality certification.

California Department of Fish and Wildlife

Under CEQA, CDFW is the trustee agency responsible for fish and wildlife resources in the State of California and has jurisdiction over the protection, conservation, and management of these resources, including native plant communities and the habitat required to support sustainable populations. In this role, CDFW offers biological expertise, providing both review and commentary on environmental documents and potential impacts associated with proposed project activities.

The Marine Region of CDFW within the Department is principally responsible for marine resources, including eelgrass issues. However, in certain circumstances where streambeds and bank characteristics are present such as within the lower reaches of Humboldt Bay's tributaries the Marine Region may share this responsibility with the Northern Region (Region 1), due the separate responsibilities for California Fish & Game Code (FGC) Section 1602 Lake and Streambed Alteration Agreements which would be required for projects that alter the bed and banks of any defined lake or stream channel; including estuarine areas capable of supporting eelgrass. The vast majority of projects with the potential to impact eelgrass in Humboldt Bay occur within the Bay proper and therefore would fall fully within the Marine Region purview.

Beyond its role as a trustee agency, CDFW is responsible for issuing Scientific Collecting Permits under FGC Section 1379 that is required as a precursor to harvesting eelgrass in support of mitigation transplanting. Further, pursuant to FGC section 6400, written permission is required from the Department to transplant eelgrass into waters of the State. This is achieved by issuance of a Letter of Authorization by the Department to a party completing eelgrass restoration. The letter typically requires submittal of information on the transplant project, methods to be undertaken to minimize impacts to donor beds, and means proposed to evaluate the extent of impact from the translocation. The authorization may be conditioned by the Department and requires notification to the Department of commencement of transplant work and reporting after completion of transplant work.

The CDFW is charged with managing impacts to state-listed species under the California Endangered Species Act (CESA). As with federally-listed species, no state-listed species are specifically considered to be associated with eelgrass in Humboldt Bay. As such, it is important to recognize that a separate CESA regulatory action may be required for projects in the Bay. This is not addressed in this Plan.

Cultural Resources Consultations under CEQA

As of July 1, 2015 lead agencies under CEQA are required to provide Native American Tribes who have expressed written interest in participating in consultations involving safeguarding of tribal cultural resources, an opportunity to coordinate on CEQA documents in advance of releasing a Mitigated Negative Declaration or Environmental Impact Report for public review. Further, tribal entities shall be given written notice of a proposed project, including a project description and location, as well as notification of the Tribe's 30-day response period for such consultations. Efforts must be made to identify mutually acceptable actions to minimize or mitigate significant impacts to cultural resources. In Humboldt Bay, the Wiyot Tribe has expressed interest in being involved in cultural resources consultations. They have also been an active partnering organization in development of the HBECMP. The Blue Lake Rancheria Tribe and Bear River Band of the Rohnerville Rancheria may also have cultural interests in areas covered by this Plan.

3.2 HUMBOLDT BAY EELGRASS MANAGEMENT

Humboldt Bay Eelgrass Comprehensive Management Plan Goals

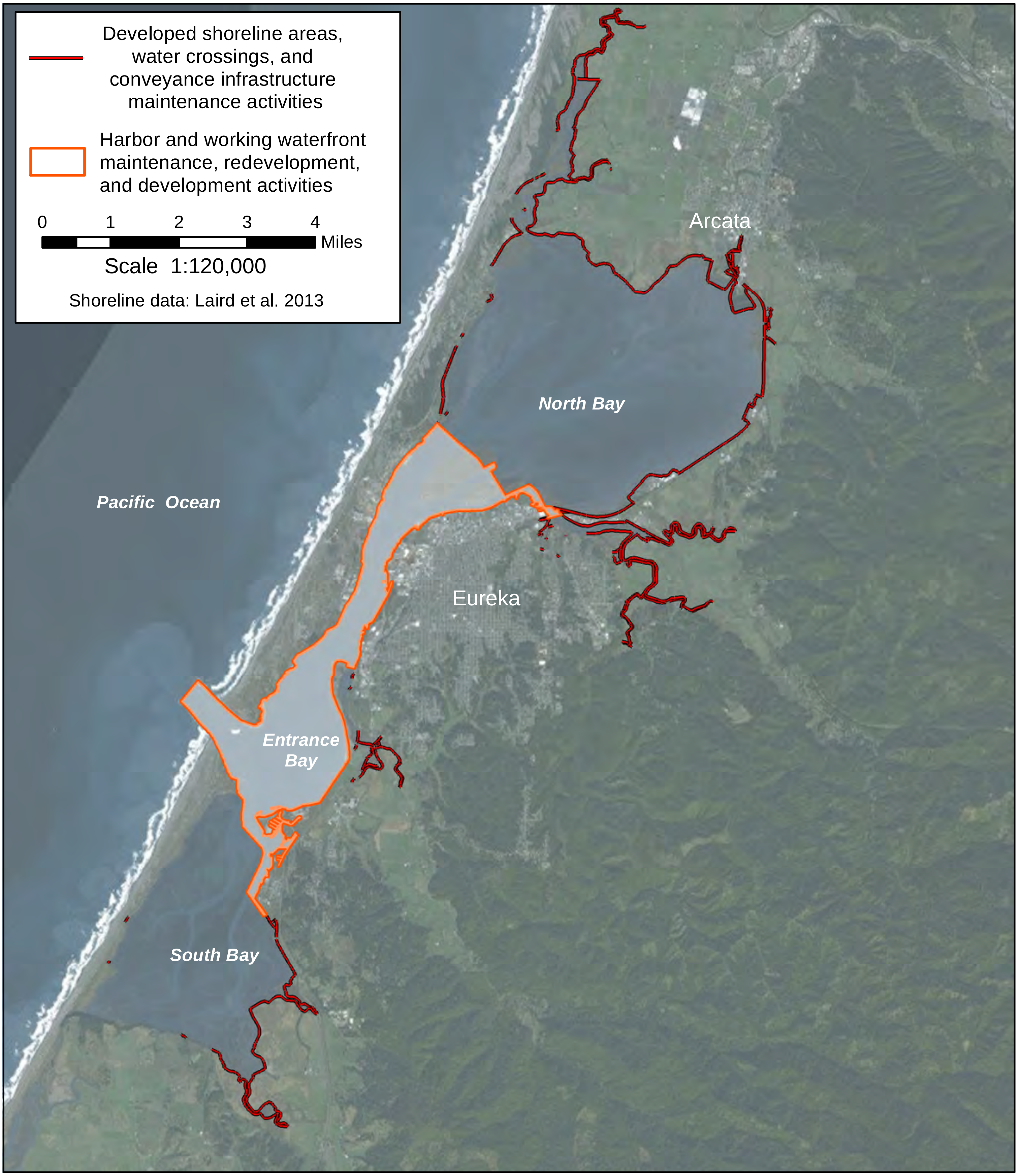
As contemplated, the Humboldt Bay Eelgrass Comprehensive Management Plan is to be adopted by the Harbor District as a means to accomplish the following:

- Disseminate Eelgrass information to project applicants by means of the Humboldt Bay Eelgrass Management Plan Website
- Support inventory, evaluation and prioritization of eelgrass mitigation/restoration opportunities in Humboldt Bay
- Facilitate efficiency and consistency in the application of eelgrass regulatory policy in Humboldt Bay
- Identify and pursue programmatic regulatory/permitting mechanism(s) capable of supporting a suite of similar activities focused on harbor maintenance and shoreline development needs within the developed, core focus area of Humboldt Bay
- Promote system-level long-term monitoring of Humboldt Bay's eelgrass population to understand interannual variability of the resource, overall system health, and the effects of climate change on the Humboldt Bay Ecosystem.

Core Focus Activities within the Plan

The overall scale of Humboldt Bay and the complexities of land and water uses are substantial. As such, an initial suite of regulatory core focus activities has been defined within the HBECMP (Figure 3). These focus activities include maintenance and redevelopment needs anticipated principally within the harbor and along the working waterfront of Humboldt Bay while also capturing expected maintenance requirements associated with developed shoreline (e.g. levees and other fortified shoreline structures), water crossing/conveyance infrastructure (e.g. tide gates, culverts, and bridges), and public access improvements in other areas of the bay. It is the area of the bay where existing development predominates along the shorelines and essential maintenance activities and redevelopment projects are likely to be focused in coming years.

While the core focus activities are fairly broad in scope, the extent of eelgrass potentially impacted as a result of these activities in coming years is a fraction of the total eelgrass in the bay. Through completion of data collection and geospatial analysis in preparation of the HBECMP, it was determined that less than 10 acres of eelgrass habitat were at risk as a result of required maintenance, infrastructure revitalization, and repurposing of waterfront facilities, which represents approximately 0.2% of Humboldt Bay's eelgrass population. However, while the scale of eelgrass impacts expected to occur under the plan would affect at most a small fraction of eelgrass habitat in the Bay, it would still result in major impacts to eelgrass under northern California standards where the largest restoration projects are still less than 1 acre in size, compared to other regions of the state where multiple acre eelgrass restoration projects are fairly common place.



Regulatory Core Focus Activities

Humboldt Bay Eelgrass Comprehensive Management Plan

Figure 3

3.3 HUMBOLDT BAY EELGRASS IMPACT PROJECT EVALUATION FRAMEWORK

An important outcome of the HBECMP will be to provide more specific up-front guidance to project applicants regarding where eelgrass habitat is known to or likely to occur, appropriate methodologies for surveying and impact assessment, and how to address eelgrass habitat as it relates to project design, planning and permitting. This up-front guidance will help project applicants in their preparation of permit applications and improve the efficiency of project planning and design efforts, while reducing HBHRCD and regulatory agency staff time spent on providing and rehashing basic information on a case by case basis. Several guidance elements including an electronic baseline eelgrass distribution map, a pre-project checklist, and eelgrass surveying recommendations will be made available through the HBECMP webpage as a means of engaging the public and disseminating basic information about eelgrass resources in Humboldt Bay. While project applicants are encouraged to make early contact with the HBHRCD, regulatory agencies and specialists to address eelgrass that may be affected by a proposed project or action, the pre-project guidance elements of the HBECMP are intended to communicate a basic understanding of eelgrass-related project requirements in an efficient and consistent manner.

Humboldt Bay Pre-Project Eelgrass Checklist

Humboldt Bay supports California's largest eelgrass population, yet people are often unaware of its distribution and the potential for impacting eelgrass habitat as a result of shoreline or in-water development, construction, and maintenance/repair activities. Eelgrass is protected by state and federal law under a 'no net loss' policy. As such, eelgrass habitat should be avoided to the greatest extent possible. In cases where project-related activities cannot avoid eelgrass habitat entirely, efforts should be made first to design the project in a manner that minimizes impacts to eelgrass, and ultimately provide for mitigation of eelgrass habitat in cases where impacts are unavoidable. Eelgrass habitat may be impacted either directly or indirectly as a result of project activities, and those impacts may be temporary or permanent depending upon the nature of the activity.

A number of measures can be employed to avoid and/or minimize potential project-related impacts to eelgrass and can be applied most effectively during initial project planning. Developing an understanding of eelgrass resources and the potential effects of a proposed project early on can save you time and money! The following checklist provides guidance for determining whether a project has the potential to affect eelgrass habitat and what to do about it.

Step 1 – Determine the Preliminary Area of Potential Effect (APE) for your proposed project:

Typically, the APE would include both the area of direct impact associated with the action for which a project applicant is seeking a permit, plus a surrounding buffer inclusive of the limits of potential construction and/or maintenance-related activities capable of impacting eelgrass habitat. It is important to ensure that the APE is sized and configured appropriately to capture the impact that would be anticipated as a result of the project. Prior to contacting either the Harbor District or the resource agencies (listed below) for further project-specific guidance, proceed to step 2 and complete the questionnaire. Additional resources that may be helpful in answering these questions are provided in (appendix x and the HBECMP webpage baseline eelgrass distribution map).

Step 2 – Complete the Pre-project Questionnaire:

New Projects-

Is the project located within 100 feet of previously mapped (known) eelgrass habitat?
☐ yes / ☐ no
Will any construction or new operational traffic occur within the vicinity of existing eelgrass?
☐ yes / ☐ no
Is any portion of the project located in an area with depths ranging from -10 to +4 feet?
☐ yes / ☐ no
Does the project result in new cover, shading or other form of light reduction of open water areas ranging in depth from -10 to +4 feet?
☐ yes / ☐ no
Is the project anticipated to affect wind or tidal circulation patterns within the bay?
☐ yes / ☐ no
Could the project affect ambient water temperature or clarity?
☐ yes / ☐ no
Does the project result in any placement of fill, including shoreline armor?
☐ yes / ☐ no
Is the project anticipated to lead to an increase in boat traffic that could affect nearby eelgrass habitat through grounding, prop scarring, wake, or shading impacts?
☐ yes / ☐ no

Maintenance/Repair Projects and Construction Activities-

Is project construction likely to increase turbidity? To what extent and for what duration?
☐ yes / ☐ no
Will construction require the use of a barge or other vessel that may temporarily impact the bay floor (e.g. spud poles, anchoring, prop scarring, etc.) within known eelgrass habitat or within depths ranging from -10 to +4 feet?
☐ yes / ☐ no
Will construction require the use of turbidity curtains in proximity to eelgrass habitat?
☐ yes / ☐ no
Will project construction result in temporary shading from moored/anchored working vessel(s)?
☐ yes / ☐ no

If you checked any of the yes boxes in the questionnaire, your project may have the potential to impact eelgrass habitat and you'll need to proceed to step 3. If you answered no to all of the questions, please provide a copy of the completed questionnaire along with a brief project description and map depicting the proposed project location, suitable eelgrass depth range, and historic eelgrass distribution in the vicinity of the proposed project. Maps should be of an appropriate scale to clearly depict the preliminary/proposed APE boundary in relation to both existing and potential eelgrass resources provided in the (appendix/HBECMP webpage).

Step 3-Conduct a Preliminary Eelgrass Survey:

If your project has the potential to impact eelgrass habitat, the next step is to conduct a preliminary/reconnaissance level eelgrass survey to inform further planning and permitting requirements. A planning level survey may be conducted at any time of year (weather permitting) to support preliminary project planning; however, surveys conducted outside of the active growing season (May-September) could under-represent the full extent of eelgrass habitat that may be present in the vicinity of a proposed action. For this reason, preliminary surveys can be extremely useful in identifying if eelgrass habitat is present and therefore, whether further planning and design for minimization, avoidance, or mitigation is warranted; however, absence of eelgrass may not rule out the need to conduct a pre-construction survey if the preliminary survey is conducted outside of the active growing season.

If a preliminary eelgrass survey is conducted during the active growing season, and no eelgrass habitat is identified in the vicinity of a proposed action, then further eelgrass surveys may not be required upon the concurrence of the resource and permitting agencies. This finding could result in a project applicant potentially avoiding the need to develop an eelgrass mitigation and monitoring program for a proposed action unnecessarily, saving both time and money. If however, eelgrass is identified within or in close proximity to a preliminary project APE, then an applicant will likely need to develop an eelgrass mitigation and monitoring program in coordination with the resource agencies as a condition of approval with respect to acquiring state and/or federal permits for the proposed action.

Extensions of the survey window may sometimes be acceptable based on prevailing climatic conditions and phenology of the beds. To complete an out of season survey for regulatory purposes requires prior concurrence of permitting agencies and NMFS and CDFW staff. A concurrence for out-of-season survey would require the submittal of a justification as to the reasonableness of an expectation that that the survey will adequately reflect the full extent of the eelgrass beds and that any depressed density of the beds can be adequately controlled for using reference sites. In general, an out of season survey should be coupled with nearby reference sites where recent high growth period surveys have been completed and thus changes in eelgrass density within the project survey area may be scaled by the ratio of high growth to out-of-season survey densities within the reference area. If the areal extent of eelgrass within the reference site declines by more than 10 percent between high growth survey condition and out-of-season survey conditions, then the out of season survey should be considered invalid unless more site specific information such as baseline surveys of the site, or other inventory information may be used to support a conclusion that pre-impact eelgrass distribution can be reasonably known from the out of season survey. There is no guarantee of approval for an out of season survey and the conclusion will necessarily be based on the merits of the survey plan, the impact to the project associated with a delay of the survey to the next growing season, and the risk of underestimating eelgrass impacts associated with the out of season survey. Further, as indicated above, areal extent declines in the reference site may suggest inadequate bed detection and can invalidate the out of season survey, irrespective of the prior agency concurrence.

Recommended Eelgrass Surveying Methods/Standards

The CEMP employs a no net-loss standard for eelgrass impacts and does not incorporate minimum threshold scales of impacts requiring mitigation, although for very small impacts out-of-kind mitigation may be possible. Because of the low threshold for impacts, it is essential that surveys be capable of accurately detecting and quantifying changes in eelgrass at the scale most appropriate for determining potential impacts. This is an equally important concern from both the regulated community and regulatory agency perspectives. Over time, there have been many examples in which impacts to eelgrass have been under estimated however, there are equally as many examples where impacts have been over-estimated. Some of the worst circumstances have been for very small projects where impacts did not truly occur, but inadequate mapping methodologies or poor execution led to erroneous determinations of impact and triggered mitigation. Similar examples exist on the other side of the spectrum where surveys were inadequate to detect and quantify impacts and thus projects have led to impacts to eelgrass that were not identified or which were later addressed by forensic evaluations that served as a poor substitute to contemporaneous survey. For this reason, the importance of conducting highly accurate surveying/mapping is critical to assessing and communicating eelgrass-project interactions.

Mapping Accuracy Standards

For project impact assessment purposes, mapping methodologies applied should be highly repeatable and should have mapping and classification accuracy capabilities of 95 percent or better. For clarification this means that if one were to examine random points within the survey area, at least 95 percent of random points would be correctly classified as eelgrass or not eelgrass based on comparing the eelgrass areal extent mapping with the independently sampled points. Further, if the same area were independently surveyed twice during the same period of time, the mapped eelgrass should be 95 percent coincidence between two surveys. These guidelines are not intended to suggest that each survey must have exhaustive accuracy analyses, but rather that survey methodologies should be selected for applications based on the expectation that this accuracy standard may be achieved. Further, it is important to note that it is often easier to meet the accuracy standard for larger surveys than smaller surveys because the tools suited for larger surveying tend to provide saturated coverage of the habitat (UAV, interferometric sidescan sonar, etc.) while tools only capable of being applied on smaller survey scales tend to subsample beds or rely on spatial interpretation from low viewing angles and thus perspective distortion increases (single beam sonar, total station surveys, diver transects, etc.)

