# Final Report: Development of a Bar-built estuary monitoring system and resource management framework tool for California State Parks


*Prepared by:*
Central Coast Wetlands Group at Moss Landing Marine Labs

*Prepared for:*
California Department of Parks and Recreation-Natural Resources Division (NRD)
United States Environmental Protection Agency
California Wetlands Monitoring Workgroup

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**Primary Contributing Authors:**

Kevin O'Connor
Ross Clark
Charlie Endris
Sarah Stoner-Duncan

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# Section 1-Introduction

## About this Document

This final report provides a framework to guide the development of a bar-built estuary (BBE) wetland monitoring program for California Department of Parks and Recreation (CDPR) at their coastal State Parks, describing standard data collection protocols. An associated wetland monitoring manual[1] was drafted as well to provide a more concise document describing just the methodologies utilized by CCWG. It is important for CDPR staff to use standardized and repeatable protocols and metrics among systems and district offices to evaluate and report the condition of the 134 bar-built estuary systems owned and/or managed by the California Department of Parks and Recreation.

## Background and Need

Bar-built estuaries, also termed river mouth lagoons, are unique and important coastal wetlands that form at the mouths of coastal watersheds. Connecting marine, freshwater and terrestrial ecosystems, BBEs are complex and dynamic systems that host a great diversity of aquatic habitats and ecosystem services. Typically, high winter streamflows and strong predominant north swell energy keep the stream mouth open; while in the summer, low streamflows and a concomitant shift of swells to the south, a sandbar forms at the mouth of the stream forming a lagoon disconnected from the ocean. As a result, water is impounded behind this bar, increasing aquatic and inundated marsh habitat during the otherwise drier summer months. BBEs can thereby provide important nursery habitat for aquatic species from both the freshwater and marine ecosystems, as well as salmonid species that migrate between the two, including species protected under the Endangered Species Act. Additionally, marsh and wetland habitat adjacent to the BBE channel are important for many resident and migratory species.

BBEs make up 51% of the estimated 539 coastal confluences in California (Heady et al. 2014). The complexity and dynamics of the BBEs along the coast, and thus the extent, diversity and dynamics of ecological services have made documenting this diversity difficult. Further, many BBEs have been physically altered, developed or historically mismanaged resulting in dramatic losses in wetland acreage and ecological services (CCWG, 2013).

New threats to BBEs, and the services they provide, include artificial management of bar closure periodicity for flood control and water quality objectives, along with potential future hydrologic alterations due to climate change impacts and increased demand for upstream freshwater resources. Some beach bar alterations are unavoidable within urbanized systems due to legal water diversions, flood protection, and protection of coastal infrastructure. However, there are a number of BBE characteristics that can be addressed and improved even in the face of inevitable human alterations (Largier et al. 2019).

State regulatory and resource management agencies are routinely tasked with making management decisions, through permitting of development projects and/or artificial breaching activities, without a full understanding of the impact these projects have on BBE resources and species. Further, many management decisions are made with a single species management focus. Thus, there is a critical need for a more detailed understanding of these dynamic ecosystems individually and in terms of their shared characteristics in order to direct

[1] California Bar-built Estuary Monitoring Manual: USEPA Three-Tiered Monitoring Strategy for Bar-built Estuaries managed by California Department of Parks and Recreation. CCWG March 2020.

management, conservation and restoration actions, and ensure the long-term health and productivity of these coastal ecosystems.

Implementing standardized monitoring protocols in BBEs across the state will enable CDPR and other state agencies to generate the information necessary to devise better strategies to enhance BBE habitats for multiple objectives (including upgrades to visitor services) and species, prioritize limited agency restoration resources, evaluate the effectiveness of management actions and strategies, and properly mitigate secondary impacts of management efforts on species and ecosystem services.

## Setting up a Monitoring and Assessment Program for BBEs

The implementation of a monitoring plan as described in this document and the accompanying monitoring manual will dramatically increase our understanding of the complexities and dynamics of BBEs and how current resource management decisions are influencing condition and functions. The intent is to establish metrics for gauging restoration success, and evaluate the ecosystem services provided by individual wetlands and document how they change through time. By combining the use of standard assessment protocols (California Rapid Assessment Method for Wetlands) with GIS-based watershed stressor analyses, historical habitat change analysis, and species and site specific indicators of condition, this monitoring plan will assist State Parks staff in identifying and prioritizing restoration actions, inform broader watershed management activities and document how actions lead to a change in BBE condition. This approach will promote geographically-defined wetland protection, restoration, and management. By maintaining and updating data in a comprehensive database (EcoAtlas.org), CDPR will be able to evaluate progress towards meeting wetland objectives.

The monitoring plan can serve as the basis for an EPA Level 1-2-3 wetland monitoring framework, forming a standardized inter-park and district monitoring strategy for BBE resources. The implementation of this strategy can be supported both by existing staff and programs at the district level and by the Natural Resources Division in Sacramento.

Note: the data generated from the USEPA Region 9 Wetland Program Development grants which funded this project are available on the CCWG website[2,3], through the EcoAtlas[4] portal and the CEMW online portal[5].

## Introduction to EPA Three-Tiered Monitoring Structure

In 2002, a consortium of scientists and managers from around the state began developing a monitoring and assessment program for wetlands modeled after USEPA's Level 1-2-3 framework. The fundamental elements of this framework are as follows (modified from WRAMP 2010 and USEPA website, accessed June 2015; Figure 1):

> Level 1: A broad landscape-level characterization consisting of wetland and riparian inventories (e.g. National Wetland Inventory) or to answer questions about wetland extent and distribution. Assessment results can also provide a coarse gauge of geology and hydrology of a watershed, broad impacts, or wetland type.

> Level 2: Rapid assessment of condition, which uses cost-effective field-based diagnostic tools to assess the condition of wetland and riparian areas. Level 2 assessments answer questions about general

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2 https://www.mlml.calstate.edu/ccwg/wetland-research/
3 https://www.mlml.calstate.edu/ccwg/estuary-map/
4 https://www.ecoatlas.org/
5 https://mywaterquality.ca.gov/eco_health/estuaries/index.html

wetland health along a gradient through qualitative assessments and “stressor checklists”. These assessments can be replicated in the future to document change in habitat condition.

Level 3: Intensive site assessments to provide data to validate rapid methods, provide more thorough or rigorous datasets on specific species or habitats, characterize reference conditions, and diagnose causes of wetland condition observed in Levels 1 and 2. Level 3 assessments can be used to test hypotheses and provide insight into functions and processes.