There are several acceptable methods of surveying eelgrass habitat capable of supporting impact assessment and monitoring at a level of accuracy and repeatability sufficient to satisfy regulatory and permitting requirements. Table 4 presents a summary of standard eelgrass surveying methods deemed most appropriate with respect to accuracy and cost effectiveness, based on the location and scale of a project. For projects that have both a subtidal and intertidal component, employing a combination of these methods generally provides the best accuracy and precision to the survey and mapping.

Table 4. Recommended eelgrass surveying methods broken out by depth range and project scale.

Depth Range	Project Scale	Recommended Survey Method
Intertidal (-1 to +4 ft):	0-1,000 m^2 (0-0.25 ac)	Total station/sub-meter GPS/ low-altitude UAV
	0-3,000 m^2 (0-0.74 ac)	Total station/sub-meter GPS/low-altitude UAV
	3,000 m^2 -100 ha (0.74-250 ac)	Low-altitude UAV
	50 ha+ (125 ac+)	Low-altitude UAV/Manned aircraft
Subtidal (-10 to -1 ft):	0-1,000 m^2 (0-0.25 ac)	Total station/sub-meter GPS w/ diver transects/single-beam or SS sonar
	1,000-2,000 m^2 (0.25-0.5 ac)	Sub-meter GPS/single-beam or SS sonar
	2,000 m^2 + (0.5 ac+)	SS sonar

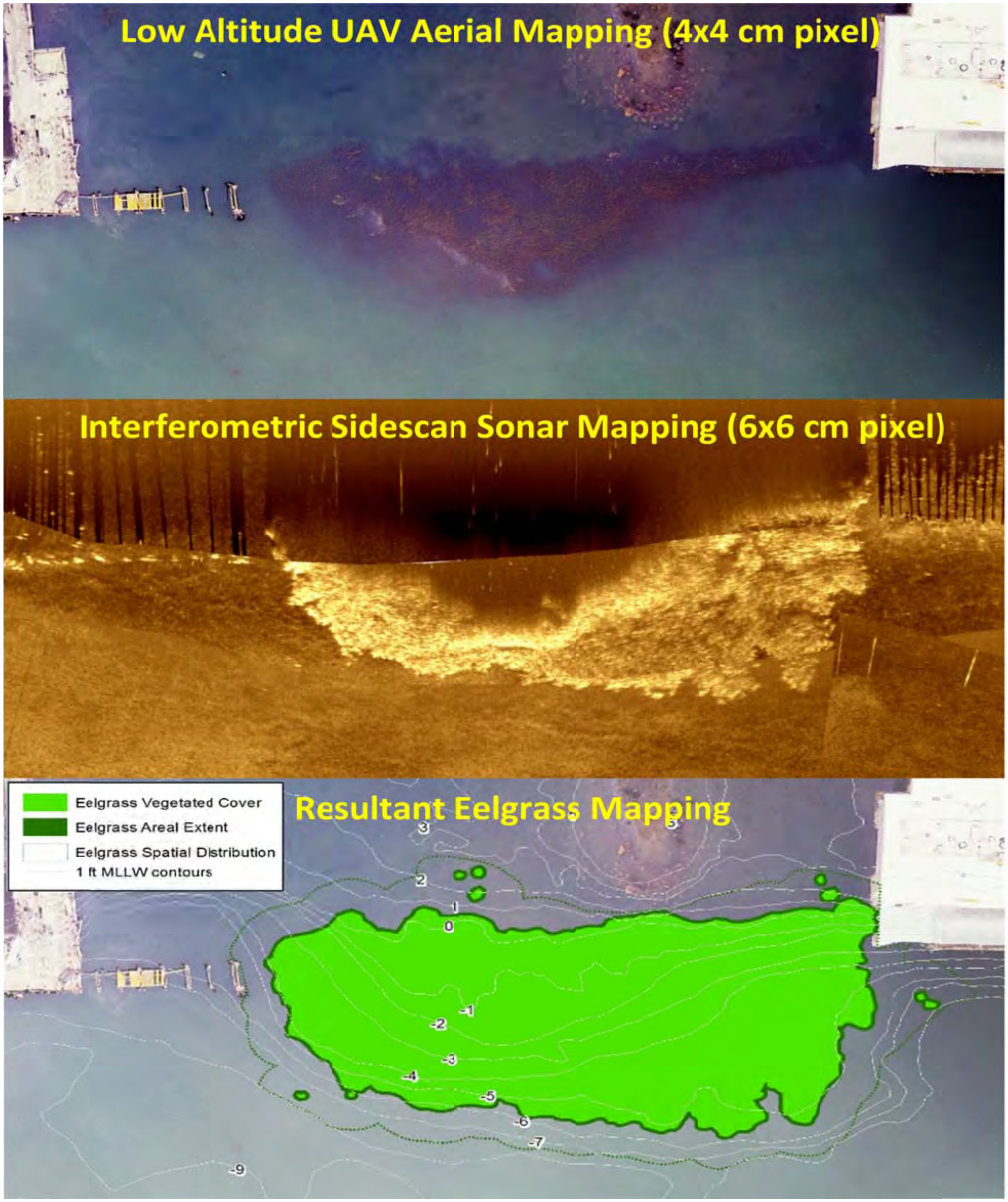
Spatial Metrics for Eelgrass Surveys

Spatial metrics for eelgrass habitat are to include: 1) areal extent, 2) spatial distribution, and 3) percent vegetated cover of eelgrass. In addition characteristics of the bed are sampled within vegetated bed areas to characterize the conditions of the bed plants at the time of survey. Spatial metrics shall be determined from a combination of field measurement of resource extent and spatial analysis of collected data. For the CMP, the following mapping methods and definitions shall be used:

- **Vegetated Cover –** Vegetated cover is defined as the limits of plants of any size and growth form inclusive of established vegetative plants, flowering plants, and seedlings present at the time of survey. Mapping tools will be used to define the extent of vegetative cover.

- **Areal Extent –** Areal extent will be defined by creating a 0.5m buffer around all vegetated cover using commercially available geo-spatial analysis software. By applying the buffer any plants within 1 meter of another plant falls within a coalesced bed. The buffering method is used to develop the extent of eelgrass where one or more leaf shoots (turions) per square meter exists.

- **Spatial Distribution** – The spatial distribution of an eelgrass bed is determined by applying a 5-meter buffer to vegetated cover. In this way, the extent of area near eelgrass plants that are considered to be within the influence of the bed is identified. The spatial distribution is an estimator of the area within which vegetated cover can expand within a single year (Donoghue 2011) and it also accounts for the near bed margin that is where most seedling recruitment occurs annually. The influence of eelgrass on the local environment may extend as far out from



Example from Bodega Bay of how multiple survey tools may be used in concert with each other to complete eelgrass surveys in a complex survey environment. UAV provides high resolution coverage in intertidal environments, but falls short of detection of deeper subtidal eelgrass beds and can often lead to an over or under-representation of subtidal beds. Interferometric sidescan sonar provides high resolution mapping of subtidal and shallow intertidal beds as well as achieving concurrent collection of bathymetry. Operated in concert, the tools can provide efficient and highly accurate survey coverage over larger survey areas while producing archivable data sets.

individual patches as 10 meters. The direct influence of the bed on surrounding environments diminishes with distance such that signals are weak at this distance and as such, the CEMP has applied a 5 meter rather than a 10 meter boundary. By using this distance, any plant within 10 meters of a nearby plant would occur within a coalesced spatial distribution. The spatial distribution is intended to characterize habitat that may intermittently support eelgrass by annual variability of the beds and which may support functions as a result of both proximity to beds and spatial dynamics of the beds. For this reason, the spatial distribution excludes areas that are unsuited to support eelgrass as a result of physical factors limiting eelgrass occurrence such as unsuitable depths, unsuitable substrate, steep slopes, over-water structures, etc. As a result, the determination of the spatial distribution is a two-step process, first requiring the determination of the 5 meter buffer from plants, and second, clipping out any areas unsuited to support eelgrass.

- **Percent Vegetated Cover –** Vegetated cover is determined by dividing the vegetated cover of the bed by the areal extent. This provides a good indication as to how fragmented the plants are across the landscape. For large continuous beds, the percent vegetated cover within a survey area will approach 100 percent, while beds defined by a number of scattered patches of small scale will approach a 0 percent cover. As a practical matter, this metric provides insights into the overall stability of the bed and how variable a bed is likely to be through time. Further, it provides information suited to selection of reference beds that are likely to exhibit similar temporal patterns as beds within potential impact areas.

<u>Plant Metrics for Eelgrass Surveys</u>

The CEMP relies on one plant metric in association with bed metrics for assessment of project impact or lack of impact. That metric is turion (shoot) density. The HBECMP adopts this same metric. However, in addition to shoot density, there is considerable additional information that is easily collected during field surveys and should be integrated into surveys as they can provide insight into the vitality of surveyed beds and potential variables that may affect the dynamics of the beds and response of the beds to perturbation. The plant metrics that should be captured in field surveys include the following:

- **Turion (Shoot) Density -** Turion density is the mean number of eelgrass leaf shoots per square meter within mapped eelgrass vegetated cover. Turion density should be reported as a mean ± one standard deviation of replicate measurements. The number of replicate measurements (n) should be reported along with the mean and deviation. Typically 20 replicates taken within an area of potential effect (APE) and 20 densities within reference site[s] provide a good sample size. Turion densities are determined only within vegetated areas of eelgrass habitat and therefore, it is not possible to measure a turion density equal to zero. Densities should be sampled throughout the vertical and horizontal extent of the sampled beds such that sampling does not bias a particular portion of the bed. Because eelgrass density is particularly sensitive to energy and light levels that are highly dependent upon elevation it is very important that vertical sample distribution be adequate to characterize the full elevation profiles of the sampled beds. Density is sampled by counting the number of vegetative leaf shoot bundles present at the meristem near the sediment surface within a $1/16m^2$ or $1/4m^2$ quadrat and presenting data standardized to turions per square meter.

- **Leaf Length –** Leaf length should be determined as a range that represents the general conditions throughout the bed. If an estimate of the average leaf length can be made (e.g., the bed is generally of uniform height, this should be done as well. Typically deeper eelgrass is longer and of lower density than shallow eelgrass which is generally shorter, narrower in width, and denser.

- **Leaf Color –** Assess the color of eelgrass. Examine plants for richness of green, chlorotic tissues, or any atypical discoloration. Chlorosis can occur when plants suffer from low light (most common), or a number of nutrient or sediment ailments.

- **Leaf Turgor –** Evaluate the stiffness of leaf tissue derived from turgor pressure. Healthy leaves with high turgor pressure often break or fold along a clean crease when bent. Leaves with considerable cell lysis can occur due to rupturing by disease or osmotic mechanisms leading to wilty soft leaves that shed easily. Breakdown of leaves is also often accompanied by flooded lacunae (air vacuoles running along the leaves that keep leaves floating vertically).

- **Leaf Epiphytic Loading –** Estimate the percentage of epiphytes on the plants by estimating the amount of green tissue observed without ephiphyte removal. Epiphytic loading should also be characterized as to the nature of the loading (e.g. red algae, green algae, bryozoa, etc.).

- **Leaf Sediment Loading** – Estimate the percent of sediment loading as a percent cover of leaves by sediment. This is done by examining leaves prior to disturbance, and then shaking the leaves in water vigorously and determining the extent of change in the amount of green tissue, or epiphytic cover between the sediment loaded leaves and those that have been rinsed of sediment. Sediment and epiphytic loading are evaluated separately so it is possible to have 100 percent sediment loading and 100 percent epiphytic loading.

- **Rhizome Mat Condition** – Note any disturbance of the rhizome mat where rhizomes are unearthed, freed from the sediment such that rootlets are in the water column, etc.

- **Phenology of Plants** – Estimate the percentage of flowering in the surveyed beds and note the presence and qualitative abundance of seedlings in the survey area.

- **Disease** – Note any indication of disease in beds. This is most commonly identified by the presence of black or brown lesions on leaves. Wasting disease is caused by a naturally occurring organism and nearly all beds have some minor level of disease that is typically associated with naturally declining tissues or physical damage where necrosis has commenced such as resulting from snail grazing or other minor damage. As a result, the extent of disease should be noted, not just presence of disease indications. Disease indicators should be identified using the following estimators and photos should be included if heavy disease is noted:

  - *Absent* – A careful examination of a bed for approximately 1 minute fails to identify definitive indications of disease, although some minor blemishes may be observed they typically appear to be associated with declining tissues or the observer questions whether the features are disease.
  - Minor – An examination of a bed over one minute reveals several indications of potential disease, but they are scattered and somewhat difficult to find. Typically only 1 in 10 leaves may show minor blemishes or lesions and declining tissues show higher occurrence of disease.
  - Moderate – Disease is immediately obvious in plants upon approach and requires no effort to detect diseased conditions. Up to 50 percent of the leaves have disease signs and many leave have multiple blemishes.
  - Heavy – Disease is easy to see in plants even from a distance of many meters. Most leaves have multiple blemishes and shed leaves with considerable blemishes are often floating freely on the water surface.

- **Accumulated Algal or other Wrack** – Not the extent of macroalgal or other wrack that has accumulated within the beds that may limit the density of beds, or smother beds. Estimate the extent of the study area bed effected by the wrack and characterize the composition of the wrack. Most commonly large wrack deposits that accumulate in eelgrass beds are dominated by one or more genera of ephemeral green algae (e.g., *Ulva*, *Enteromorpha*, *Chaetomorpha*).

- **Other Observed Conditions** – Note any other features within the bed that may be important to controlling conditions within the bed through time. Some of the factors that have been observed include high bat ray foraging pit occurrence, dense ghost shrimp burrows, high density of sand dollars, high grazing indications, propeller scaring , mariculture activities, red tides, etc.

The observations made as to the conditions of beds are intended to facilitate better understanding and communications of the site conditions. These are not assessment metrics and thus there is no formal quantification structure. In general information may be presented as a narrative discussion of the conditions and observations rather than a more rigid presentation.

Bathymetry within Eelgrass Survey Areas

Detailed bathymetry with contour interval of not more than 1-foot (0.30 m) intervals based on local vertical datum of MLLW are to be included within the survey area and most specifically the project APE and reference sites as identified below. The bathymetry need not be specifically developed for the project and need not be collected by licensed surveyor or hydrographer as information is for resource management and not for civil construction purposes. For very small projects, it is adequate to develop bathymetry by lead-line soundings and contour extrapolation using measured tides within the bay as derived from the most applicable of the active harmonic tide stations in the bay (hb021, hb0301, or hb0401) accessible at https://tidesandcurrents.noaa.gov/cdata/. For larger projects, more detailed bathymetry should be provided. Bathymetry is necessary to evaluate the suitability of reference sites and the limiting factors affecting the spatial distribution of beds. In most instances, bathymetry supporting an in water project planning and development exercise is adequate to support the needs for eelgrass surveys.

Defining the Area of Potential Effect (APE)

For small infrastructure replacements, the first questions to be asked are:

- What is the scale of the work?
- How is the work to be performed? (Land-side, water-side, scows, tugs, spudding, turbidity curtains, water access routes, duration of work).
- What do the surrounding condition look like? (Bathymetry, eelgrass distribution patterns, infrastructure constraints, access corridor constraints and staging area limits).
- What are the ways in which things can go wrong? (inaccurately inventory and sample eelgrass-both intertidal and subtidal, inaccurately identify bathymetric conditions, incorrectly manage impact predictions and assessment from shading and post-construction operations, inadequate contractor education or bed marking during construction leading to unforeseen damage from propeller wash, vessel grounding, turbidity curtain drag, and other sources).
- What reasonable measures are appropriate to avoid or minimize impacts? (These vary but generally include marking proximate beds prior to initiation of construction, completing brief contractor training even if by providing site eelgrass and bathymetric map and simple avoidance recommendations. Applicants should consider putting some of the avoidable eelgrass impact risk on the contractor through contract requirements, carefully plan protective measures and build these into contract documents considering that more protection measures are not necessarily better protection measures.

What is the right boundary for an area of potential effect and where should a reference site be located? (The boundary is defined by the answers above. Generally, this is done by the applicant and evaluated by the agencies with the thoughts above in mind. There are equally erroneous problems with making the APE too big or too small as discussed below).

For planning level surveys, it is recommended that an applicant survey a broader area than what would ultimately be required for the pre- and post-construction surveys. The greatest cost of survey is not in the field time, but rather the planning, mobilization, data processing, and reporting. These are generally not scalable. For this reason, a broad planning level survey is recommended to understand eelgrass distribution in the project area relative to depth distribution, existing infrastructure, travel and access routes, etc. This also facilitates evaluation of potential reference site establishment and provides baseline conditions for both the potential designated APE and reference sites. The APE and reference site(s) are generally designated after, and not before the Planning Level survey, as the distribution of the resources in the areas are relatively important to defining the resources at risk. Further, the reference site designation should best match the defined APE.

After the APE and reference sites are determined, future surveys may be scaled to these two bounded locations. The ideal reference site is located near but not immediately adjacent to the APE. The presumption is that all eelgrass in the APE may be subject to injury. As a result, an error in this bounding that bleeds to an adjoining reference site would be diluted in potential for detecting injury. Conversely, an APE that is too large and captures a large amount of eelgrass outside of the true impact potential area would be subject to greater risk of being driven by noise unrelated to the project action. This may result in an applicant being held to impacts that they didn’t cause, or an applicant having impacts that are not detected and therefore not attributed to the project.

The scale of the APE is always project specific and dependent upon a number of inter-related factors as described above. Project applicants are encouraged to consult with resource agencies and specialists to make an appropriate determination of the spatial extent of the APE and associated reference area(s) for the proposed project or action. The analysis and findings resulting from a planning level survey are critically important in determining the path forward for a particular project. The results of the planning survey will generally fall into three categories:

- Eelgrass is present within the APE and needs to be addressed
- Eelgrass is absent but the site is suitable and a pre-construction survey is needed to determine the potential for impact
- Eelgrass is not present and the location is not likely suitable. No further work is required.