All three Levels of the USEPA’s three-tiered structure should be implemented as needed and funding is available. Level 1 and 2 provide needed preliminary information on wetland area and condition which is needed to develop and implement a site-intensive (Level 3) monitoring program. The strength of site-intensive data collection to document site specific function, species abundance, or detailed restoration trajectories is a vital component of any monitoring program. The adoption of all thee “tiers” in the monitoring framework have been found to provide site specific information needed for permitting and local management efforts while also providing the integrated data necessary to track statewide management of the resource.

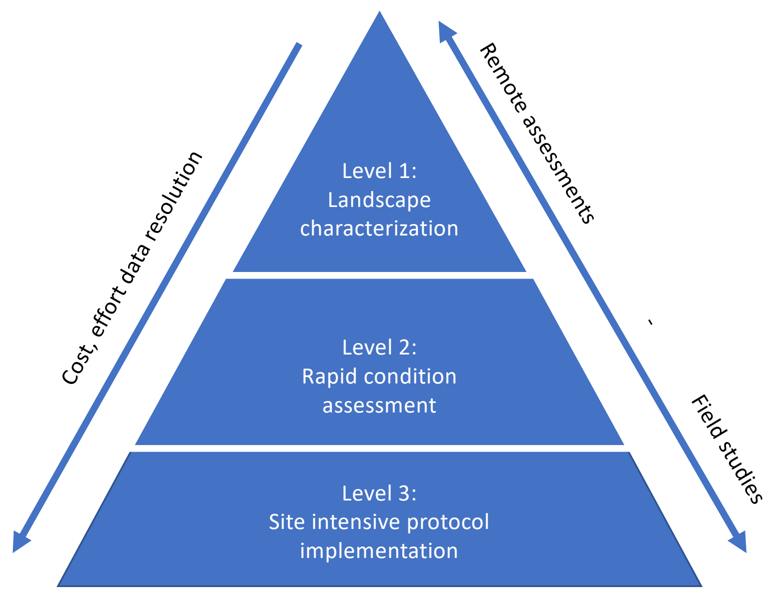



**Figure 1. Conceptual model of USEPA three-tiered wetland monitoring structure**

## Connection to WRAMP and EPA

The State of California and the California Wetlands Monitoring Workgroup (CWMW) both call for consistency in wetland monitoring and have integrated the work of the State Wetland and Riparian Monitoring Program[6] into their operations where feasible. The State Wetland and Riparian Monitoring Program (WRAMP) consists of coordinated, comparable regional and statewide efforts that use standardized methods to monitor the effects of natural processes, climate change, and government policies, programs, and projects on the distribution, abundance, and condition of wetlands and riparian areas[7]. This manual aims to address several challenges and

[6] https://mywaterquality.ca.gov/monitoring_council/wetland_workgroup/docs/2010/tenetsprogram.pdf
[7] https://mywaterquality.ca.gov/monitoring_council/wetland_workgroup/wramp/index.html

gaps identified in the California Wetland Monitoring Workgroup's WRAMP, namely the standardization of wetland assessment protocols for bar-built estuaries.

# Section 2-Understanding BBEs: Definitions & Characteristics

## Classification System

California has a number of wetland classification systems in use including Cowardin Classification System, Hydrogeomorphic Wetland Classification System (HGM), Coastal and Marine Ecological Classification Standard (CMECS), and California Rapid Assessment Method (CRAM). Each of these classification systems provides unique methods to characterize a set of wetland types that exist along any definable linear scale. Many of these classification systems suggest a temporal uniformity that does not exist in the natural environment. The most useful classification methods reflect the seasonal, inter-annual and decadal fluctuations in hydrogeomorphic conditions. They also help to distinguish systems that still function in this natural temporal flux from those systems that have been altered through management, yet still exist within an acceptable subset of the natural conditions to maintain the original habitat classification.

### CCWG Coastal Confluence Classification

The following California coastal confluence classification was developed by CCWG for an inventory of all coastal confluences in California. The classification was used as the sample frame from which sites were selected for the verification and validation of the CRAM module for Bar-built estuaries and completion of assessments of bar-built estuaries along the coast. (Images taken from Google Earth and The California Coastal Records Project)

*Bar-built Estuary (BBE):* In systems with a strong fluvial influence, there is sign of estuary mouth closure by the formation of a sand bar at some point during the year. A pond forms behind the bar and connection with the marine environment is reduced or severed.

*Example: Santa Maria River*

*True Lagoon:* Similar to bar-built estuaries, a sand bar forms across the mouth of the system creating a pond or lake with reduced or severed connection with the marine environment. However, there is a very small watershed and little fluvial influence and the system (may) open infrequently.

*Example: Stone Lagoon*


*Open River Mouth:* A very large coastal confluence that does not close to the marine environment due to large freshwater flows or local geology, but frequently shows some effect of a bar formation.

*Example: Klamath River*


*Bay/Estuary:* open bay with fringing estuarine wetlands or semi-enclosed estuary that is always open to tidal action.

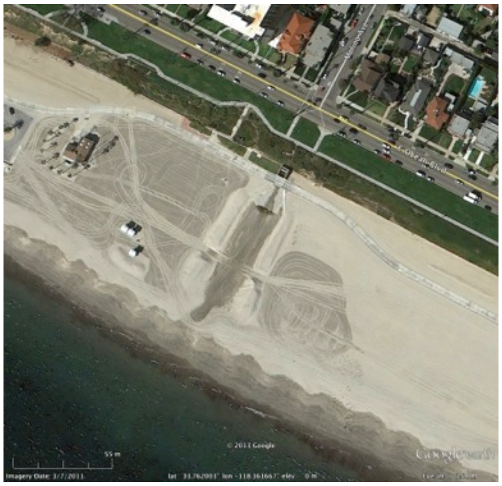
*Example: Drakes Estero*

*Creek Mouth:* a small coastal confluence that does not close off to the marine environment from the formation of a sand bar or form a ponded system. This may be due to natural reasons (steep gradient or large grain size on the beach), or anthropogenic in that it used to be a BBE but lost all habitat and ability to close.

*Example: Big Devil's Canyon*

*Urban Drain:* a coastal confluence in an urban setting with no obvious watershed area or historical drainage feature.

*Example: Long Beach-Molino Ave.*



## Bar-built Estuary Definition

Bar-built estuaries are the reaches of coastal rivers and streams that are ecologically influenced by seasonal closures of their tidal inlets through the formation of a sand bar or small barrier beaches. The BBE beach berm formation and resulting marine/freshwater hydrologic interactions are driven by a dynamic set of processes that vary regionally depending on watershed and climatic conditions, the volume of river sediment input, long-shore sediment transport, and wave exposure. The frequency and duration of inlet closure can be natural or managed. Many of these systems frequently exhibit prolonged non-tidal phases, seepage tides, or significant tidal choking, resulting in the tidal regime being muted in comparison to the adjacent marine system when the tidal inlet is open. The salinity regime of a bar-built estuary can be highly variable, ranging from fresh throughout very wet years to hypersaline during extended droughts. This salinity regime trends toward freshwater in more northern systems where rainfall averages are greater. Depending on the local geology, these systems can support a vast set of tidally influenced wetland resources or support little more than a channel width lagoon, based on the level of confinement provided by adjacent hills.

## Bar-built Estuary Characteristics

Unique processes such as beach bar formation, seasonal flooding, and ocean overtopping create variability in surface water elevations and salinity gradients that are unique to these systems (Figure 2). The presence and absence of these events will determine the level of services and condition. Decreases in the level of services and condition often correlate with human management and watershed impacts. The below hydrograph demonstrates how marine and watershed dominance (and the interaction of both systems) can lead to varying salinity and water levels. These variable hydrologic states support a complex set of habitat types and an array of fresh, marine and terrestrial species.

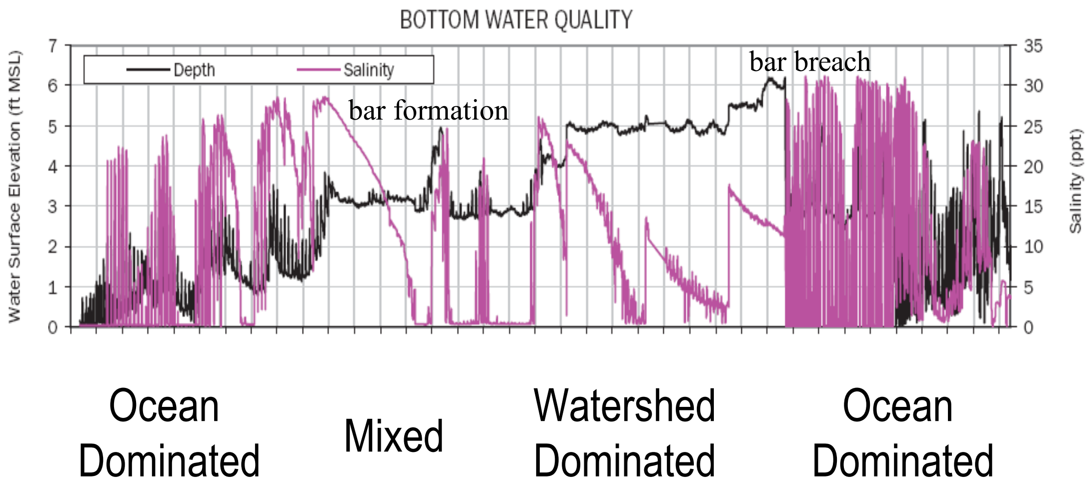



**Figure 2. Hydrograph indicating the changes in depth and salinity of an BBE over time (derived from 2nd Nature).**

## Characteristic Hydrologic Processes

(adapted from Australian Online Coastal Information- www.ozcoasts.org.au and Largier et al. 2018).

The mixing of fresh and marine waters drives ecological functions of BBEs. Unlike open estuaries, tidal exchange within BBEs is highly variable (not semidiurnal) due to beach bar dynamics leading to unique water chemistry and hydraulic conditions. Documenting this variability using monitoring equipment of varying costs can help define current hydrologic conditions and provide insight into management actions needed to reestablish (where necessary) the natural, dynamic mixing of waters (Figure 3).

### *Freshwater input*

Freshwater enters from the watershed. Although the volume of freshwater input varies regionally and seasonally (depending on local watershed and climatic conditions), it is typically relatively high in most riverine BBEs.

### *Fresh water inundation of low-lying areas*

Floods, or high runoff events, driven by climatic and watershed processes, can result in the inundation of low-lying marsh areas adjacent to the main channel by fresh water. This water often supports freshwater wetland ecosystems (side channel and backwater habitats), and typically is either taken up by vegetation, or evaporates. In some cases, there is a direct hydrologic link to the main channel allowing the water to drain back out. Inundation of these marsh areas can also occur when the mouth of the system closes.

The natural formation or expansion of backwater habitats is possible under some infrequent extreme fluvial flood events that cause erosion of meander scars or secondary channels, followed by abandonment of channels (WWR, 2010).

### *Freshwater flow*

When the mouth is open, current flow in channels is strong, due to their small relative volume, and the consequent short residence time of water (the time taken for water to travel through the BBE). Floods may completely force marine water out of the BBE.

When the mouth is closed, water circulation in BBE systems generally ranges from well mixed to salinity-stratified, depending on the degree of wave over wash from the marine environment, volume of freshwater input, and climate (Nichols et al., 1985). In most cases, BBEs have lower salinity water towards their head, with the salinity of the water in the central basin and next to the inlet increasing. The volume of freshwater causes stratification (or layering) in the water column, which varies with seasonal flow. Buoyant low-salinity fresh water floats above the denser, high-salinity ocean water.

### *Salt wedge inflow of more dense seawater*

After bar formation, high tides often continue to wash over the bar for several weeks and can continue for the remainder of the summer during extreme high tide events. The volume of this addition is usually relatively insignificant compared to the freshwater flow, however, this depends on the size of the BBE (Smith, 1990).

A 'salt-wedge', or intrusion of denser saline marine water can penetrate the BBE through the entrance when the mouth is open. Riverine BBEs are generally characterized by limited tidal intrusion because of friction effects and the relatively strong river flow. Some mixing occurs at the interface between the less-dense freshwater, and higher-density marine water. The distance that the salt-wedge penetrates is dependent on tidal range and the amount of fluvial flow received by the system (Kurup et al., 1998, WWR, 2008). During high fluvial flow events (which may be seasonal), fresh floodwater rapidly pushes the salt water intrusion seaward (beyond the mouth), completely removing stratification from the delta (Hossain et al., 2001, Eyre, 1998).

### *Seepage through the Bar*

Seepage through the bar is potentially sufficient to stabilize BBE water levels at low freshwater inflows, preventing a bar breach from occurring. However, the rate of seepage depends on the water depth and hydraulic pressure that it provides, which can result in deep impoundments. Alternatively, at extremely low inflows, seepage can result in very low depths behind the berm. When this occurs, seepage from the ocean can occur at high tides, which can increase salinity stratification and mean salinity in the BBE (Smith, 1990).

### *Outflow of brackish water*

Exchange of ocean water and estuarine water occurs through the entrance of the estuary, although the amount of exchange depends on the size and length of the entrance channel. Often the outflow of freshwater exceeds the inflow of marine water.