The preliminary/planning level survey provides key information regarding the need for further eelgrass mitigation/monitoring program development and is strongly recommended. If properly executed, the preliminary survey provides sufficient information early in the life of a potential project to determine whether further surveying is required and whether or not a mitigation and monitoring program is needed. If a mitigation and monitoring program is ultimately needed, the preliminary planning survey provides the information necessary for developing the program and further establishes criteria for consensus among the resource agencies regarding permit requirements and conditions.

Establishing Reference Site[s]

A reference site or multiple reference sites should be established in order to serve as an unaffected area of eelgrass that exhibits natural bed dynamics that are unaffected by a particular project being assessed. The reference site[s] are selected to be as similar in nature to the APE as possible, yet removed from any potential influence of project activities that may influence the APE. In some instances, the APE is located along an environmental gradient such that areas down gradient or up gradient may exhibit differing conditions than the APE. In such instances, it is generally desirable to establish up and down gradient reference sites and use the performance of both reference sites in evaluation of expected natural performance of the APE. Typically the two reference sites are presented independently since it is not possible to know for certain whether the sites along the gradient would perform closer to one or the other of the reference sites or the mean of the two. As such, comparison of the APE is done with each reference site independently or to the envelope of conditions represented by the reference sites.

The greater the similarity in conditions between the reference site and APE at the time of reference site establishment, the more robust the comparisons between performance of APE and reference site eelgrass beds can be. Where long-term or regional data are available to use in evaluating long-term dynamics, these data should be reviewed for potential information value to guide site selection. To the extent practical, reference site[s] selected should have the following general characteristics when compared to the APE:

- Reference sites should be of a similar spatial scale as the APE;
- To the extent practical, reference sites should have similar bed metrics as the APE in terms of areal extent, spatial distribution, percent vegetated cover, and turion density;
- The bathymetric distribution of eelgrass beds and available area within the reference site should be similar to that of the APE;
- Non-project related stressor conditions should be as similar as possible within the reference site[s] as within the APE. It is not desirable to find unimpaired reference conditions if the APE is an impaired site, however, it should not be influence by the project being evaluated;
- The reference site[s] should be established in areas that are not anticipated to be disturbed by another activity in the future that may negate the value of the site as a reference.

Mapping Standards and Deliverables

As derived from the CEMP, for all actions that may directly or indirectly affect eelgrass habitat, an eelgrass habitat distribution map should be prepared on an accurate bathymetric chart with contour intervals of not greater than 1 foot (local vertical datum of MLLW). The mapping should utilize the following format and protocols:

Bounding Coordinates

- **Horizontal datum** - Universal Transverse Mercator (UTM), NAD 83 meters, Zone 10 is the preferred projection and datum. Another projection or datum may be used; however, the map and spatial data should include metadata that accurately defines the projection and datum used. (UTM is preferred over CA State Plane coordinates as data can be readily viewed in Google Earth Pro without additional conversion and thus is more efficiently explored by resource agency staff when delivered).

- **Vertical datum** - Mean Lower Low Water (MLLW), depth in feet.

Units

Transects, grids, or scale bars should be expressed in meters. Area measurements should be in square meters.

Deliverable Spatial Data File Format

A spatial data layer compatible with readily available commercial geographic information system software producing file formats compatible with ESRI® ArcGIS software should be delivered to the HBHRCD, NMFS, and CDFW. In addition to a spatial data layer, a hard-copy map should be included with survey reports. The projection and datum should be clearly defined in the metadata and/or an associated text file.

Eelgrass maps should, at a minimum, include the following:

- A graphic scale bar, north arrow, legend, horizontal datum and vertical datum;
- A boundary illustrating the limits of the area surveyed;
- Bathymetric contours for the survey area, including both the action area(s) and reference site(s) in increments of not more than 1 foot;
- An overlay of proposed action improvements and construction limits, and;

- The boundaries of eelgrass vegetated cover, aerial extent, and spatial distribution including any areas identified as being excluded based on physical unsuitability to support eelgrass habitat.

Additional Resources

For more information on how to address eelgrass in project planning and design, consult the CEMP (http://www.westcoast.fisheries.noaa.gov/publications/habitat/california_eelgrass_mitigation/Final%20CEMP%20October%202014/cemp_oct_2014_final.pdf).

Local Agency Contacts

Humboldt Bay Harbor, Recreation and Conservation District
601 Startare Drive
Eureka, CA 95501
(707) 443-0801

U.S. Army Corps of Engineers
601 Startare Drive #100
Eureka, CA 95501
(707) 443-0855

California Department of Fish and Wildlife
619 2nd Street
Eureka, CA 95501
(707) 445-6493

NOAA Fisheries
1655 Heindon Road
Arcata, CA 95521
(707) 825-4840

North Coast Regional Water Quality Control Board
550 Skylane Boulevard, Suite A
Santa Rosa, CA 95403
(707) 576-2220

California Coastal Commission
1385 8th Street
Arcata, CA 95521
(707) 826-8950

3.4 EELGRASS MITIGATION/RESTORATION OPPORTUNITIES IN HUMBOLDT BAY

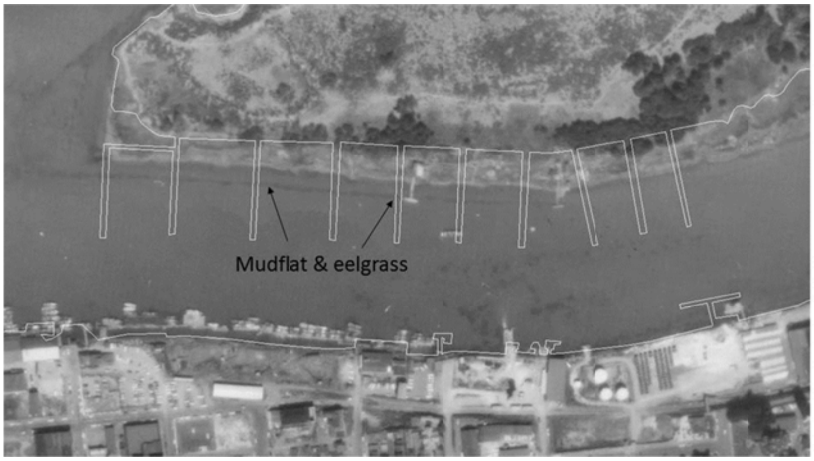
History of Eelgrass Mitigation in Humboldt Bay

Projects for which compensatory mitigation has been required for eelgrass resources in Humboldt Bay date to as early as 1979 in association with the Woodley Island Marina Construction Project. At this time, eelgrass was not differentiated from the mudflats that were also impacted and impacts were mitigated through out-of-kind (eelgrass compensated for by non-eelgrass habitat enhancements) mitigation. From this early period forward to relatively recently, eelgrass impacts have been mitigated through a combination of out-of-kind and in-kind (eelgrass for eelgrass) mitigation actions. Over time, the number of out-of-kind mitigation projects has diminished with a concurrent increase in the proportion of in-kind mitigation projects being undertaken. Figure 4 presents the locations of previously completed eelgrass mitigation projects within Humboldt Bay.

Eelgrass Mitigation Projects not Involving Eelgrass Restoration

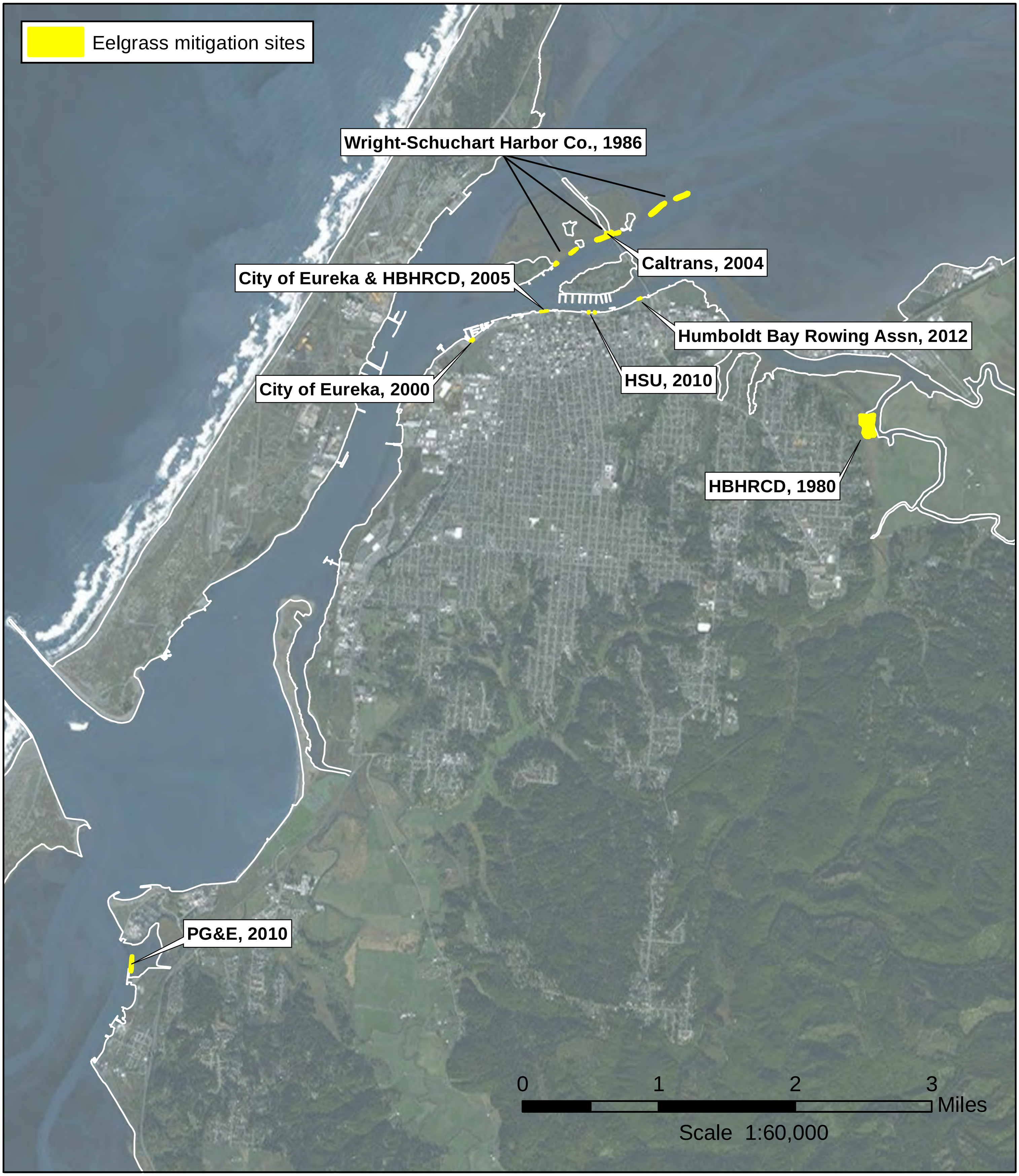
- **Woodley Island Marina Construction Project (1979-1981)**

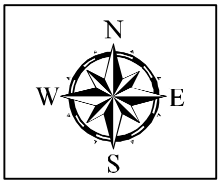
Between 1979 and 1981, the HBHRCD constructed Woodley Island Marina to serve the commercial and recreational mooring needs of the harbor. Construction of the marina impacted approximately 3 acres of salt marsh, 5.9 acres of mudflat with some eelgrass, and 7.9 acres of riparian and upland habitat, resulting in the need for compensatory wetland mitigation. To fulfill mitigation requirements associated with construction of the marina, the HBHRCD purchased a 22 acre parcel located at the end of Park Street in Eureka that encompassed a 13.7 acre log pond which was historically tidal salt marsh. Restoration of the site was then initiated in December 1980 and included breaching of the perimeter levee to restore tidal action to the lower 9.4 acres of the log pond and construction of a setback levee in the upper portion of the log pond to enhance existing freshwater wetlands at the site (Jacobsen 1986). In approving the CDP for the project, the California Coastal Commission stipulated that the Park Street mitigation site be left undeveloped and retained in perpetuity for fish and wildlife purposes as a condition of the permit.



Aerial image of Woodley Island and the Eureka Waterfront prior to marina Construction in 1970. The white lines indicate the present day shoreline and marina location. Image credit: Laird et al. 2007

Although eelgrass is not mentioned in the permit language with respect to mitigation, eelgrass habitat was a subcomponent of the mudflat habitat identified as having been impacted by the project. A review of historic aerial imagery captured in 1970 (Laird et al. 2007) depicts the intertidal mudflats and associated narrow ribbon of channel fringing eelgrass that existed prior to marina construction. Given that this project was initiated shortly





Humboldt Bay Eelgrass Mitigation History

Humboldt Bay Eelgrass Comprehensive Management Plan

Figure 4

after adoption of the California Coastal Act (1976) but prior to the earliest known record of eelgrass mitigation being made an explicit permit requirement in Humboldt Bay (1986; NMFS 2014), eelgrass was not yet a subject of specific mitigation targets at this time. It was only later that the higher habitat value of eelgrass was recognized and embodied first in project-specific permit language and later in the adoption of the Southern California Eelgrass Mitigation Policy in 1991 (NMFS 1991). This project's mitigation element has been included in this Plan because the Woodley Island Marina is subject to periodic maintenance dredging which may have the potential to impact eelgrass habitat. Since the project's initial impacts to multiple wetland habitats were quantified and successfully mitigated for under the regulatory framework existing at the time, no further mitigation of wetland habitats including eelgrass has been required within the marina for subsequent maintenance within the initial established project footprint. Similar treatment is anticipated in future episodic maintenance activities where eelgrass mitigation is not required. However, maintenance dredging may result in a risk of impact to listed species (e.g. longfin smelt) that may require mitigation.

- **Other Out-of-Kind Eelgrass Mitigation Projects**

Other projects have required mitigation for eelgrass through means that did not require restoration of eelgrass habitat, however, in most instances; these projects have been small and poorly documented projects where marine debris and deteriorating infrastructure has been removed as compensation for eelgrass injury. Creosote pile removals have been a common means of addressing eelgrass losses on very small scales and have been used as compensatory mitigation up until very recently. Such mitigation has typically been treated as discrete actions such that impacts are based on pre-project estimates of eelgrass area, and mitigation is a determined number of piles or square footage of debris removal to be undertaken. As such, these projects have not resulted in well documented follow-up on mitigation completion or effectiveness at offsetting functional impacts. Small out-of-kind mitigation projects have been omitted from Figure 4. With federal and state regulatory policy migrating towards more explicit performance metrics and no-net-loss standards based on ecosystem functions, the natural transition has been towards greater documentation of mitigation actions and a greater reliance on in-kind mitigation where metrics of functional replacement are easier to establish.

Eelgrass Transplant Mitigation Projects in Humboldt Bay

Ten eelgrass restoration projects described below represents what is known about eelgrass restoration projects in Humboldt Bay (Table 5). While this is only a small fraction of the 131 eelgrass restoration projects that have been completed statewide from 1976-2017, they provide tremendous insights into successes and failures in eelgrass restoration in Humboldt Bay. Past attempts at restoring eelgrass have either involved active transplanting of eelgrass within Humboldt Bay or projects that have attempted eelgrass restoration through passive restoration (e.g. removal of abandoned wharves and pilings to enhance/restore potential habitat).

Of the projects currently underway in Humboldt Bay that are employing debris removal as a means of achieving eelgrass mitigation, some may ultimately result in an expansion of eelgrass although the primary mitigation benefit is seen as the debris removal itself. These projects have not been included in this list as a result of the fact that project implementation and/or post-implementation monitoring have not yet been completed or projects were not monitored and thus too much information is lacking for a valid review.

Table 5. History of Eelgrass Mitigation Transplants in Humboldt Bay

Project Proponent	Location	Year	Size (acres)	Unit Type	Success Status	Net Result
unknown	Indian Island	1982	Unk.	bareroot	no	-
unknown	Indian Island	1986	<0.25	bareroot	no	-
Wright Schuchart Harbor Co.	Indian Island	1986	0.5	unknown	no	-
City of Eureka	Eureka/Del Norte Street Pier	1991	<0.25	none	no	
City of Eureka	Eureka Small Boat Basin	2000	<0.25	plugs	yes	
Caltrans	SR255 Bridge	2004	<0.25	bareroot	no	-
HB HRCD	Inner Channel Maintenance	2005	<0.25	bareroot	partial	+
PG&E	HBP Pipeline removal	2010	<1.0	plugs	partial	-
HSU Aquatic Center.	Eureka Waterfront	2010	<0.1	none	yes	+
HB Rowing Assoc.	HB Rowing Association Dock	2012	<0.1	bareroot	yes	+

- **1982 and 1986 Unknown Proponent Projects on Indian Island**

In reviewing available planning and monitoring documents, reference is made to prior attempts to transplant eelgrass along the eastern shoreline of Indian Island in 1982 and 1986; however, no additional information was discovered that describes the locations, details, or ultimate fate of these efforts.

- **Wright-Schuchart Harbor Co. Industrial Yard & Dredging (1986)**

In 1986, construction of the Wright-Schuchart Harbor Co. Industrial yard located on the industrial waterfront of the City of Eureka at Marina Way (near the current location of the Wharfinger Building) included a dredging component that resulted in the disturbance of 0.43 acre of eelgrass, triggering a need for mitigation. An eelgrass mitigation and monitoring program was conducted and consisted of salvaging eelgrass donor material from the dredging site and conducting bare-root transplanting at several locations within the intertidal mudflats along the eastern shoreline of Indian Island both north and south of the Samoa Bridge. Bare-root transplanting incorporating twist ties and metal landscape staples to anchor planting units was conducted over a combined area of 0.92 acre during June 1986. Monthly monitoring conducted during the winter and spring of 1987 indicated a complete failure of the mitigation effort as of July 1987. Likely causal factors implicated in the failure of the mitigation effort include planting in areas where the slope was too steep, elevations were too high, and energy was too extreme to support eelgrass based on observations of substrate erosion resulting from wind-waves and/or boat wake, desiccation, and partial smothering by ephemeral green algae (*Enteromorpha* spp.). It is also likely that the selected anchoring materials would have led to the abrasion or severing of shoot and rhizome tissues under conditions of higher current velocity or wind-wave exposure that would have likely exacerbated the decline of the transplants during the winter of 1986-1987.