### *Internal currents*

Wind-induced currents can drive the internal circulation of larger lagoonal systems. Secondary circulations can be generated by tides. Tidal ranges are often small (~0.1 m) compared to tidal ranges in the ocean, and internal circulation patterns are disrupted during extreme high-flow events.

### *Evaporation*

In general, due to the relatively low surface area of most BBEs, evaporation is a minor component (depending on climatic conditions) and does not exceed river input. While significant evaporation can occur in larger lagoonal systems, it does not exceed the amount of freshwater input (Heggie et al., 1999).

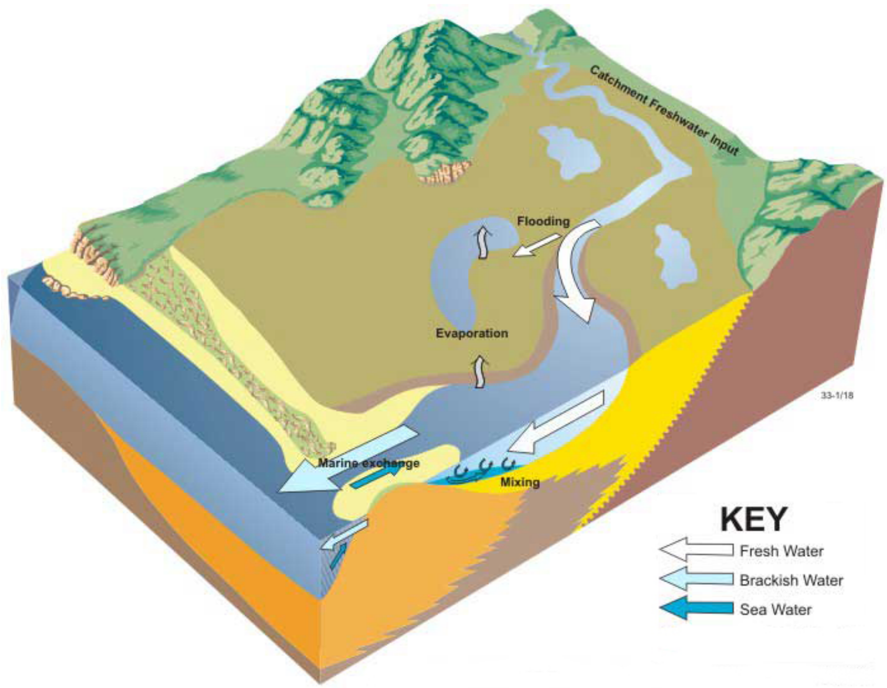



**Figure 3. Conceptual figure of characteristic hydrologic processes for a bar-built estuary (figure adapted from Australian Online Coastal Information- www.ozcoasts.org.au).**

## Characteristic Sediment Transport Processes

(adapted from Australian Online Coastal Information- www.ozcoasts.org.au).

Sediment transport processes, both fluvial inputs from the watershed and littoral transport along the coast drive mouth state, water elevation and marsh accretion rates. Under natural conditions, the marsh plain is seen to form at an elevation that supports existing plant communities through periodic flooding and drying cycles unique to each system. When watershed sediment transport is altered, marsh and channel conditions may be compromised leading to excessive sedimentation or erosion. Understanding both sediment supply dynamics and erosion and accretion processes can help define coastal and watershed management actions needed to reestablish system stability (Figure 4).

### *Fine and coarse sediment input from the watershed*

Fine and coarse sediment enters the estuary from the watershed. The amount of sediment input varies regionally depending on watershed and climatic conditions, and the volume of river input. However, the amount of terrigenous sediment delivered to these systems is usually relatively large. Seasonal and climate factors dominate the function of BBEs, with episodic high-flow events causing intense flushing, sedimentation, and erosion in the main channels and floodplain (Eyre et al., 1999).

### *Deposition of fines in freshwater wetlands*

Limited deposition of fine sediment (including clays, muds and organic material) occurs upon the floodplain during high flow events (Jones et al., 1993). This is enhanced by the baffling effects of floodplain vegetation associated with marsh areas, and leads to slow vertical accretion of the floodplain. Some lateral deposition of sediment can occur, including the development of coarse sediment point-bar deposits.

### *Fine sediment accumulation*

Fine sediment (i.e., muds, clays, and organic material) is deposited on the fringes of the central basin by river processes, and tides. Deposition in these environments is aided by the baffling effects of vegetation such as saltmarshes (Boorman et al., 1998, Brown, 1998, Temmerman et al., 2003). Coarse sediment (i.e., sands and gravels) may also accumulate in the fringing environments during floods. Biological activity and waves cause significant reworking of fine sediment on un-vegetated intertidal flats.

### *Downstream transport of fines*

BBEs are characterized by net seaward-directed sediment transport, associated with the relatively high river discharge and relative absence of available accommodation space for sediment deposition (Bhattacharya et al., 1992). Consequently, fine suspended sediment, and coarse sediment (as bedload) is moved downstream along the bottom of the channels, due to unimpeded river flow. Some lateral deposition of both types of sediment can occur, including the development of coarse sediment point-bar deposits.

### *Transport of fine material into the central basin*

Suspended sediment is transported into the central basin, where it is deposited in a low-energy environment. Benthic micro-algae (BMA) assist in the stabilization of fine sediment (Wulff et al., 1997, Cahoon et al., 1999, Murray et al., 2002). Seagrasses, where present, also promote sedimentation and stabilize the substrate (Moriarty et al., 1985). The low-energy conditions, and large relative size of the central basin means that this region is the primary repository for fine material and particle-associated contaminants (Hodgkin et al., 1998, Heggie et al., 1999, Heap et al., 2001, Harris et al., 2002). Resuspension of the fine sediment can occur in BBEs with either very shallow central basins or a lack of stabilizing vegetation, causing significant turbidity.

### *Export of sediment*

The majority of deposition occurs seaward of the mouth, and results in the net export of sediment into the marine environment (Jones et al., 1993, Hume et al., 1993). Fine suspended sediment is generally transported offshore, coarser sediment tends to accumulate close to the entrance, although this material is generally redistributed by wave action (Melville, 1984, Cooper, 1993).

### *Tidal infilling by coarse marine sediments*

At the entrance, tidal currents are locally accelerated in the constricted entrance, and form flood and ebb tidal deltas (Roy, 1984). Sedimentary processes are dominated by the landward transport of coarse sediment derived from the marine environment (Green et al., 2001). Sediment can be exported to the ocean through the inlet, particularly during spring tides and flood events (Harvey, 1996).

After bar formation, high tides often continue to wash over the bar for several weeks and can continue for the remainder of the summer during extreme high tide events (Smith, 1990).