- **City of Eureka Small Boat Basin Rehabilitation Project (2000)**

In 1999, the City of Eureka conducted rehabilitation work involving excavation and placement of rock slope protection along the shoreline adjacent to the City's small boat basin. Placement of rock permanently impacted approximately 21,500 ft^2 (0.49 ac.) of unvegetated intertidal mudflat and 1,750 ft^2 (0.04 ac.) of eelgrass habitat present within the boat basin. To mitigate for impacts to eelgrass habitat, a transplant receiver site was specifically engineered in the southwest corner of the boat basin at an elevation of approximately -1 ft MLLW by constructing a rock retaining wall and backfilling the site with clean bay mud excavated from the marina. Upon completion of construction, the mitigation site ranged in elevation between -2 and +1 ft MLLW. The site was subsequently planted in June, 2000 using eelgrass plugs (clumps of eelgrass plants with intact roots and associated mud) dug from an adjacent drainage channel and planted over an area of approximately 7,150 ft^2 (0.16 ac.) at the mitigation receiver site, representing a 4:1 transplant ratio. The site was subsequently monitored and achieved final success criteria for both eelgrass areal coverage and turion density. This project represents the first known attempt to intentionally construct a transplant receiver site in Humboldt Bay designed with an understanding of the optimal depth range and substrate characteristics necessary to support eelgrass growth in Humboldt Bay. It is also considered the first known eelgrass restoration success in Humboldt Bay.

- **Humboldt Bay Bridges Seismic Retrofit Project (2004)**

The project entailed conducting a seismic retrofit of the existing Humboldt Bay (Samoa) Bridge, which was originally built in 1971. The seismic retrofit, completed in 2004, involved strengthening bridge columns and footings, which resulted in both temporary and permanent impacts to eelgrass habitat associated with dredging (excavation) and placement of fill. The project's Coastal Development Permit required creation of 107 m^2 (1,152 ft^2) of potential eelgrass habitat and mitigation of impacts to 38 m^2 of existing eelgrass at a 1.2:1 ratio consistent with the guidance provided by the Southern California Eelgrass Mitigation Policy (SCEMP; NOAA 1991) resulting in an initial 45.6 m^2 (491 ft^2) of required eelgrass mitigation.

Caltrans performed hydrodynamic modeling and data collection to support an eelgrass transplant site suitability selection for the Humboldt Bay Bridge seismic retrofit project in 2003. They identified and then subsequently modified the same site that Wright-Shuchart planted in 1986, that had previously failed. Compensatory eelgrass mitigation was initiated by Caltrans and project partners immediately following construction, through the removal of rock and rubble and excavation of a bench along the intertidal mudflats of Indian Island. The mitigation site ranged in elevation from -1 to +2 feet Mean Lower Low Water (MLLW) and mimicked the natural contours of the adjacent mudflats. Eelgrass clusters were subsequently harvested from locations that were impacted by pier enlargement and transplanted into the mitigation site in the summer of 2004. Despite efforts to conduct hydraulic/hydrodynamic modeling to inform mitigation site design, the mitigation site was monitored for two years before it was ultimately determined to have failed, primarily as a result of aggradation of sediment that created unfavorable elevations for eelgrass to persist at the site. Subsequent coordination between Caltrans, NMFS, and CDFW have documented a continuing accrual of mitigation delay multiplier to achieve the requisite mitigation such that by October 2015 the project's adjusted eelgrass impact for which in-kind mitigation is required had increased by 531% to 242 m^2 (2,605 ft^2).

- **Humboldt Bay Maintenance Dredging Project (2005)**

The HBHRCD in partnership with the City of Eureka conducted maintenance dredging along the Eureka waterfront in 2006 and 2007, to restore sufficient water depths to support vessel berthing. Dredging resulted in permanent impacts to approximately 81 m^2 (872 ft^2) of eelgrass habitat located along the mudflats adjacent to the Fisherman's Work Terminal and F Street docks. In 2005, eelgrass was salvaged from the dredging sites prior to dredging and transplanted into areas of unvegetated mudflat along the waterfront between D and E streets, within a mosaic of patchy eelgrass habitat near the upper margins of eelgrass distribution. Transplanting was conducted using a bundled bare-root method employing twist ties and metal landscape staples to anchor eelgrass planting units. After completing five years of post-implementation monitoring, the project achieved final success criteria for eelgrass vegetated cover but fell short of meeting success criteria for density during years 3-5 of the monitoring program. Following completion of the monitoring program and consultation with CDFW biologist Vicki Frey regarding the shortfall in eelgrass density, recommendations were made to continue monitoring the mitigation site. Additional annual monitoring of the mitigation site was conducted from 2010-2012; however, the site ultimately failed to achieve success criteria for eelgrass density and no further actions were taken.

- **PG&E Humboldt Bay Pipeline Project (2010)**

In 2009, Pacific Gas and Electric Company (PG&E) decommissioned an inactive, underground fuel oil pipeline which ran between the Humboldt Bay Power Plant in King Salmon and Olson's Wharf in Field's Landing, passing through bluff scrub, salt marsh, unvegetated mudflat, and eelgrass habitat within the pipeline alignment. Excavation and removal of the 390 m (4,200 ft) long pipeline was reported to have resulted in a disturbance area which impacted approximately 0.58 acres of salt marsh and bluff scrub, 0.04 acres of unvegetated mudflat, and 1.14 acres of eelgrass habitat. Salt marsh and bluff scrub habitat were replanted in December 2009 and January 2010, and eelgrass transplanting was conducted between March-May 2010, within 0.79 acre (70%) of the impacted eelgrass area utilizing eelgrass plugs harvested from nearby donor beds. Throughout most of the disturbance area, the shallow depth of the pipeline resulted in a relatively narrow, linear disturbance of the intertidal mudflats and associated eelgrass habitat, which were subsequently restored to elevations similar to what occurred in the area prior to pipeline removal in advance of the transplanting. However, a portion of the disturbed area near Olson's Wharf (0.33 acre) where the pipeline was located at greater depth, was not restored to the pre-construction grade nor replanted with eelgrass following pipeline removal because it was believed that the area was too deep to plant (despite observations in Year 1 that indicated sediment aggradation and eelgrass colonization were occurring in this area). It is not clear where the remaining 0.02 acre of impacted eelgrass was located that was not replanted.

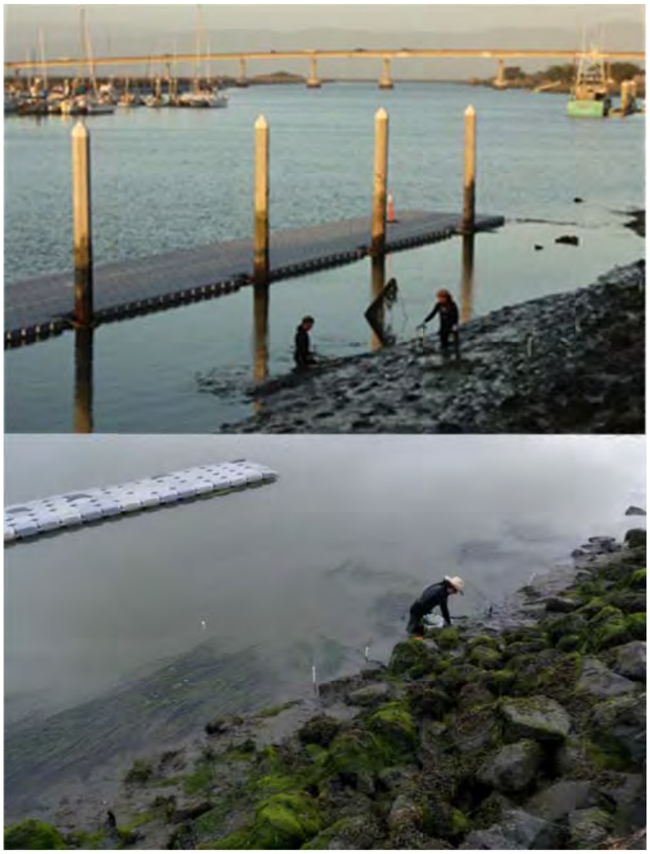
Following completion of the 5-year post-implementation monitoring program, the project was considered partially successful based on achieving mitigation success criteria for the 0.79 acres of intertidal eelgrass out of a total of 1.12 acres of eelgrass identified as having been impacted by the project. Of the 0.33 acre subtidal eelgrass disturbance area, 0.09 acres remained unvegetated with eelgrass following completion of 5 years of post-implementation monitoring. As a result, 1.03 acres of the 1.14 acres initially impacted was recovered within the initial impact footprint based on monitoring reports reviewed, resulting in a determination of partial success.

- **HSU Aquatic Center Floating Dock Construction Project (2010)**

In 2010, construction of a new floating dock and gangway at the HSU Aquatic Center on the Eureka waterfront had the potential to impact approximately 8 m^2 (90 ft^2) of existing eelgrass beds and 21 m^2 (229 ft^2) of unvegetated mudflat. Impacts were primarily anticipated from overhead shading. As a significant component of the overall project, a failing wooden wharf, adjacent creosote-treated pilings, and a gangway that were previously located within potential eelgrass habitat at the project site were removed to facilitate passive eelgrass mitigation. Additionally the alignment of the new gangway was positioned to minimize adverse shading impacts to eelgrass. Removal of these structures exposed 84 m^2 (908 ft^2) of additional intertidal mudflat habitat, which in combination with the overall design, resulted in the project achieving final eelgrass mitigation success criteria within two years following project construction.

- **Humboldt Bay Rowing Association Floating Dock Permitting Project (2012)**

In 2012, The Humboldt Bay Rowing Association (HBRA) initiated a permitting project to reconcile existing conditions at the club's floating dock in Eureka, which had previously been constructed and permitted for seasonal use by Humboldt State University (HSU) prior to ownership transfer of the dock. The dock and associated gangway were initially permitted for seasonal use and were to be removed each spring in order to minimize light attenuation and resulting impacts to the fringing eelgrass beds adjacent to the dock. As the dock and gangway were not removed seasonally for several years prior to ownership transfer, a small gap in the existing eelgrass bed totaling approximately 8 m^2 developed under the gangway. HBRA subsequently pursued development of an eelgrass mitigation and monitoring program to address shading impacts to eelgrass and update the permit for the floating dock/gangway. Since the disturbance area was very small, mitigation was conducted onsite through a combination of substrate remediation (hand removal of displaced rock armor, concrete rubble and refuse to increase the extent of potential eelgrass

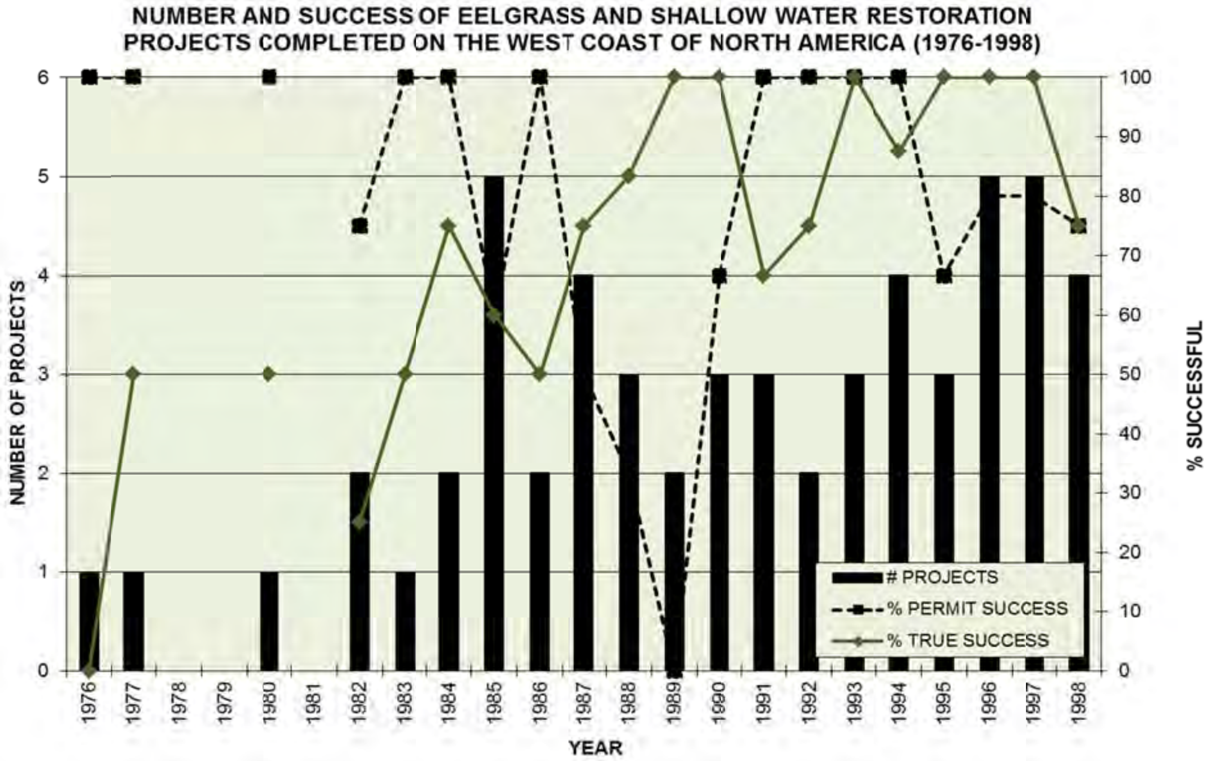


Substrate remediation to remove non-functional revetment rubble and restoration planting of eelgrass into areas where debris and rubble had been removed was conducted at the Humboldt Bay Rowing Association Dock. This 2012 project is the first in Humboldt Bay subject to full standards of the SCEMP as a precursor to adoption of the CEMP. In 2017, the project met established 5-year success milestones. Image credit: Pacific Watershed Associates habitat) and bare-root transplanting of eelgrass within existing gaps in eelgrass cover. Eelgrass was harvested from a nearby CDFW-approved donor bed in Eureka Slough and subsequently transplanted into 18 m^2 (2:1 mitigation ratio) of suitable habitat at the project site in July 2012. Following five years of post-mitigation monitoring, the project achieved final success criteria for both eelgrass area and density and ultimately satisfied the outstanding permitting requirements for the dock and gangway.

Successes and Failures with Eelgrass Restoration

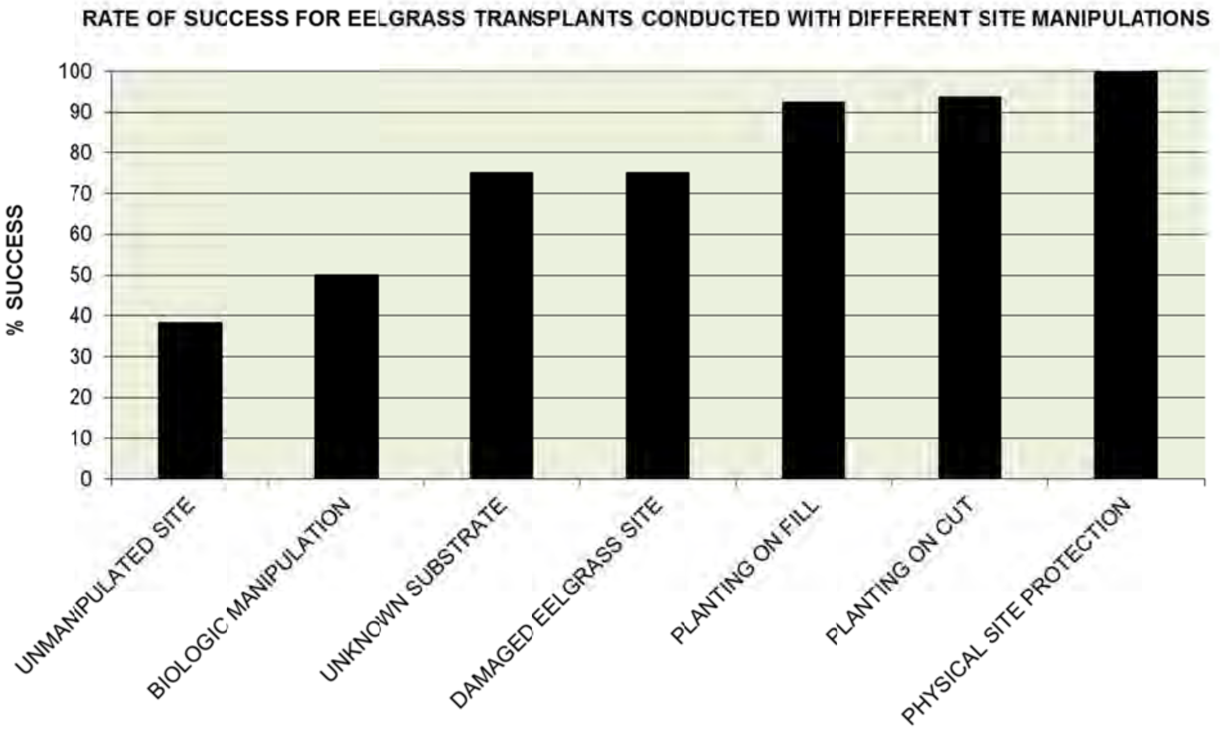
While the number of eelgrass restoration projects completed in Humboldt Bay provides a poor basis for conclusions regarding the types of projects that lead to successes and failures in eelgrass restoration, broader reviews into eelgrass restoration success and failure have been conducted. These reviews provide insights into successful restoration requirements and are also supported by the limited examples from Humboldt Bay. In 1998 an analysis of eelgrass transplant success history on the North American west coast was completed (Merkel 1998). This analysis located information on 56 restoration projects conducted from British Columbia to San Diego between 1976 and 1998 that were specifically intended to restore eelgrass and which were not of a smaller scale research nature. Research transplants were excluded as they often times were translocation between beds, or intended to determine stressor limitations and thus were not designed for restoration purposes, but rather were intended to answer broad ranging questions. During this analysis it was necessary to develop multiple definitions for success including: 1) compliance with permit conditions, 2) achieving restoration objectives, and at least replacing eelgrass losses. Over time, the definition of success has become more refined thus leading to fewer projects that can be evaluated against vague and low threshold permit conditions such as, “The applicant shall attempt to restore eelgrass…”. Such conditions from permits of the past would allow a project to meet permit success, but still fall short of other success metrics. In most instances during the evaluation period, inadequate monitoring existed to evaluate projects for long enough to determine that they had achieved eelgrass replacement goals for more than a year or a few years.

During the evaluation period a significant policy change occurred with the adoption of the Southern California Eelgrass Mitigation Policy in 1991 based on policies developing in the preceding few years. In reality, the policy had more influence on permit specificity than it did on resource management philosophies in that it was a detailed recitation of habitat survey standards, mitigation objectives to replace lost function, including those associated with temporal losses, and standards for monitoring restoration projects. Finally, the SCEMP squarely placed the burden for successful execution of mitigation on project applicants. While the elements of the SCEMP were generally in use in southern California by 1991, translation into permit conditions was generally so abbreviate as to leave broad latitude for interpretation and often resulted in insufficiencies that allowed for success based on permit condition, but not resource management goals. While the SCEMP was a regional policy, it is important in the evaluation completed due to the high percentage of eelgrass restoration projects conducted in southern California compared to all other portions of the coast. In the 1998 review, it was noted that during the period just before the SCEMP adoption there was a great decline in successful compliance with permit conditions even though there was a commensurate increase in true success based on eelgrass replacement. This related to enhanced clarity of eelgrass replacement requirements but poor translation into permit conditions. With the adoption of the SCEMP, there was both a greater clarity of mitigation and monitoring expectations and a simplified means of presenting these expectations in permit language by reference to the SCEMP. The result was a general improvement in both permit success and true biological success.



Eelgrass transplant history of success and failure rates derived from a review of 56 projects reviewed to determine if there were patterns in restoration successes that could be used to support future eelgrass restoration in San Francisco Bay where poor overall eelgrass restoration success and limited experience was a high concern. (Adapted from Merkel 1998)

While the history of successes and failures found in the review is interesting in its own right, it is perhaps more interesting to note shifts in eelgrass restoration approaches that have developed through time and the variable biological success that has come from different restoration methods. In the review of projects from 1976 through 1998, restoration methods were classified into seven different restoration approaches based on site preparation for transplanting rather than planting methods applied. These included planting into unmanipulated sites, changing site exposure to biological stressors (e.g., creating barriers to ray foraging and removal of invasive mussel mats) prior to planting, planting into unknown substrates or conditions, planting in previously damaged eelgrass sites, planting on fills used to raise the bottom, planting on cuts where high elevations are lowered to suitable elevations to support eelgrass, and planting in sites that are physically modified to create energy barriers, better flushing, or enhanced substrate conditions. It was determined in this review that the approach to restoration played a key role in whether a site would ultimately result in success with respect to eelgrass restoration. In fact, planting into unmanipulated sites, in spite of being the most common approach to restoration had the lowest success rate at only 38 percent success, while sites engineered to accept eelgrass by physically altering condition based on identified limiting factors all had success rates above 90 percent (Merkel 1998). At present, the vast majority of eelgrass restoration sites are designed and constructed to meet the restoration need rather than planting into unmanipulated areas.



Eelgrass transplant biological success rate based on a standard of meeting a no-net-loss of area standard. This standard was adopted in the 1998 review due to the low number of projects that included temporal impacts or metrics beyond areal extent. (Adapted from Merkel 1998)

An additional observation made during this investigation was that no restoration project that specifically limited restoration to the explicit restoration goal ever met that target. This is not surprising since eelgrass is intrinsically dynamic and gaps within restoration sites are a natural result of bed dynamics. As such successful projects always accounted for variability in beds through restoration of a greater extent of eelgrass than needed to achieve the minimum restoration goals. The oversizing of restoration sites provided a cushion against failures due to natural bed dynamics.

As indicated, the sample size of eelgrass restoration projects conducted in Humboldt Bay is too small to independently draw conclusions from these sites, however it is clear that the greatest success in restoration in Humboldt Bay followed a pattern similar to that observed elsewhere in that sites designed and manipulated to be successful and those that were oversized for their mitigation need were the most successful and sites planted in unmanipulated conditions generally failed.

The SCEMP recognized the value of the oversizing of mitigation sites and integrated opportunities for surplus recapture and application to future mitigation needs. The result of this element of the SCEMP was a building extent of eelgrass surplus held by major entities in port and harbor development and maintenance such as the U.S. Navy, City of San Diego, and Port of San Diego. The development of surplus eelgrass for future applications was so well embraced that many entities began seeking opportunities for garnering eelgrass opportunistically and by 1998 over 53 acres of surplus eelgrass had been developed.

While changes in federal mitigation banking policy have made it more difficult to capture and apply surpluses of restored eelgrass habitat to future mitigation needs thus undermining one of the primary benefits of the SCEMP. The CEMP adoption carried forward much of the structural elements of the SCEMP that provided these benefits and further developed the CMP providing a means for developing the tools needed to retain and apply eelgrass surpluses developed. Under the CEMP, such surplus development and application in the future can be readily accommodated; however, the regulatory framework for managing the surplus has become more complicated over time.

Preliminary Inventory of Eelgrass Mitigation and Restoration Opportunities

A conceptual inventory of eelgrass mitigation and restoration opportunities has been developed to provide context regarding the types of activities and general locations where these opportunities may be found within Humboldt Bay. The following examples represent an ecologically driven identification of opportunities; the list is neither meant to be prescriptive nor is it exhaustive. No effort has been taken to sort sites or further refine site suitability based on factors such as zoning, land-use planning, ownership, or other parameters that may heighten or degrade the suitability of a specific site with respect to eelgrass restoration. In addition, the identification of eelgrass restoration/mitigation opportunities has been done at a relatively high overview level and physical or biological site constraints may still be found that either promote or degrade suitability. Additional opportunities to restore eelgrass habitat exist within the former bottomlands surrounding the bay and are described but not explicitly mapped due to the complexities and uncertainties regarding future planning and land-use. Activities broadly identified in this preliminary inventory may also be scaled down and applied at a project site level (e.g. substrate remediation or debris removal) opportunistically, which may be particularly applicable for small-scale impacts associated with shoreline maintenance or redevelopment activities.

Substrate remediation of former shellfish bottom culture sites represents the most spatially extensive eelgrass restoration opportunity in North Bay, however; these opportunities may be somewhat complicated by ownership and active mariculture lease areas. This strategy offers a high likelihood of success if implemented correctly, but costs are somewhat uncertain absent more focused field investigations to determine substrate remediation volume and material disposal/re-use options. Given the extensive nature of this type of restoration opportunity in North Bay, it warrants further investigation through a pilot study or demonstration project as a means of exploring the relative costs and benefits of such an approach.

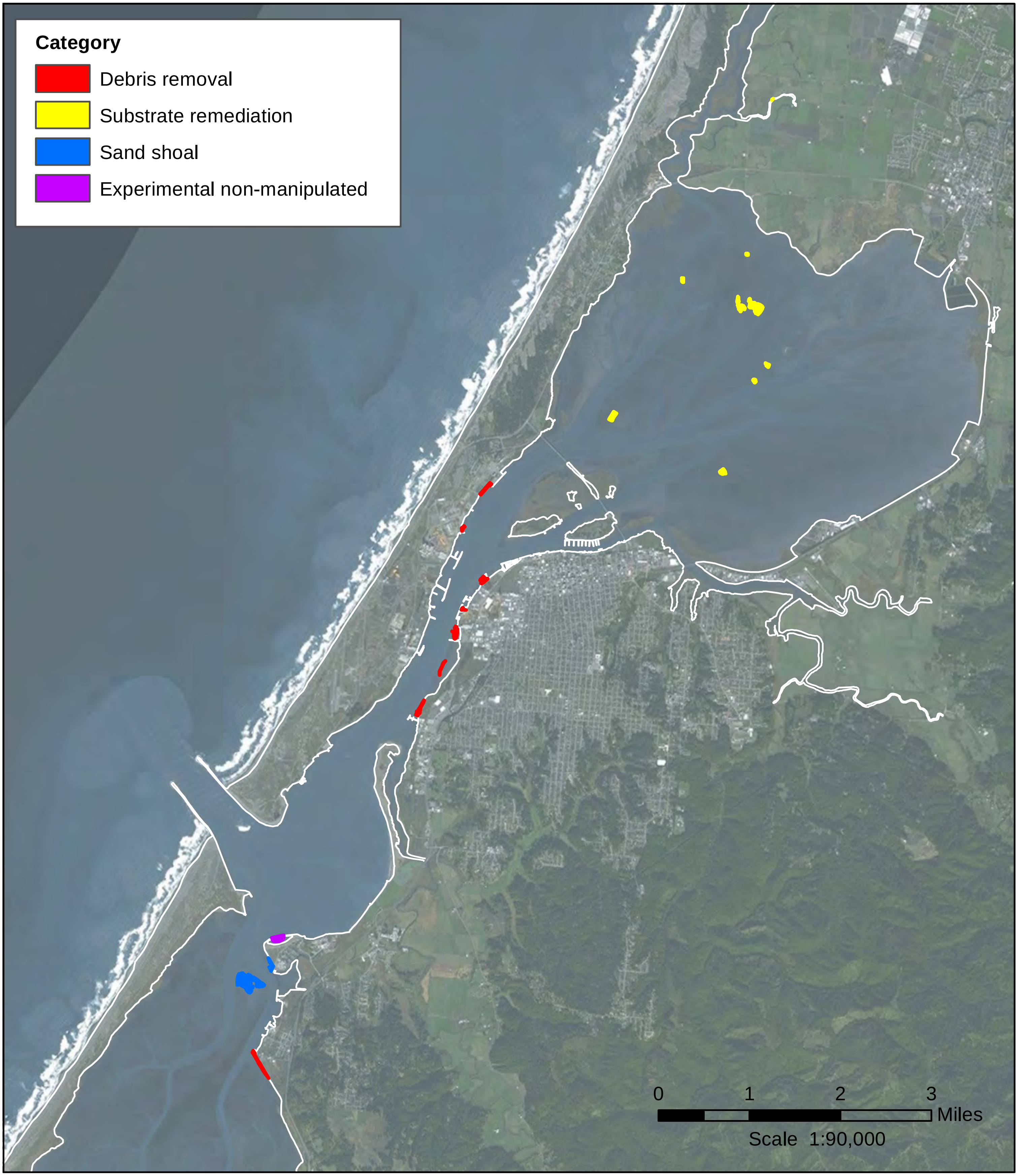
Within Humboldt Bay's developed working waterfront, removal of debris including piling fields, wharves, derelict floats and other legacy shoreline infrastructure represents the principal opportunity to restore eelgrass habitat that has either been displaced physically or by shading. Generally, debris removal has a high likelihood of success and is a good strategy for pursuing mitigation, particularly for smaller impacts occurring at the site level where opportunities exist either at or in close proximity to a proposed project. As the credit associated with removal is limited to the footprint effect of the debris being removed and because removal costs can be relatively high, this strategy generally makes the most sense for shoreline redevelopment or maintenance projects where the impacts to eelgrass are relatively small.

In South Bay, the primary opportunities to conduct restoration or mitigation of eelgrass habitat include legacy debris removal and site development combined with active transplanting of sand shoals. Additionally, a site exhibiting potentially favorable characteristics for experimental, unmanipulated transplanting of anchored bare-root planting units directly into subtidal sand flats immediately offshore of King Salmon Beach was also identified and is described further below. The sand shoal sites in South Bay reflect a legacy of shoreline modification, armoring and dredging-related changes in bay morphology, and likely provide the most cost-effective means of mitigating for larger-scale impacts to eelgrass (e.g. one or more acres) in Humboldt Bay. Additionally these opportunities offer amongst the most favorable ecological outcomes with respect to developing eelgrass habitat capable of supporting wildlife habitat uses that are generally forgone when mitigation is conducted in proximity to more developed areas of the bay. Figure 5 depicts the distribution of identified eelgrass restoration opportunities by category in Humboldt Bay.

Removal of derelict infrastructure

Several projects either recently implemented or currently in the planning/permitting phases in Humboldt Bay have pursued marine debris removal as a form of compensatory eelgrass mitigation. For relatively small-scale impacts to eelgrass, removal of derelict infrastructure may provide a cost-effective and environmentally desirable means to achieving eelgrass mitigation. Particularly within the working waterfront and former industrial shoreline areas within the bay, removal of pilings, wharves, derelict floats and other legacy infrastructure can provide credit potentially equivalent to the cross-sectional area of substrate exposed assuming the area is within the depth range capable of supporting eelgrass and sediment characteristics are suitable. Additionally, as the majority of derelict pilings are made of creosote-treated wood, their removal may also have a positive impact on ambient water quality. Removal of decking associated with abandoned wharves, piers and other over-water structures even in the absence of the removal of associated pilings can be particularly advantageous in improving light availability and thereby facilitating passive mitigation of eelgrass. Of critical importance in evaluating the feasibility of infrastructure removal as a means of achieving passive eelgrass mitigation is understanding the point at which the costs and/or logistics associated with removal are likely to surpass that of other mitigation techniques such as bare root transplanting. Aside from considerations of scale, debris removal as a mitigation strategy is likely best suited to projects located in close proximity to existing opportunities or where debris removal may be a necessary precursor to project implementation.

Derelict wharf along Channel in south Humboldt Bay at the south end of Fields Landing. Decking was removed from the final remaining portions of the wharf as late as 2009. The shade removal exposed areas of the intertidal to recruitment of eelgrass. As much as 1.8 acres of bay coverage was removed from 2005 to 2009 with the result being recruitment of approximately 0.5 acres of eelgrass back on to the exposed mudflats.



Eelgrass Mitigation/Restoration Site Inventory

Humboldt Bay Eelgrass Comprehensive Managment Plan

Figure 5

Although the likelihood of success for debris removal is generally high, it is likely to be limited to resulting in credit for a footprint effect. For this reason the relatively high cost of removal under most circumstances, limits the scale of this type of eelgrass mitigation opportunity.

Substrate remediation

Removal of marine debris impacting eelgrass habitat through displacement and changes in substrate suitability (e.g., concrete floats, rock, shell hash and rubble) from potential eelgrass habitat can provide an effective means of achieving in-kind, off-site mitigation for impacts.

There are several potential advantages associated with pursuing this form of passive in-kind mitigation, versus active transplant mitigation, within Humboldt Bay for projects whose impacts are of an intermediate scale. Under existing regulatory policy, active transplant mitigation within Humboldt Bay requires the creation of a suitable transplant receiver site at a depth capable of supporting eelgrass, either through the raising (filling) of subtidal lands, or by lowering (excavating) terrestrial or intertidal land where tidal action can be restored or the correct elevation established within the existing tidal frame. Raising subtidal land to achieve eelgrass mitigation would be a complicated undertaking, as most of the subtidal areas of Humboldt Bay are either subject to unfavorable wave exposure conditions (e.g. Entrance Bay) or in the case of subtidal channels, require the maintenance of sufficient hydraulic capacity to convey tidal waters to and from intertidal mudflat and salt marsh habitat in the estuary.

Substrate remediation opportunities to restore suitable substrate conditions to areas that are armored and in cases armored and elevated as a result of both anthropogenic activities are common in historic shellfish mariculture areas of the North Bay. Upper Images credit source:Pacific Watershed Associates

Excavation of certain intertidal areas such as sand flats or terrestrial areas where tidal action can be restored to create new eelgrass habitat may be a more technically feasible option with respect to creating a site suitable for active eelgrass transplanting. You could either construct new channels or benches, or widen and/or deepen existing, shallow subtidal channels so eelgrass habitat could be expanded there. This strategy might be both feasible and self-maintaining, and would be made more cost-effective by performing it over a relatively large area. A relatively small standalone eelgrass mitigation project may not be cost-effective using this strategy, as it may require substantial modeling and analysis to be successful.

Another advantage associated with the passive removal of marine debris to restore eelgrass habitat (versus conducting active transplant mitigation) is that up-front mitigation ratios may be lower than the prescribed active transplant ratio for eelgrass mitigation (4.82:1; CEMP 2014).

Site Development and Mitigation Transplanting

Eelgrass is abundant and widely distributed throughout Humboldt Bay, occupying a substantial proportion of the area within the bay that is physically capable of supporting it. In comparing classified hyperspectral imagery depicting eelgrass distribution in October 2004 (Judd 2006) to a physical model depicting potential eelgrass habitat in South Humboldt Bay on the basis of depth, wave exposure and substrate suitability, eelgrass was found to occupy 91% of modeled available habitat (Gilkerson 2008). Further, it was noted that most of the areas identified as being potentially suitable to eelgrass but not identified as being occupied by eelgrass in the hyperspectral classification tended to occur in regions that were either too deep to be fully resolved by aerial imagery or in areas of the intertidal flats where the co-occurrence of ephemeral green algae overwhelmed the spectral signature of eelgrass. Taken together, these observations suggest that eelgrass in South Humboldt Bay was very near carrying capacity at the time of these studies and this likely holds true throughout the majority of Humboldt Bay based on analysis of more recent multispectral imagery captured in 2009 (Schlosser and Eicher 2012).

The fact that eelgrass appears to be growing throughout the vast majority of the areas capable of supporting it under existing conditions strongly suggests that efforts to conduct transplanting to achieve compensatory mitigation of eelgrass in Humboldt Bay be predicated on first developing a suitable receiver site. While the majority of Humboldt Bay is comprised of unconsolidated fine grained sediment capable of supporting eelgrass habitat, light limitation, steep side slopes, and excessive current velocities within the bay’s larger channels limit eelgrass distribution in subtidal areas, while desiccation, thermal stress, and wind-wave energy set the upper limits capable of supporting eelgrass throughout the intertidal flats of the bay. These upper and lower limits of eelgrass distribution vary with respect to location and are further subject to dynamic adjustment through time in response to variable environmental conditions manifesting across the bay. For these reasons, it is generally necessary to manipulate a receiver site prior to transplanting in order to be successful.