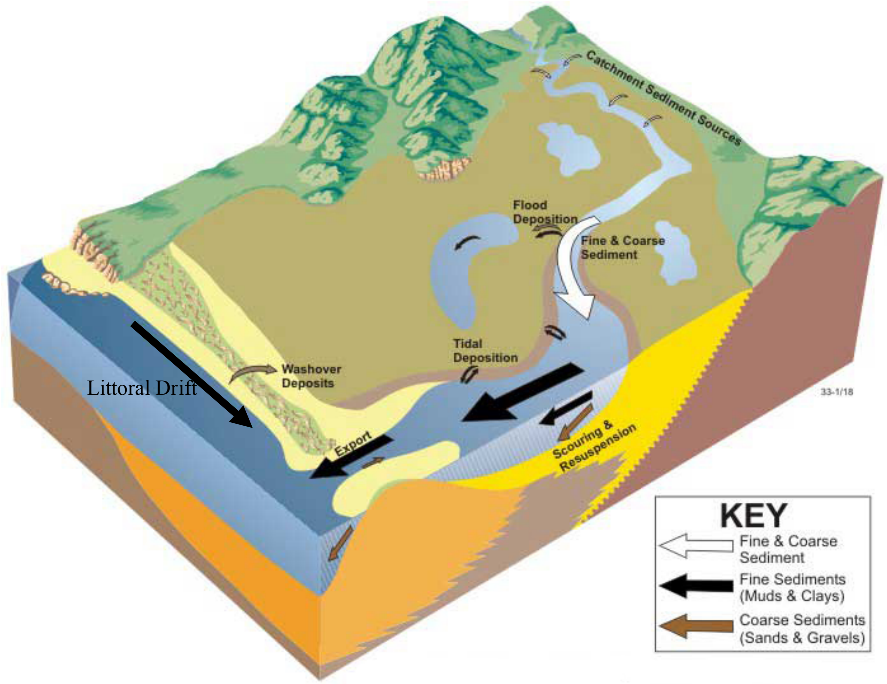



**Figure 4. Conceptual figure of characteristic sediment processes for a bar-built estuary (figure adapted from Australian Online Coastal Information- www.ozcoasts.org.au).**

## Bar Formation

Bar formation, and thus estuary closer, is dependent on a number of variables including: wave dynamics, sand abundance and distribution, coastline shape, streamflow, channel width and volume. When seasonal stream discharge declines in late spring, the sandbar closure is driven by coastal dynamics such as spring tidal conditions and southern swell events. If coastal swells deliver sufficient sediment to the beach berm to exceed the elevation of the lagoon water surface the mouth closes, reducing or isolating marine flow into the BBE.

Cross-sectional constrictions of lagoon width near the mouth, such as bridge structures, likely alter the formation of a sustained sandbar barrier, and can impair ability of the sandbar to remain intact. Heavily flood-controlled lagoons must accommodate lagoon water storage along the beach environment due to the significant reduction in the surface area of the lagoon and the associated lack of horizontal water spreading capacity within the leveed channel (Beck et al., 2006).

In many cases, coastal lagoons transition from a deltaic river-dominated system in the winter and spring, to a backwater fresh/brackish environment in the summer and fall. These changes in circulation and climate result in a relative increase in primary production rates and organic matter accumulation in lagoons from winter to summer.

## Emergent Marsh Community:

Natural sources of water other than input from the watershed that can influence BBEs include groundwater, surface runoff from adjacent uplands, and direct precipitation. The plant community of BBEs is highly correlated to spatial and temporal variability in water height as well as average seasonal groundwater heights.

Marsh habitat development on active floodplains is mainly controlled by the magnitude and frequency of flooding caused by watershed runoff and mouth closure. Floods cause complex patterns in topography and sediment texture that strongly influence the duration of inundation and permeability of floodplains. In addition to vertical recharge during overbank flooding, horizontal recharge through channel banks during high flows that do not exceed channel banks, and high base flows in fluvial channels can contribute to high water tables for adjacent floodplains.

## Anthropogenic Stressors

The condition of a BBE is determined both by natural processes and land use activities in its watershed. Activities that affect watershed runoff quantity and reduce water quality are likely to have deleterious impacts on multiple measures of BBE condition. Stressors are the anthropogenic events or activities that have deleterious effects on the physical and ecological functions of BBEs in California. These stressors should be documented and where possible quantified to aid management prioritization.

### *Altered freshwater input.*

Human activities in upstream reaches of coastal confluences can alter critical components of estuarine hydrodynamics which may result in fundamental changes to the physical, chemical and biological characteristics of estuaries, and in turn lead to a reduction in estuarine health. Reservoirs and diversion structures such as dams and weirs, and direct pumping of water from the stream channel for domestic, industrial and intensive agriculture can directly alter the natural magnitude and variation of riverine flows (Flemer et al., 2006).

### *Channel Modification.*

Modifications to stream channels such as channel straightening for flood mitigation or channel dredging can also directly impact these systems causing significant decreases in estuarine volume and productivity (Hofstra et al., 1987). Additionally, there can be impact on more subtle components of natural flow regimes such as the duration of high flow events.

### *Watershed Land Use.*

Land use and management practices, such as the removal of riparian buffers, clearing of native forests, and expansion of urban areas can change the natural timing, magnitude and duration of rainfall runoff and ultimately increase the volume of storm water that is generated within a watershed. Land use practices in the watershed can also increase sedimentation rates.

### *Urban encroachment/loss of floodplain habitat.*

Encroachment by urban development in the lower watershed and in the estuarine floodplain can lead to direct loss of habitat (HDR, 2008).

### *Mouth Management:*

Modification of the entrance of the bar-built estuary, either in the form of breaching or a permanent structure (bridge), can affect the volume and frequency of flood events and tidal flows, as well as the timing of annual breach events.

### *Contaminants and Nutrient enrichment.*

Excessive loads of contaminants nutrients can cause the eutrophication of coastal waterways. The general pattern of change involves a shift from large macrophytes (including seagrasses) towards fast-growing macroalgae and phytoplankton (including harmful species found in blooms) that can capture and use light more efficiently. High loadings of organic matter to the sediment promotes oxygen consumption through decomposition, and can potentially lead to anoxic or hypoxic events. Low dissolved oxygen concentrations (and toxic algae) can harm benthic invertebrates, fish, and other organisms. Nutrient enrichment can also compromise the ability of seagrass meadows and salt marshes to support fish and invertebrates even before a change in habitat areas occurs (Flemer et al., 2006).

## System Functions

Bar-built Estuaries positively influence a variety of highly valued hydrological and ecological processes. These positive influences are termed functions. The most common functions of Bar-built Estuaries are briefly described below. Functions can be inferred through the presence of various habitat structures and by the presence of indicator species that benefit from these ecological processes.

### *Fish and Wildlife Support*

Bar-built Estuaries provide water, food, and refuge for many native species of residential and migratory wildlife, including numerous endangered or threatened plants and animals. They provide vital resting, breeding and feeding areas for migrating waterfowl. Additionally, they serve as nursery habitat, and drought refuge for anadromous fishes, turtles and frogs. Unique services include;

- winter/spring anadromous passage,
- summer rearing,
- winter refuge,
- spring feeding/ growth
- suitable conditions within the estuary complex all year
- escape cover from predators
- spring brackish transition/ feeding habitat
- configuration and size/depth can affect summer rearing
- refuges against droughts and floods
- abundant invertebrate food from marsh and marine detritus

### *Water Quality Enhancement*

Chemicals and nutrients can enter a wetland through surface water and sediment, or through ground water. The major inorganic nutrients entering wetlands are nitrogen and phosphorus. In the wetland, nitrogen and phosphorus are removed from the surface water and transferred to the sediment, wetland plants or atmosphere.

### *Recreation*

Bar-built Estuaries provide a variety of recreational uses including bird-watching, hiking, camping, and hunting. They are often the subject visual arts.

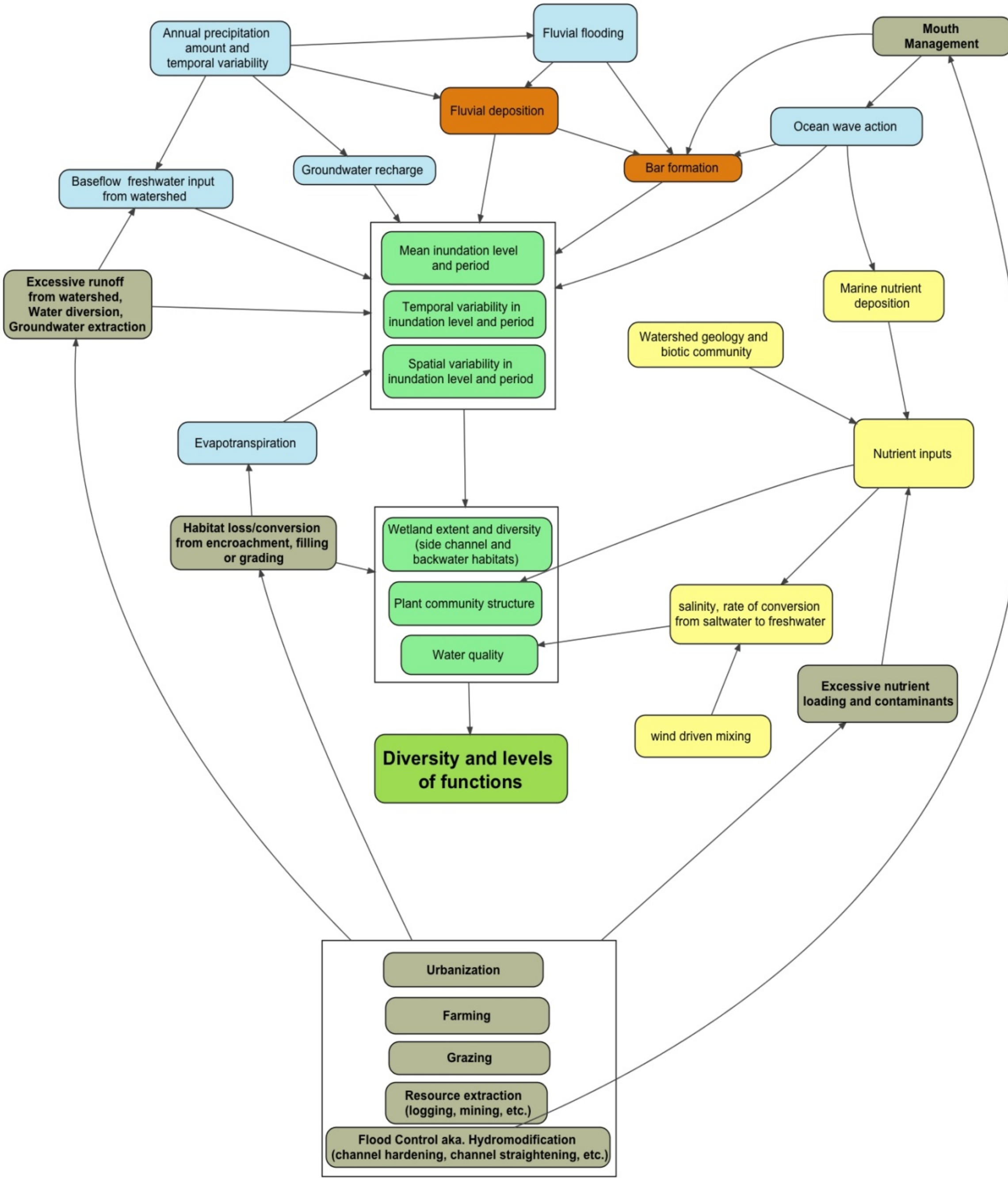



**Figure 5. Conceptual model of natural inputs and outputs of water (blue boxes) and sediment (brown boxes), stressors and their effective processes (gray boxes), nutrients (yellow boxes), and BBE responses (green boxes).**

## Effect of Mouth State on Estuary Functions and Conditions

### Overview

The sand barrier between the estuary and the sea is continuously altered by the action of waves, tides, winds, and river outflow effecting sediment erosion, transport and deposition. Bar-built estuaries can be separated from the sea at times when deposition due to the action of waves or wind exceeds the scouring action of flows due to river and tides. Mouth closure is common during the dry season and low-inflow conditions can persist for many months during a drought or in systems with weak river inflow. However, if there is a net water inflow, water level rises until inflows are balanced by a combination of evaporation, seepage through the sand barrier, and limited outflow over the sand barrier. During these perched conditions, water levels often rise enough to inundate marshes, creating high-water conditions in the marsh that differ from tidal systems (Figure 6). Breaches can occur naturally when overflow past the sand barrier is strong enough to erode a new channel – this occurs most commonly in winter. A seasonal cycle of opening and closing occurs naturally and is observed in many regions globally – including California, Australia, New Zealand, South Africa, Portugal, Chile and many other countries (e.g., Ranasinghe & Pattiaratchi 2003; Perissonotto 2010).