Generally speaking, planting in cuts or fills designed to achieve the appropriate depth and substrate characteristics necessary to support eelgrass have resulted in highly successful eelgrass mitigation efforts on the Pacific Coast (Merkel 1991, Merkel & Associates 1998). Additionally, modification of the wave, current and circulation environments may also allow for the creation of suitable eelgrass habitat in areas that don’t currently support it. Because these opportunities are very site and circumstance specific, multiple factors must be weighed and alternatives carefully considered prior to advancing a specific site design in a particular location.

Although there are a number of factors to consider with respect to site development including location, substrate conditions, slope, wave exposure, and current velocity, manipulation of site elevation through excavation (lowering) or placement of fill (raising) to achieve a depth profile that falls within the central core of the local eelgrass depth range is generally the most cost-effective means of site development. Due to the high ecological value of intertidal mudflats owing to their abundance of benthic infauna and subsequent importance particularly to shorebirds, lowering of intertidal mudflats to accommodate eelgrass mitigation is not generally supportable within Humboldt Bay on a large-scale.

There are however, limited opportunities within Humboldt Bay to lower intertidal sand shoals whose present configuration reflects historic modifications to the bay's entrance and adjacent shoreline areas; developing transplant receiver sites by lowering (e.g. dredging or excavation) these areas to elevations capable of supporting eelgrass could be cost-effective, highly-likely to succeed, and thereby avoid the conflicts associated with impacting intertidal mudflat habitat. Two such locations exist at the northern end of South Humboldt Bay and include the shoal adjacent to the shoreline north of the mouth of Fisherman's Channel and the sand shoal across Fields Landing Channel directly west of King Salmon (Figure 5).

While the raising of subtidal areas through placement of fill to achieve the appropriate depth for eelgrass may be technically feasible, there may be limited opportunities to pursue this strategy within Humboldt Bay due to the need to maintain channel hydraulic capacity in most subtidal areas of the bay outside of Entrance Bay. It may be possible to pursue channel deepening in certain sloughs and tributary channels that are aggraded as a result of legacy watershed sediment impacts and this topic could be explored further by engaging agency partners through an experimental/pilot study approach.

Experimental Restoration Efforts

Although eelgrass is strongly presumed to be near its carrying capacity within Humboldt Bay and that site development is generally a necessary precursor to conducting transplant mitigation, there may be locations suitable to opportunistic/experimental transplanting efforts absent site development or modification. One such location is offshore of the beach at King Salmon (Figure 5), where the existence of several isolated patches of eelgrass were noted both in the 2009 NOAA imagery as well during an interferometric sidescan sonar survey conducted during fall 2016. These patches are persisting in a location that is very near the upper energy threshold that eelgrass is capable of tolerating and the patchy distribution likely reflects the marginal conditions inherent to the site. However, it may be possible to facilitate greater continuity of eelgrass in this location through targeted bare-root transplanting based on the results of similar efforts conducted in wave-exposed environments in southern California. Based on observations and previous experience with such efforts, it is believed that transplanting mature, anchored bare-root eelgrass bundles in this kind of setting has the potential to facilitate colonization of areas too energetic to consistently support sufficient seedling recruitment. Further, if the initial transplant effort is successful and mature plants are able to become established, the expansion an increased coverage of eelgrass at the site is likely to lead to a dampening of wave and current energy over time that could then promote future seedling recruitment and overall bed stabilization.

Synergistic Restoration of Former Tidelands

Additional opportunities to restore or mitigate eelgrass habitat exist within the footprint of former/reclaimed tidelands that surround much of the modern Humboldt Bay shoreline. The capacity to generate additional habitat within these areas is difficult to quantify and complicated by private ownership and other factors. Further, while reclaiming/restoring former tidelands increases the tidal prism, which has been shown to promote eelgrass expansion through enhanced tidal circulation, often the expansion of eelgrass in response to these actions occurs beyond the extent of a particular project area and may be hard to quantify.

The restoration of tidal influence to former bay tidelands diked and drained primarily in support of agricultural development beginning in the late 1800's, has tremendous merit with respect to mitigating impacts to tidal wetland habitats within Humboldt Bay. Restoration of tidal function within these former tideland landscapes is likely best approached with a goal of restoring the full suite of intertidal habitats (e.g. saltmarsh, intertidal mudflat, and lower intertidal/shallow subtidal channels capable of supporting eelgrass), as opposed to achieving a single tidal wetland habitat endpoint for several reasons. The majority of the bay's undeveloped former tidelands which still have the potential to support tidal wetland restoration consist of historic saltmarsh habitat and to a lesser spatial extent, intertidal mudflat and drainage channels with eelgrass (1870 Saltmarsh distribution; Humboldt Bay and Eel River Historical Atlas 2009).

Following diking and draining, the majority of these former tidelands have subsequently subsided on the order of several feet, primarily as a result of the oxidation and compaction of previously saturated, buried organic material within the underlying marsh soils. Conversely, the loss of tidal hydrologic connectivity, as well as subsequent agricultural activities (tilling, cultivation, grazing, etc.) within these areas, led to the partial infilling of the intertidal and shallow subtidal drainage channel network once these areas were cut off from tidal influence. The overall effect of this activity resulted in substantial lowering of the majority of the former tidelands, in combination with an overall reduction and homogenization of the topography in these areas.
In most cases, as a result of current ground surface elevations, the outcome of restoring tidal influence alone in these areas would lead to the creation of a disproportionate amount of intertidal mudflat relative to historic conditions. Since Humboldt Bay still contains substantial intertidal mudflat and eelgrass habitat relative to historic conditions (Schlosser and Eicher, 2012), restoration of these former tidelands with an emphasis on creating saltmarsh habitat may be the preferred outcome with respect to restoring lost ecological function.

Restoring tidal function and recreating saltmarsh habitat can best be accomplished by importing fill material to recreate suitable marsh plain elevations. This could add substantially to tideland restoration costs, but the potential integration of a small eelgrass component into the larger restoration project could also provide added ecological and financial value. It would be feasible to restore saltmarsh in former tidelands through the importation of fill material in conjunction with the creation of a relatively shallow drainage channel network of sufficient capacity to service a restored marsh plain. Excavation of a deeper and broader drainage channel network to a depth capable of supporting substantial eelgrass would provide added ecological benefit and partially offset the amount of imported fill required to build the marsh plain.

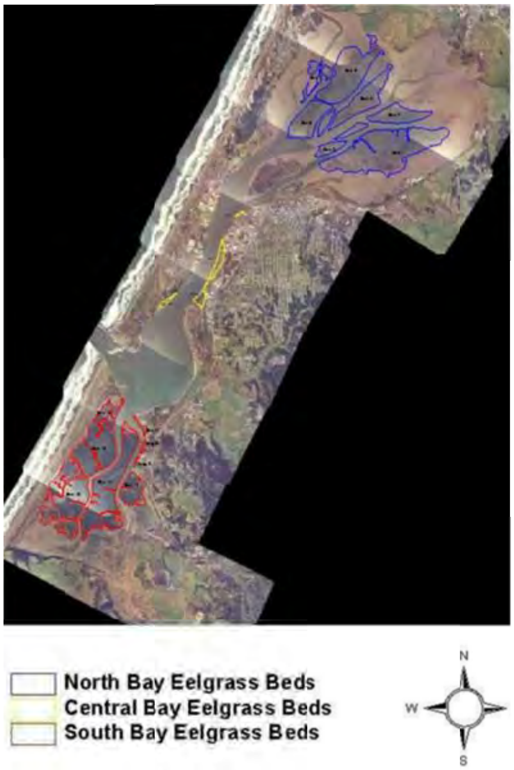
Due to the overwhelming magnitude of regional subsidence relative to historic salt marsh extent, it may be worthwhile to consider an alternative endpoint with respect to the proportion of salt marsh relative to eelgrass and mudflat habitat components within a tideland restoration project. Placing greater emphasis on developing additional eelgrass habitat in cases where it is more cost-effective to lower substrate elevations to be suitable to eelgrass as opposed to raising elevations to develop salt marsh, may be a reasonable ecological trade-off.

For the sole intent of establishing additional eelgrass habitat for the purpose of mitigation, this approach is unlikely to be cost-effective; however, given the substantial loss of salt marsh habitat in Humboldt Bay relative to historic conditions, reclaiming former tidelands in this manner would address the lost habitat function of these critically-important tidal wetlands. Although in-kind mitigation of eelgrass is generally the preferred approach to conducting eelgrass mitigation, it would be useful to establish an understanding of the degree to which the resource agencies might consider partial out-of-kind mitigation for the restoration of former tidelands to a matrix of tidal channels with eelgrass, intertidal mudflats and salt marsh. If this type of transaction is possible, it could help establish criteria for quantifying eelgrass mitigation credit associated with the action of restoring former tidelands and increasing the tidal prism.

3.5 HUMBOLDT BAY EELGRASS MONITORING PROGRAM

Humboldt Bay holds an estimated 31 percent of the state's eelgrass resources and ranks first with respect to eelgrass extent. However, of the largest systems supporting eelgrass, it is the least well tracked with respect to long-term spatial dynamics. This is likely the result of many factors. Foremost among these are likely the scale of the system and the economics of the region. With very little development pressure on the bay there has not been a significant management or regulatory driver for development and maintenance of a continuous monitoring program. This is not to suggest that monitoring programs have not been undertaken in the bay, only that a long-term directed effort to understand spatial patterns has not been undertaken and there is presently no monitoring program to temporally or spatially track other biometrics on a systemwide scale.

In 2001, the Humboldt Bay Cooperative Eelgrass Project was established to develop a baseline understanding of eelgrass resource dynamics in Humboldt Bay, through a collaborative effort involving the California Sea grant Extension Program, California Department of Fish and Game, Humboldt Bay Harbor, Recreation and Conservation District, and Humboldt State University. Over a seven year time period, members of contributing organizations and agencies as well as volunteers participated in the study, which involved both field and laboratory work aimed at characterizing a broad range of eelgrass biometrics. Under this program, data were collected twice annually during favorable low tides in both winter and in summer seasons. A total of 15 eelgrass bed sites spanning North, South, and Entrance Bay were delineated and monitored individually to assess eelgrass turion density, length, width, incidence of flowering, and biomass.



Monitoring beds defined under the 2001-2009 Humboldt Bay Cooperative Eelgrass Project.

In 2009, the Humboldt Bay Cooperative Eelgrass Project terminated when the HBHRCD began participating in the SeagrassNet Monitoring Program (www.seagrassnet.org) and established two sites, one in North and one in South Bay, with the goal of tying Humboldt Bay's eelgrass populations to worldwide trends in seagrass habitat. Unfortunately, with the change in monitoring framework, it became more difficult to answer regional or system-scale management concerns under the new program.

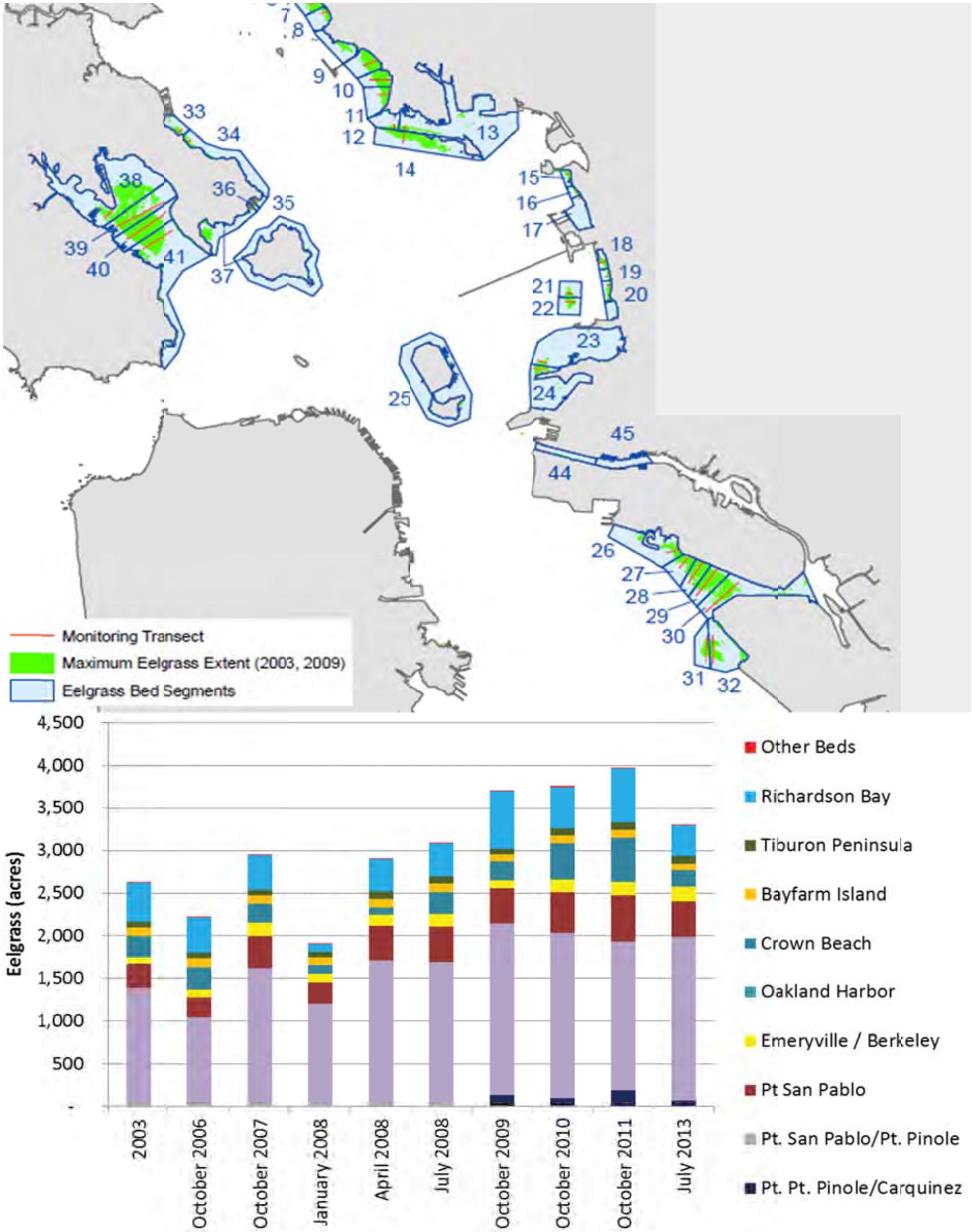
In San Diego Bay Mission Bay, Newport Bay, San Pedro Bay, Morro Bay, and San Francisco Bay, regional monitoring programs are undertaken and have persisted for various lengths of time to track the distribution of eelgrass within monitored systems (Bernstein et al. 2011, Merkel & Associates 2013). Other systems are slowly being integrated into regional and local monitoring programs as well. Most recently, these have included, San Clemente Island (Merkel & Associates 2017a), and Anaheim Bay (Merkel & Associates 2017b). These programs are used to track long-term trends and are designed to serve various management and planning functions as well as to provide a metric for monitoring system health.

The regional eelgrass monitoring programs presently being undertaken range from comprehensive systemwide surveys on a high frequency basis, to subsampling programs conducted on a more infrequent basis. The most common monitoring methodologies follow the recommendations of Bernstein, et al. (2011) which are based on the San Francisco Bay regional monitoring program (Merkel & Associates 2008). These program relies on development of a comprehensive distribution map for eelgrass within the region for a "Benchmark Year" to which annual subsampling along fixed belt transects may be scaled. This benchmark scaling allows for tracking and assessment of eelgrass distribution patterns and variability over both spatial and temporal scales. Surveys are conducted in a manner that uses remote sensing tools to physically inventory approximately 5 percent of the eelgrass existing in the system, with the sampling being distributed across bed segments that have been defined based on system geography and site characteristics with the intent that variability on the surveyed transects should reflect variability within the spatially defined bed segments. The methodology has been developed and tested in San Francisco Bay and found to yield a variance of only 1.4 percent baywide when scaled over multiple benchmark years (Merkel & Associates 2013).

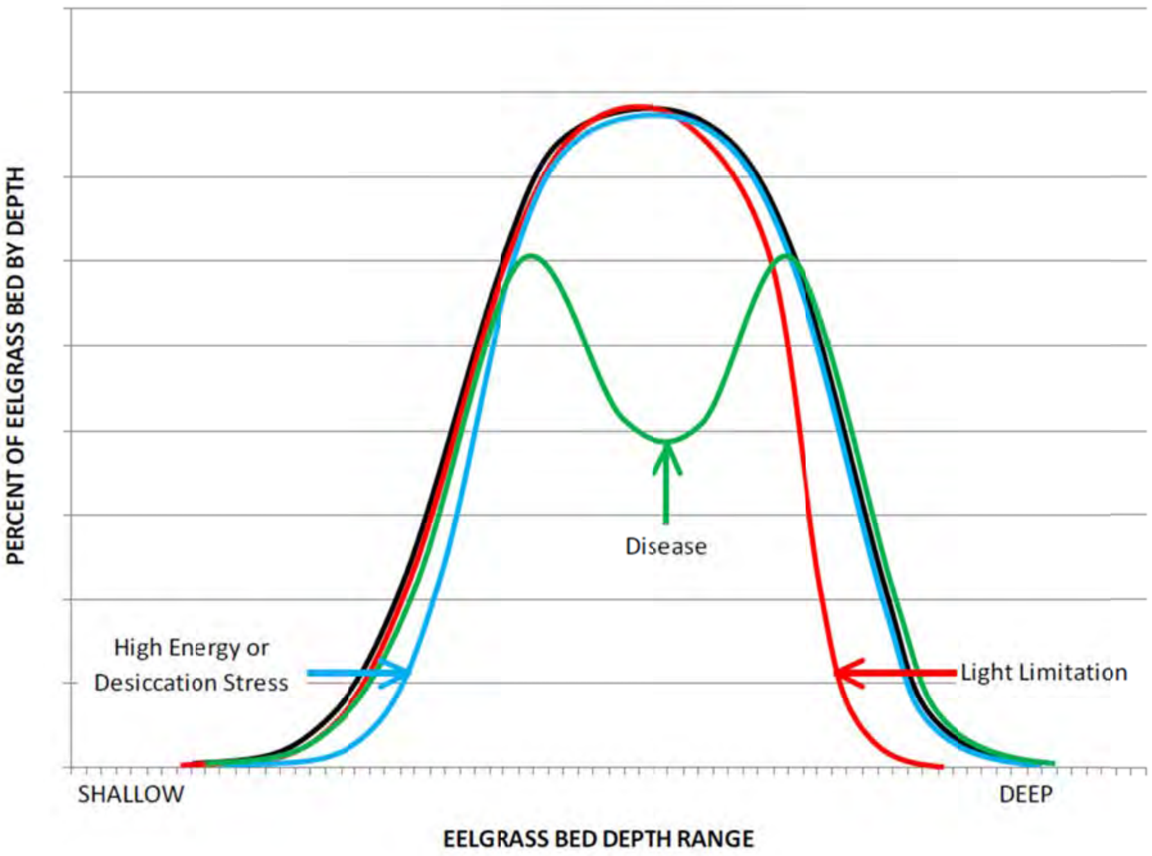
The data outputs for these monitoring programs include "Benchmark Year" comprehensive survey maps, and monitoring interval charts depicting how the distribution of eelgrass changes through time by bed segment. The data are then available to be pooled or analyzed in different manners to explore spatial and interannual trends. Further, because data are collected through belt transect methods (e.g., sidescan sonar, low altitude photography), trends in vegetated cover can also be explored. Finally, in some systems, the monitoring program has been coupled with bathymetric survey that allows examination of trends in eelgrass that are indicative of various major stressors including light limitation, desiccation stress, and disease.