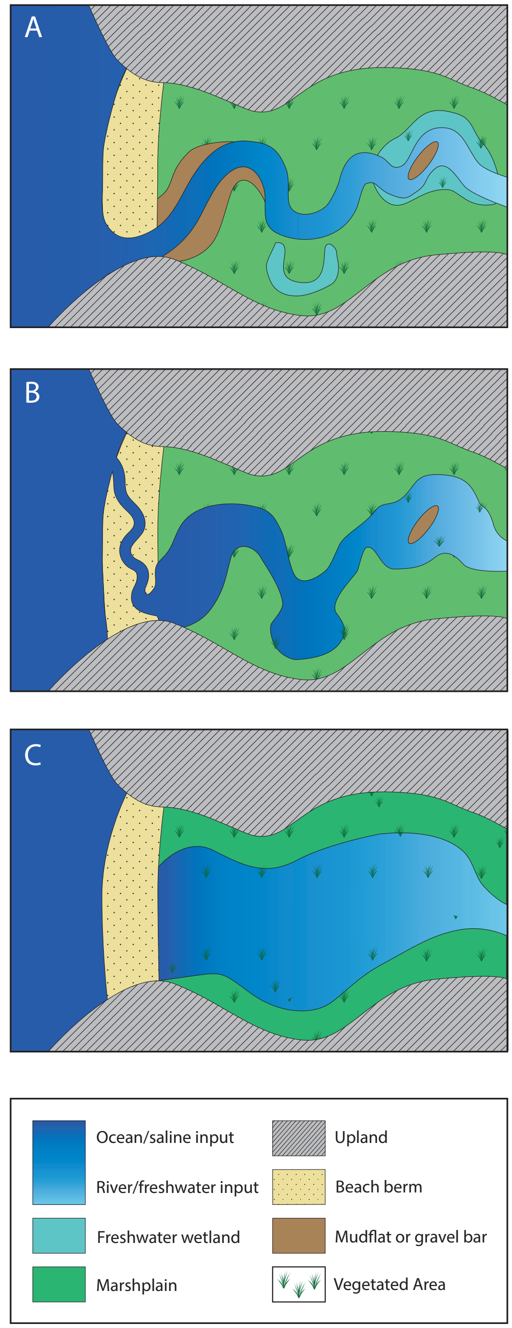



**Figure 6. The three primary bar formation phases of a BBE. A) Fully open to tidal input B) Partially open to tidal input C) Closed to all but largest wave overtopping events (figure adapted from Australian Online Coastal Information- www.ozcoasts.org.au).**

### Water Elevation

- When the mouth is open, water levels vary tidally. However, tidal fluctuations are typically muted in an estuary with a constricted mouth as the tidal range is limited by the rate at which water can be conveyed through the mouth. Water level minima at low tide are managed by the height of the base of the mouth channel (Behrens et al. 2013).
- During strong river flow, water levels rise in the estuary even when the mouth is open, owing to the constriction of outflow through the mouth.
- When the mouth is closed in wetter regions, during rainy seasons, and/or in urban watersheds with high dry-weather flows, a positive water balance (net inflow) can cause water levels to rise when the mouth is closed. Rising water elevations may inundate marshes and adjacent flood plains
- In arid regions or dry seasons, BBE water level may drop during prolonged closures due to a negative water

balance. This results in drying of the marshes and mudflats in late summer. In some BBEs seepage through the sand barrier is significant and this may either accelerate lowering of the water level (if BBE water level is above ocean), slow declines or raise water elevation (if BBE water level is below ocean).

- There is often a balance between river inflow and outflow to the ocean due to high BBE water levels that drive barrier overflow and seepage through-flow. This results in water levels that remain relatively steady for months (i.e., perched state). Further, as water level rises, the areal extent of ponded water increases, extending over the marsh plain, thus reducing water level fluctuations and increasing total evaporative water loss.

- Estuary water elevation may increase due to wave overtopping events at high tide (Williams et al 2014).

- Sand barrier elevation and maximum water levels in the estuary are expected to increase in the future due to sea level rise (Wainwright 2012; Booysen 2017). This prediction assumes sediment is available to build the sand barrier. Sufficient sediment to support marsh accretion is also site-specific and uncertain.