In Humboldt Bay, it is recommended that a monitoring program be revitalized that couples biometric sampling comparable to that conducted between 2001 and 2009 by the Humboldt Bay Cooperative Eelgrass Project with spatial monitoring following recommendations of Bernstein et al. (2011). Conversely, the spatial program may be coupled with an existing project specific effort currently being pursued by HSU and SeaGrant to look at 22 sites within the Bay. These may need to be expanded to capture more developed areas of the Bay, but it is much easier and efficient to integrate efforts than to duplicate work already being performed. Although highly desirable, it is not necessary to initiate this program with the completion of a new comprehensive benchmark survey as the 2009 NOAA survey can largely fit this function. However, given both the Bernstein recommendation for comprehensive surveys every 5 years and the lack of adequate inventory of subtidal environments in the bay, it is suggested that a new benchmark survey be completed to support a monitoring effort.

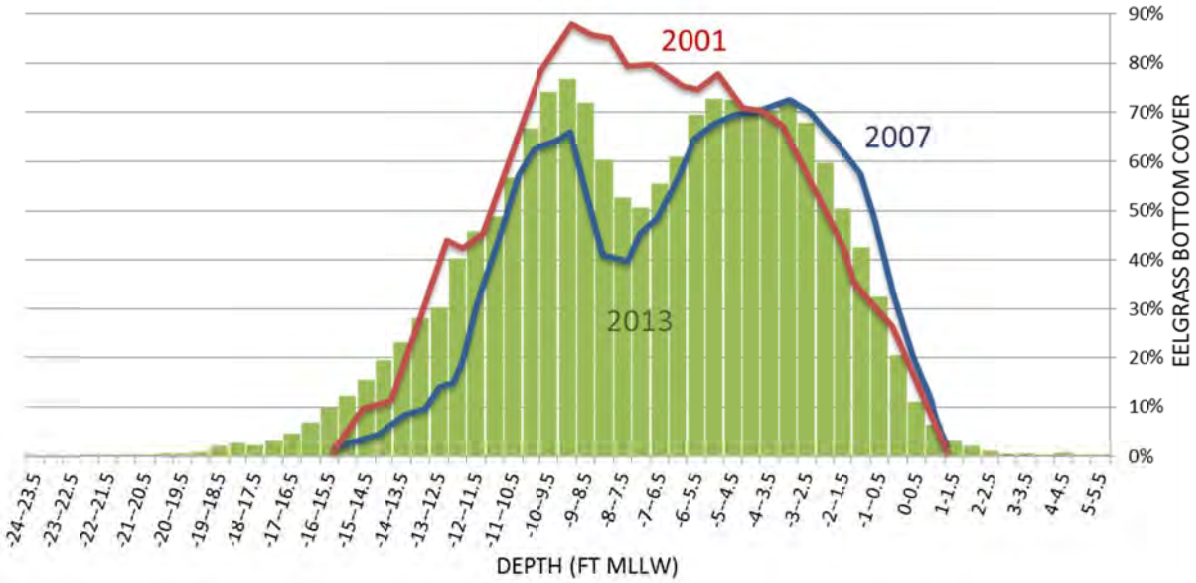
While undertaking a subsampling monitoring program is less expensive than regular saturation surveys, it remains a substantive commitment. Further, modest monitoring is more beneficial to be undertaken regularly than it is to be undertaken sporadically in a more elaborate form. For this reason, it is suggested that a partnership consortium be developed for the monitoring program, or that the monitoring program be integrated into an existing partnership forum where it can be consistently managed and funded, with limited effort on a single partnership entity.



Example section of regional monitoring program layout in San Francisco Bay allowing for tracking of interannual or interseasonal patterns of eelgrass distribution by region through use of belt transects scaled to benchmark comprehensive surveys.



Diagrammatic model of eelgrass depth distribution response to various types of eelgrass stressor displaying how information from eelgrass depth distribution monitoring can assist in tracking changes in the bay.



Example results from depth distribution analyses in Mission Bay that led to some of the early concerns that disease may be impacting eelgrass in southern California (Merkel & Associates 2013).

3.6 HBECMP REGULATORY LINKAGES

The HBECMP provides recommended structure to managing, assessing, restoring, and monitoring eelgrass habitat within Humboldt Bay, however such a plan provides its greatest functionality when coupled with regulatory programs that garner benefit from the plan and contribute to plan implementation. For this reason, the plan has been structured to be a guidance document that may be integrated into the regulatory framework as a CMP under the CEMP through which implementation would meet compensatory mitigation needs for eelgrass for projects reliant on the plan. To achieve the essential regulatory connections the following structure is planned:

- The HBHRCD would serve as the initial intake coordinator for regulatory permitting and would serve up website information and be a repository of information on eelgrass as it pertains to regulatory and management actions under this CMP.

- The HBHRCD would maintain eelgrass ledgers identifying surpluses, impacts, and shortfalls in eelgrass throughout the Bay, however HBHRCD would only be responsible for those impact obligations generated by the District.

- Eelgrass surveys and impact assessment methodology within Humboldt Bay for regulatory applications would follow the standards as outlined in this CMP, inclusive of baseline surveys for project planning, pre-construction, post-construction, and any follow up surveys required.

- Mitigation of eelgrass impacts under this CMP structure will be addressed as follows:
  - Early projects undertaken under this CMP will follow the restoration scaling of the CEMP wherein 4.82:1 (restoration to impact area) to achieve not less than 1.2:1 (mitigation to impact) requirements. Any surplus eelgrass developed through this restoration effort will be retained in programmatic mitigation sites and applied to future project eelgrass mitigation needs.
  - For projects resulting in impacts to eelgrass in excess of 0.1 acre, mitigation may be implemented as follows:
    - 1) a stand-alone action applying the full 4.82:1 restoration ratio and 1.2:1 mitigation ratio, or
    - 2) restoration may be undertaken at a 1.2:1 minimum ratio with any shortfalls being backed by the programmatic mitigation site surplus (provided it exceeds the impact acreage and has been established for greater than 3 years). In the case of any shortfalls, the programmatic mitigation site surplus may be used to achieve full mitigation by purchase of the shortfall area. Should the project specific restoration generate an eelgrass surplus, the surplus would roll into the CMP surplus.
  - For projects resulting in eelgrass impacts of less than 0.1 acre in size, mitigation may be implemented as follows:
    - 1) a stand-alone action applying the full 4.82:1 restoration ratio and 1.2:1 mitigation ratio, or

        - 2) restoration may be undertaken at a 1.2:1 minimum ratio with any shortfalls being backed by the programmatic mitigation site surplus (provided it exceeds the impact acreage and has been established for greater than 3 years). In the case of any shortfalls, the programmatic mitigation site surplus may be used to achieve full mitigation by purchase of the shortfall area. Should the project specific restoration generate an eelgrass surplus, the surplus would roll into the CMP surplus, or
        - 3) through acquisition of eelgrass credit from the surplus at a cost that would serve to fund CMP implementation, management, development and maintenance of programmatic eelgrass mitigation sites.
    - In the event that surplus credits within programmatic mitigation sites are depleted at any point below that necessary to insure against shortfalls in project mitigation or to make up mitigation needs for direct credit acquisition, the programmatic sites will not be relied on and the restoration ratios and mitigation requirements will default back to the CEMP standard ratios.
    - Projects undertaken within the Bay shall be evaluated to determine if there are opportunities to develop or restore eelgrass with project implementation on an opportunistic basis. Where practical and feasible voluntary eelgrass restoration may be conducted and any surplus eelgrass generated from such efforts may be maintained in programmatic mitigation sites provided the following has occurred:
        - 1) The restoration site has met establishment milestones continuously for three years following development, typically Years 3-5 following eelgrass restoration actions;
        - 2) The site is located in an area that is not expected to be in conflict with future land-use activities that would be counter to the site's maintenance as eelgrass habitat;
        - 3) The site becomes subject to long-term tracking in the same manner as other programmatic eelgrass mitigation sites.

- Eelgrass mitigation shall achieve the following establishment milestones to be considered to have achieved the mitigation goals:
    - *Month 0* – Monitoring should confirm the full coverage distribution of planting units over the initial mitigation site as appropriate to the geographic region.
    - *Month 6* – Persistence and growth of eelgrass within the initial mitigation 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 mitigation site. For seed buoy restoration programs, there should be demonstrated recruitment of seedlings at a density of not less than one seedling per four (4) square meters with a distribution over the extent of the initial planting area. The timing of the monitoring event should be flexible to ensure work is completed during the active growth period.
    - *Month 12*– The mitigation site should achieve a minimum of 40 percent coverage of eelgrass and 20 percent density of reference site(s) over not less than 1.2 times the area of the impact site.

  - *Month 24*– The mitigation site should achieve a minimum of 85 percent coverage of eelgrass and 70 percent density of reference site(s) over not less than 1.2 times the area of the impact site.
  - *Month 36*– The mitigation site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.2 times the area of the impact site.
  - *Month 48*– The mitigation site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.2 times the area of the impact site.
  - *Month 60*– The mitigation site should achieve a minimum of 100 percent coverage of eelgrass and 85 percent density of reference site(s) over not less than 1.2 times the area of the impact site.
  - For projects that are mitigation by previously established eelgrass within programmatic mitigation sites, the mitigation ratio shall be 1:1 (mitigation area to impact area).

- For established programmatic mitigation sites, the available credits within the sites shall be determined by a 4-point moving average of the areal extent of eelgrass within the site based on annual surveys. This methodology provides a continuous annual accounting of eelgrass surplus available to be applied to mitigation needs. If the extent of credit based on the 4-point mean ever falls below the area of the mitigation allocated to prior projects, no credit can be used until the mean rises above the prior debit levels. This methodology follows that applied to established eelgrass mitigation banking programs and has demonstrated a good track record for implementation since 1990 (Merkel & Associates 2017d).

- The HBHRCD shall investigate the development and processing of programmatic permits or other regulatory approvals or interagency memoranda of understandings to secure regulatory certainty in the acceptance and adoption of this CMP to govern eelgrass impact handling within Humboldt Bay for projects meeting the core focus activity types covered by this plan.

- The HBHRCD shall implement the following in order to provide plan information and to ensure that the plan is adaptive in structure:
  - provide an annual update of the activities undertaken under this plan through the eelgrass portal on the District's web-site;
  - convene a meeting on an approximately 5-year basis (likely in association with permit renewal cycles) in order to evaluate the plan performance and make any adaptive management changes to the plan needed to meet shortcomings in the plan, and;
  - make non-cycle interim plan changes, as needed, by full mutual agreement among all partners under the plan.

Programmatic Permitting, Project Tracking and Mitigation Credit/Capture

A programmatic permitting structure such as a Regional General Permit (RGP) may provide an efficient mechanism for addressing a suite of projects with similar permitting requirements such as required maintenance dredging activities, shoreline infrastructure repair and new construction within specific areas and at scales where anticipated impacts to aquatic resources are both minimal and similar in nature. RGP's are administered by the individual U.S. Army Corps of Engineers District's whose jurisdiction covers the region of interest. Examples of the successful implementation of RGP's within the greater San Francisco Bay Area may provide useful case studies to draw from. Examples include RGP 3 (Conduct activities related to waterfowl hunting and management), RGP 7 (Construct and improve boat docks, ramps, storm water outfall work, etc.), and RGP 9 (Conduct maintenance dredging in the San Rafael Canal, Marin County, by waterfront property owners), and RGP 15 (East Bay Regional Park District Routine Maintenance Projects). The RGP is used as a tool to implement eelgrass restoration projects within San Francisco Bay using RGP 19 (NMFS Eelgrass Restoration Program). As a result, the RGP structure is familiar to many of the HBECMP partners as a tool for efficient management of regulatory processes.

Advantages of establishing a programmatic permitting mechanism such as an RGP include ensuring a strong protective mechanism for aquatic resources of concern, efficiency of permit administration, and consistency in decisions and determinations relating to projects falling under the permit. An RGP focused on minor projects within Humboldt Bay could provide both structure and utility to programmatic mitigation site development that would serve all projects under the permit and provide a rapid and relatively streamlined means to capture and retain surplus eelgrass habitat restored beyond action specific obligatory mitigation requirements. Such a mechanism would allow for development of one or multiple mitigation sites to meet a broad range of needs without the necessity of developing a formal mitigation bank or in lieu fee program. The mechanics of the mitigation site would continue to require an accounting ledger of available mitigation area that is supported by a spatial and/or relational database that could facilitate application of surplus eelgrass restoration to mitigation needs of future projects that fall within the framework of activities authorized under the RGP.

Although a formal mitigation banking program or in lieu fee program may ultimately be desirable to support Humboldt Bay, at present, it is not clear that a broad demand for eelgrass mitigation credits beyond harbor sustaining activities is required. More exploration of the broader need is warranted and is discussed in Section 4 of this plan.

Pilot Plan Project (Fisherman's Channel Dredging / Clam Island Eelgrass Mitigation)

The HBHRCD is proceeding forward with a maintenance dredging project to remove accumulated sediment from Fisherman's Channel (the main access channel to the King Salmon waterways and the prior once through cooling water intake channel to the now decommissioned PG&E power plant. This dredging is anticipated to result in impacts to eelgrass of approximately 1.3 acres requiring an approximately 6.3 acre initial restoration effort at 4.82:1 with an ultimate requirement for successful establishment of approximately 1.6 acres of eelgrass. To mitigate eelgrass impacts, Merkel & Associates has identified a suitable site on a sand bar on Clam Island in the immediate vicinity of the Fisherman's Channel dredging need. The dredged materials may be lowered to generate suitable areas for eelgrass restoration with the excavated sediment being piped to White Slough along with the Fisherman's channel sediment for beneficial reuse in wetland restoration being undertaken by the U.S. Fish & Wildlife Service within the Humboldt Bay National Wildlife Refuge.

It is fully anticipated that the Clam Island mitigation site will generate considerable surplus eelgrass once established, thus meeting both the project specific mitigation needs for Fisherman's Channel maintenance dredging and providing a programmatic mitigation site suitable for application in mitigation of other small scale impacts as outlined in this plan. Because the timing for the Fisherman's Channel dredging is not well aligned with the needs of development of a longer-term programmatic permit, the intent is to move forward with permitting of Fisherman's Channel dredging while earmarking the mitigation site to serve as programmatic mitigation for a second regulatory action that solidifies the application of this site to mitigation of multiple future smaller projects.

The HBHRCD may use surplus eelgrass mitigation credit established from the Fisherman's Channel Clam Island to support one or more regulatory structures that provide for holding, exchanging, and tracking eelgrass mitigation credits in association with core focus activities addressed in this plan. This may be an RGP, an in-lieu-fee program, or a formal mitigation bank. The details are to be developed at a future date to support plan implementation. The implementation of the Plan elements including eelgrass monitoring, impact, mitigation, and restoration surplus tracking, maintaining the website, and development of mitigation sites creates an expense to the HBHRCD that is partially offset by efficiencies in its own project implementation, but may also be offset by selling mitigation credits from the developed sites, or development of a consortium of partners with shared interests. The development of specific regulatory structures and partnerships for implementation of this plan is the focus of the "next steps" discussion in Section 4. While the details of the "next steps" are not yet known and require further consideration, including evaluation of costs and benefits to the District and its partners, the development of a programmatic mitigation asset in the form of eelgrass at Clam Island in association with the Fisherman's Channel project provides an impetus for action in order to ensure that the surplus is retained for application to future needs.

4.0 EELGRASS MANAGEMENT PLAN NEXT STEPS

This section identifies the next steps in advancing the HBECMP to a state of secured implementation. These steps are outside of the scope of the present plan development and lead into regulatory action needs and implementation partnerships. The actions identified are arranged in the general order that they would logically follow from the point of plan completion to plan implementation. However, many of these actions may be implemented in parallel or out of the strict numeric order in which they are presented. As such, the order actions appear on the list should not be considered a constraint to advancing a particular element forward.

For the next phase in plan implementation the actions are summarize as follows:

1) Circulate the Humboldt Bay Eelgrass Comprehensive Management Plan to resource and regulatory agencies for review with the intent of adopting this CMP as a functional plan to meet the objectives of the CEMP and replace the regiment of the CEMP for core focus activities within Humboldt Bay.
    a. Provide a 45 day review period to obtain comments and input on any revisions or additions to meet a regulatorily acceptable form.
    b. Make revisions and respond to how comments were addressed. Obtain letters of concurrence from agencies supporting adoption of the CMP for Humboldt Bay.

2) Develop annualized implementation costs for the plan including all aspects considered to be required for regulatory program adoption for Humboldt Bay.

3) Evaluate benefits of taking on the plan obligations considering plan implementation costs compared to costs, schedule, and regulatory risks of not adopting the CMP. This discussion should engage other affected parties within the regulated community to determine if there is an interest in shared expense or partnering on elements of the plan that would enhance the benefit-cost ratio. Potential partners may include Caltrans, Humboldt County, the City of Eureka, City of Arcata, and others that may have infrastructure upgrade or maintenance responsibilities that may interact with eelgrass resources.

4) Follow up on Fisherman's Channel/Clam Island mitigation implementation. Transition the annual monitoring/reporting for the Fisherman’s Channel mitigation site into an accounting balance tracking program and investigate the credit-exchange marketing of anticipated surplus eelgrass mitigation credit. Quantify HBHRCD eelgrass mitigation needs to determine potential for surplus credit accrual and future exchange. Begin planning for the next opportunistic eelgrass mitigation site to develop.

5) Investigate the potential frameworks for regulatory actions that may support plan implementation by providing regulatory administrative or mitigation cost relief by streamlining of permits by providing programmatic management structure to addressing eelgrass impacts. Consider tools of RGP, In Lieu Fee Programs, Mitigation Banking, and Special Area Management Plan (SAMP) options to implement the CMP. Select a path for pursuit of regulatory adoption of the Plan, complete CEQA action, and submit agency applications for processing.

6) With consideration of partnering interests and participation agreements, submit the Plan and agency support to the Board of Harbor Commissioners for adoption of the plan in consideration of permitting and regulatory program benefits.

7) Pursue development of a baywide cooperative monitoring program that can integrate resources and interests into a long-term monitoring program that will support multiple management interests in the Bay. This cooperative program should investigate potential for reinvigorating many of the partners from the pre-2009 Humboldt Bay Cooperative Eelgrass Project including the California Sea grant Extension Program, California Department of Fish and Game, Humboldt Bay Harbor, Recreation and Conservation District, and Humboldt State University and potentially adding additional partner groups that can support the monitoring program with staff and equipment resources such as the City's and County, NGO's, private industry, and the public.

8) Seek to implement pilot studies to investigate a) remediation of legacy substrate impacts through dredging/excavation of a shell hash/cobble site, b) lower-order channel excavation to alleviate historic/anthropogenic sedimentation as a means of eelgrass restoration, c) review/reconstruct eelgrass gains following tideland/saltmarsh restoration projects or look to integrate a monitoring component into a tideland restoration project to develop a better understanding of tidal prism/eelgrass expansion relations in Humboldt Bay.

9) Investigate potential for developing a multivariate, hydrodynamic model of Eelgrass habitat suitability in Humboldt Bay. This could improve the predictive capacity for eelgrass occurrence given the right combination of physical conditions that can be monitored and/or modeled.

5.0 REFERENCES

Barnhart, R. A., M. J. Boyd, and J. E. Pequegnat. 1992. The ecology of Humboldt Bay, California: an estuarine profile. Fish and Wildlife Service. United States Department of the Interior, Biological Report 1

Bernstein, B; K Merkel, B Chesney, M Sutula. 2011. Recommendations for a southern California regional eelgrass monitoring program. Prepared for the National Marine Fisheries Service. Technical Report 632.

Boyd, M.J., T.J. Mulligan, and F.J. Shaughnessy. 2002. Non-indigenous Species of Humboldt Bay, California. A report to the California Department of Fish & Game. Humboldt State University, Arcata, CA.

Burdick D.M., Short F.T., Wolf J. (1993) An index to assess and monitor the progression of the wasting disease in eelgrass, Zostera marina. Mar Ecol Prog Ser 94:83–90

Burgette, R. J., R. J. Weldon II, and D. A Schmidt. 2009. Interseismic uplift rates for western Oregon and along-strike variation in locking on the Cascadia Subduction Zone. Journal of Geophysical Research 114: 1-24.

Cole SG and Moksnes P(2015) Valuing multiple eelgrass ecosystem services in Sweden: fish production and uptake of carbon and nitrogen. Front. Mar. Sci. 2:121. doi:10.3389/fmars.2015.00121

Di Lorenso E. and N. Mantua. 2016 Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Climate Change 6, 1042–1047 (2016)

Duarte, C.M., Middelburg, J.J. & Caraco, N. 2005. Major role of marine vegetation on the oceanic carbon cycle. Biogeosciences, 2:1–8

Ecoscan Resource Data. 1992. Humboldt Bay Ecosystem Study. 28 pp.

Fourqurean, J.W., Duarte, C.M., Kennedy, H., Marbà, N., Holmer, M., Mateo, M.A., Apostolaki, E.T., Kendrick, G.A., Krause-Jensen, D., McGlathery, K.J., 2012. Sea-grass ecosystems as a globally significant carbon stock. Nat. Geosci. 5, 505–509.

Gilkerson, W. 2008. A spatial Model of Eelgrass (*Zostera marina*) Habitat in Humboldt Bay, California. Master's Thesis. Humboldt State University, Arcata, CA.

Gilkerson, W. and Leroy, T. 2013. Modeling Relative Sea-Level Change and its impacts to Eelgrass and Salt Marsh Distribution within Humboldt Bay, Northern California. Presentation for the 31st Annual Salmonid Restoration Conference, March 13-16, 2013, Fortuna, California.

Harding, L.W., Butler, J.H., 1979. The standing stock and production of eelgrass, Zostera marina, in Humboldt Bay, California. California Fish and Game 65, 151–158

Johnstone, J. A., and T. E. Dawson, 2010: Climatic context and ecological implications of summer fog decline in the coast redwood region. Proc. Natl. Acad. Sci., 107, 4533–4538

Judd, C. 2006. Mapping aquatic vegetation: Using bathymetric and hyperspectral imagery to classify submerged eelgrass in Humboldt Bay, California. M.S. Thesis, Humboldt State University, Arcata, California.

Keller, M. 1963. The growth and distribution of eelgrass (Zostera marina L.) in Humboldt Bay, California. M.Sc. thesis, Humboldt State University, Arcata, CA.

Keller, M., and S. W. Harris. 1966. The growth of eelgrass in relation to tidal depth. Journal of Wildlife Management 30:280–285

Kiriakopolos, Stephanie L.E.. 2013. Herbivory Selects for Semelparity in a Typically Iteroparous Plant Species, Zostera marina. M.Sci. Thesis SFSU.

Koch, M., G. Bowes, C. Ross, and X. H. Zhang. 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. Global Change Biology 19:103-132.

Laird, A. 2010. Humboldt Shoreline Inventory Mapping and Sea Level Rise Vulnerability Assessment. State Coastal Conservancy.

Laird, A., B. Powell, J. Robinson and K. Shubert. 2007. Historical atlas of Humboldt Bay and the Eel River delta. Humboldt Bay Harbor, Recreation, and Conservation District, Eureka, CA.

Laird, A., B. Powell, and J. Anderson. 2013. Phase 1: Humboldt Bay Shoreline Inventory, Mapping and Sea Level Rise Vulnerability Assessment. Prepared for the State Coastal Conservancy.

Lee, D. E., J. M. Black, J. E. Moore and J. S. Sedinger. 2007. Age-specific stopover ecology of black brant at Humboldt Bay, California. Wilson Journal of Ornithology 119: 9-22.

McCone, K. and C.E. Tanner. 2009. Role of salinity in the susceptibility of eelgrass Zostera marina to the wasting disease pathogen Labyrinthula zosterae. Marine Ecology Progress Series (377) 123-130.

McGlathery, K.J., Reynolds, L.K., Cole, L.W., Orth, R.J., Marion, S.R. & Schwarzschild, A. 2012. Recovery trajectories during state change from bare sediment to eelgrass dominance. Marine Ecology Progress Series, 448, 209–221.

Mello, J. 2000. The areal distribution of Humboldt Bay (Humboldt County) California Eelgrass. Unpublished work. California Department of Fish and Game, Eureka, CA.

Merkel, K.W. 1991. Identifying impacts and developing mitigation for eelgrass (*Zostera marina*) meadows within developing and expanding marina. In: Ross, N.W. (ed.). 1991 Marina Research Reprint Series. International Marina Institute, Wickford, RI

Merkel & Associates. 1998 Analysis of Eelgrass and Shallow Water Habitat Restoration Programs along the North American Pacific Coast: Lessons Learned and Applicability to Oakland Middle Harbor Enhancement Area Design. August 1998.

Merkel & Associates. 2008. 2008 San Diego Bay Eelgrass Inventory and Bathymetry Update. Prepared for U.S. Navy Region Southwest Naval Facilities Engineering Command and San Diego Unified Port District.

Merkel and Associates, Inc. 2009. Baywide Eelgrass (*Zostera marina* L.) Distribution and Status within San Francisco Bay: Program Development and Testing of a Regional Eelgrass Monitoring Strategy. Prepared for California Department of Transportation, and NOAA-Fisheries. December 2009.

Merkel & Associates. 2013. 2013 Eelgrass Status in California. Presentation to Marine Region California Department of Fish & Wildlife. November, 7 2013, San Diego, California.

Merkel & Associates. 2013. Eelgrass (Zostera marina L.) Distribution and Status within San Francisco Bay: July 2013 Regional Eelgrass Monitoring Results. November 2013.

Merkel & Associates. 2015. 2015 Monitoring Report Morro Bay Eelgrass Recovery Program, Morro Bay, CA. Prepared for Morro Bay National Estuary Program. September 2015.

Merkel & Associates 2015. 2015 Southern California Bight Regional Eelgrass Surveys. Prepared for NOAA National Marine Fisheries Service, West Coast Region Protected Resources Division. December 2015.

Merkel & Associates. 2017**a**. Pre-Dredge Eelgrass Survey Report In Support of the Morro Bay 2017 Maintenance Dredging Project. May 2017

Merkel & Associates. 2017b. 2014-2016 San Clemente Island Eelgrass Inventory and 2016 Islandwide Eelgrass Monitoring Program, Naval Auxiliary Field, San Clemente Island, Naval Base Coronado, California. Prepared for NAVFAC Natural Resources Branch. February 2017-

Merkel & Associates. 2017c. 2016 Southern California Bight Regional Eelgrass Surveys. Prepared for NOAA/National Marine Fisheries Service, West Coast Protected Resources Division. March 2017.

Merkel & Associates. 2017d. Eelgrass Mitigation Bank Ledger and Asset Report 2017 Eelgrass Surveys Navy Mitigation Sites 1, 2, 4, 5, and 6, San Diego Bay. Prepared for Natural Resources Branch Southwest Division Naval Facilities Engineering Command. September 2017.

Moffit, J., C. Cottam. 1941. Eelgrass depletion on the Pacific coast and its effect upon black brant.US Fish and Wildlife Service, Wildlife Leaflet No.204

Moore, J. E. and Black, J. M. 2006a. Slave to the tides: spatiotemporal foraging dynamics of spring staging Black Brant. Condor 108: 661–677.

Moore, J. E., M. Colwell, R. Mathis and J. M. Black. 2004. Staging of Pacific flyway brant in relation to eelgrass abundance and site isolation, with special consideration of Humboldt Bay, California. Biological Conservation 115: 475-486.

Morro Bay National Estuary Program. 2013. Morro Bay National Estuary Program Morro Bay Eelgrass Report 2013. December 2013.

Morro Bay National Estuary Program 2012. Comprehensive Conservation and Management Plan, 2012 Update. Morro Bay, California.

Muehlstein LK (1989) Perspectives on the wasting disease of eelgrass Zostera marina. Disease of Aquatic Organisms 7: 211–221.

NOAA Fisheries, West Coast Region. 2014. California Eelgrass Mitigation Policy and Implementing Guidelines. October 2014.

NOAA Fisheries, West Coast Region. Eelgrass Data, California. Website. http://www.westcoast.fisheries.noaa.gov/maps_data/eelgrass_data.html

NOAA National Marine Fisheries Service. 1991. Southern California Eelgrass Mitigation Policy. July 31, 1991, as amended.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M and Williams SL. 2006. A global crisis for seagrass ecosystems. Bioscience. 56:987-996.

Palacios, S. L. and R. C. Zimmerman. 2007. Response of eelgrass Zostera marina to CO~ 2 enrichment: possible impacts of climate change and potential for remediation of coastal habitats. MARINE ECOLOGY-PROGRESS SERIES- 344

Patton, J.R. , T.B. Williams, J. Anderson, and T.H. Leroy. 2017. Tectonic land level changes and their contribution to sea-level rise, Humboldt Bay Region, northern California. U.S. Fish and Wildlife Service Final Report. 47 pp.

Pinnix, W.D., P.A. Nelson, G. Stutzer, K.A. Wright. 2012. Residence time and habitat use of coho salmon in Humboldt Bay, California: an acoustic telemetry study. Environ. Biol. Fish. Online May 2012.

Reynolds, L.K., L.A. Carr, and K.E. Boyer. 2012. A Non-native Amphipod Consumes Eelgrass Inflorescences in San Francisco Bay. Mar. Ecol. Prog. Series 451:107-118.

Schlosser, S., N. Kalson, and A. Pickart. 2005. Historical and current distribution of salt marsh and eelgrass in Humboldt Bay. Pp. 60-67 In: A Regional Perspective to Restoring Physical and

Ecological Processes in Humboldt Bay. Humboldt State University, March 14-15, 2005. 184 pp.

Schlosser, S. and A. Eicher (2012). Humboldt Bay and Eel River Estuary Benthic Habitat Project (PDF). University of California San Diego: California Sea Grant College Program Publication No. T -075. p. 246.

Shapiro and Associates, Inc. 1980. Final Humboldt Bay wetlands review and baylands analysis prepared for the US Army Corps of Engineers, San Francisco District, CA.

Shaughnessy, F. and J.Tyburczy. 2017. Investigating potential pH buffering capacity of Eelgrass (Zostera marina) habitat in Humboldt Bay, California. (In Press)

Shaughnessy, F. J., W. Gilkerson, J. M. Black, D. H. Ward, and M. Petrie. 2012. Predicted eelgrass response to sea level rise and its availability to foraging black brant in Pacific coast estuaries. Ecological Applications 22: 1743–1761.

Short, F.T. and S. Wyllie-Echeverria. 1996. A Review of Natural and Human-induced Disturbance of Seagrasses. Environmental Conservation 23 (1) 17-27.

Short, F.T. 2014. Eelgrass Wasting Disease: an Overview. Salish Sea Ecosystem Conference. 34. http://cedar.wwu.edu/ssec/2014ssec/Day1/34

Short, F.T. and S. Wyllie-Echeverria. 1996. A Review of Natural and Human-induced Disturbance of Seagrasses. Environmental Conservation 23 (1) 17-27.

Short, F.T., L. Muelstein and D. Porter. 1987. Eelgrass Wasting Disease: Cause and Recurrence of a Marine Epidemic. Bio. Bull. (173) 557-562.

Stillman, R. A., K. A. Wood, W. Gilkerson, E. Elkington, J. M. Black, D. H. Ward, and M. Petrie. 2015. Predicting effects of environmental change on a migratory herbivore. Ecosphere 6(7):1–19.

Swanson, C. R. 2015. Annual and seasonal dissolved inorganic nutrient budgets for Humboldt Bay with implications for wastewater dischargers. M.S. Thesis. Humboldt State University, Arcata, California.

Tennant, G. 2006. Experimental effects of ammonium on eelgrass (Zostera marina L.) shoot density in Humboldt Bay, California. M.S. Thesis. Humboldt State University, Arcata, California.

Waddell, J.E. 1964. The effect of oyster culture on eelgrass (Zostera marina L.) growth. Master’s Thesis. Humboldt State University, Arcata, CA.

Ward, D. H., A. Morton, T. L. Tibbitts, D. C. Douglas, E. Carrera-Gonzáles. 2003. Long-term change in eelgrass distribution at Bahía San Quintín, Baja California, Mexico, using satellite imagery. Estuaries 26:1529-1539.

Waycott, M., Duarte, C., Carruthers, T., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T., Williams, S.L., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proc. Natl. Acad. Sci. USA 106: 12377−123.

Appendix A. Partnership Meeting Attendees and Meeting Minutes

Partnership Meeting Attendees

Partner Meeting Attendees	10/20/16	11/28/16	2/6/17	9/11/17	9/29/17
Aldaron Laird (Trinity Associates)	x	x			
Bianca Hayashi (County of Humboldt Public Works)	x	x	x		
Brendan Thompson (N Coast Regional Water Quality)	x				
Cassidy Teufel (California Coastal Commission)	x		x	x	
Emily Benvie (City of Arcata)			x	x	
Emily Teraoka (Stillwater)			x	x	
Erik Schlagenhauf (Hogg Island Oyster Company)			x		
George Williamson (Planwest/Harbor District)		x	x	x	x
Greg O'Connell (SHN)	x	x	x		x
Jack Crider (Humboldt Bay Harbor District)			x	x	
Jennifer Kalt (Humboldt Coast Keeper)				x	
Jim Clark (Audubon Society Redwood Region)	x				
Joe Tyburczy (California Sea Grant Extension)	x	x	x	x	x
Joel Gerwein (California Coastal Commission)		x		x	x
Jon Finger (Hogg Island Oyster Company)			x		
Julie Neander (City of Arcata)	x				
Kasey Sirkin (ACOE)		x	x	x	
Kathy Rogers (Merkel & Associates)	x	x	x	x	x
Keith Merkel (Merkel & Associates)	x	x	x	x	x
Larry Doss (Humboldt Bay Harbor District)	x				
Lauren Garcia (California Coastal Commission)	x	x	x		
Lia Webb (GHD)	x				
Lucas Sawyer (Hog Island Oyster Company)	x		x		
Matt Goldsworthy (NOAA/NMFS)	x	x	x	x	x
Melissa Kraemer (California Coastal Commission)	x	x			
Miles Slattery (City of Eureka)	x	x			
Patrick Higgins (Humboldt Bay Harbor District)	x		x		
Randy Lovell (CDFW State Aquaculture Coordination)	x	x			
Rebecca Garwood (CDFW)	x	x	x	x	x
Stephen Kullmann (Wiyot Tribe)	x	x			
Tim Nelson (Wiyot Tribe)			x		
Vanessa Blodgett (Planwest/Harbor District)		x	x	x	x
Whelan Gilkerson (Merkel & Associates)	x	x	x	x	x
Hank Seemann (Humboldt County Public Works)				x	
Kurt Roblek (U.S. Fish & Wildlife Service)					x

Appendix B. Public Meeting Minutes