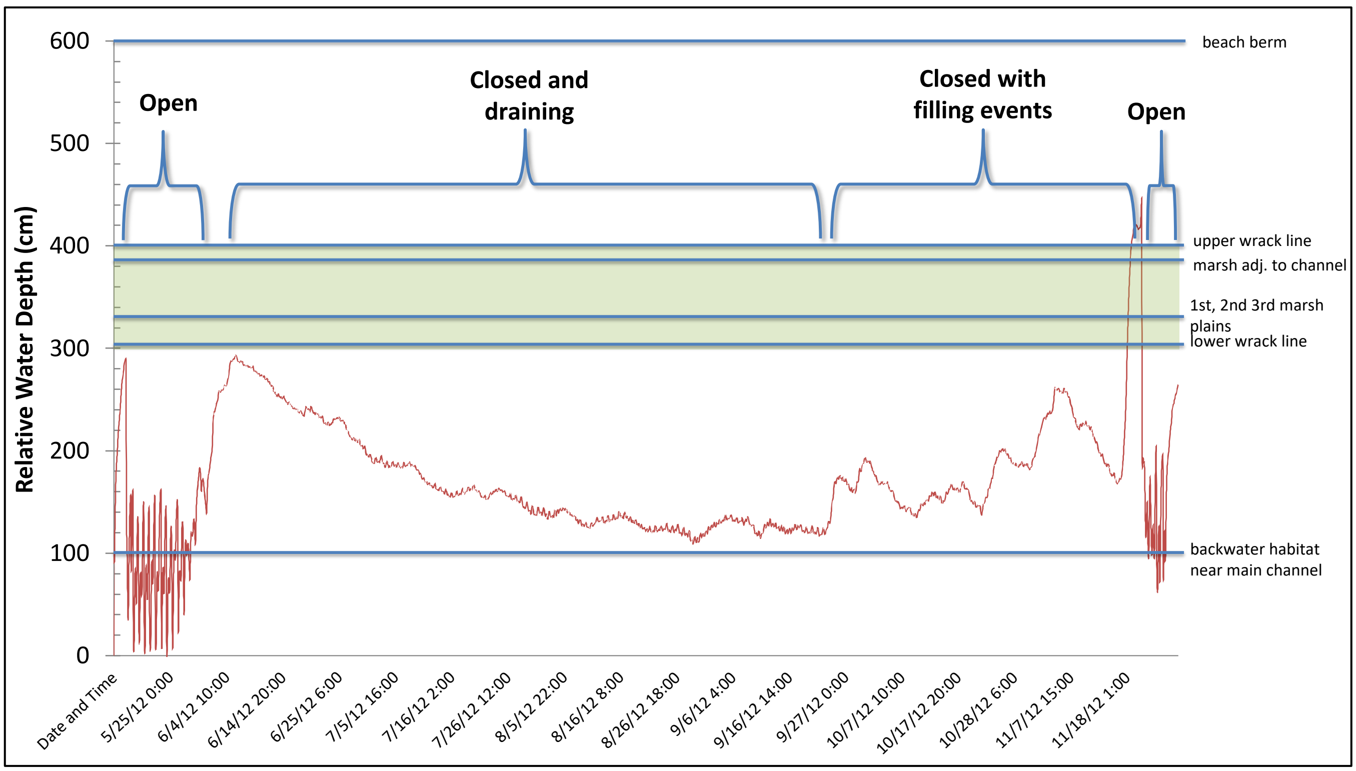



**Figure 7. Water elevation (red line) in the main channel of the Gualala River estuary – a BBE in northern CA. This plot shows tidal (open) and non-tidal (closed and draining or filling) states. Blue lines represent the elevations of different features on the marsh plain, while the green band represents the overall marsh plain elevation. Data provided by CCWG.**

## Stratification

- When the mouth is open, a salt-wedge tidal intrusion of seawater results in tidally varying stratification in some BBEs (Largier & Behrens 2010) while in others the tidal flows can keep the estuary mixed resulting in strong longitudinal gradients in salinity and temperature (Gale et al. 2007).
- When tides are strongly muted, or when BBEs are closed or perched, a layer of seawater can be trapped at depth in the estuary, with low-salinity water near-surface, resulting in water column stratification. Depending on the wind, water depth, and depth/strength of stratification, the water column may mix after a few weeks or months, yielding a homogeneous water column. In BBEs where seepage is important, the dense deep water may be lost through the sand barrier and the water column mixes sooner.
- Stratification in closed BBEs can be enhanced when seawater over-washes the sand barrier during big waves at high tide (Nylen 2015) – and also in some systems by seepage of seawater into the BBE when water levels are lower than in the ocean. Freshwater inflow during closures increases the thickness of the upper layer and thus also increases the vertical stability of the water column.
- When the mouth is perched, with outflow of the surface layer, strong stratification may get stronger as wave/tide over wash is more likely and also because the outflowing surface layer sharpens the stratification.

## Water Quality

- When the mouth is open, the outer estuary is characterized by cold, oxygenated ocean waters at high tide and warmer, low-salinity water at low tide (Largier & Behrens 2010). It is unusual to observe extreme water quality levels as the outer basin is readily flushed by tides. However, in the inner basin waters can warm and may be subject to eutrophication effects and/or pollutant accumulation.
- When a closed/perched/muted BBE is stratified, hypoxia (<2 mg/L) can develop in the high-salinity bottom layer due to an accumulation of biological oxygen demand (BOD) and an absence of ventilation through vertical mixing (Hewett 2015; Sutula et al 2016). At times, this bottom layer can become anoxic when the mouth is closed (Largier et al. 2018).
- Persistent anoxia (<0.5 mg/L) can lead to an accumulation of reduced compounds in the lower layer (Sloan 2006; Richards et al. 2018). When mixed with overlying waters, these compounds drastically reduce oxygen levels throughout the water column.
- Where there is pollutant loading, particle-associated pollutants can accumulate in this trapped bottom layer.
- Seawater intrusion due to wave over wash during a perched/closed state reduces lower-layer hypoxia transiently, but it also enhances stratification and may lead to more severe hypoxia (Largier et al. 2018). Further, wave over wash events may import an abundance of marine algae and kelp that enhances BOD and exacerbates hypoxia.
- Oxygen levels may also decline following the annual die-off of aquatic vegetation (e.g., Potamogeton) or when waters inundate marshes on which there is an accumulation of decomposed plant material (e.g., Pescadero Lagoon, Largier et al. 2018).
- If a closed lagoon remains stratified, the bottom layer may remain cool, whereas if the water column mixes the entire lagoon warms up in summer, reaching temperatures stressful for juvenile salmonids.

- Alternatively, when a closed/perched/muted BBE is stratified, the bottom salty layer's temperature can increase in certain conditions in the absence of tidal cooling. These temperatures are harmful for juvenile steelhead and likely other fish in the lagoon (Smith 1990; Casagrande and Watson 2003; 2nd Nature 2015).

### Marsh Plain Condition

- When the mouth is open, intertidal marshes are inundated regularly during high tides (e.g. Los Peñasquitos Lagoon). When the mouth closed, intertidal marshes dry out if lagoon water level is low – alternately, they may be persistently inundated when water levels rise.

- Supratidal marsh plains found in BBEs are inundated during mouth closure events or perched conditions after water level has risen sufficiently (e.g., Pescadero Lagoon). These marshes are also inundated during storm events when high river inflow backs up in the estuary due to constricted outflow over the sand barrier (e.g., Russian River). During open mouth conditions, supratidal marsh plains are fully drained and may dry out (e.g. Scott Creek Estuary).

- The marsh plain within a BBE is subject to fluctuations in inundation (depth and duration) and salinity, which support a diversity of stratified plant communities, often residing at different elevations on the marsh plain, and different to those found in perennial estuaries. Thus, these fluctuations support a diversity of aquatic habitats and unique ecological functions, including benefits to terrestrial and estuarine species (feeding, reproduction, etc.) (Clark and O'Connor, 2019). For example, when a marsh plain is flooded, salmonids have access to the flooded marshes, preying on abundant invertebrates, using the side channels for cover, and avoiding high flows and predation in the main channel.

- BBEs that receive dry-weather flows when closed or perched (e.g., urban lagoons in southern California) can experience impacts to sensitive plant species by leaching salt from soils, reduced foraging habitat for listed bird species (Belding's savannah sparrow) as marsh habitat is inundated, and expansion of breeding habitat for vectors known to transmit West Nile virus to human hosts.

### Biotic Condition of the Channel

- When the mouth is open, fish can migrate between ocean and estuary, e.g., salmonids and flatfish (Hughes et al. 2014).
- When the mouth is open, imported pelagic nutrients can fuel estuarine primary production (phytoplankton, seagrass, macrophytes) while tidal exchange also serves to export algal blooms, precluding eutrophication effects.
- When the mouth is open, freshwater submerged aquatic vegetation may be constrained by desiccation and/or competition from brackish submerged aquatic vegetation in higher salinity water (DeDecker 1987).
- When the mouth is open, benthic invertebrate communities are dominated by marine taxa (Netto et al 2012).
- During prolonged closures, the extent and severity of hypoxia and/or high temperatures can severely constrain the quality and quantity of habitat available to fish, specifically juvenile salmonids. Further, when hypoxia prevents fish from using deeper water, they become more exposed to near-surface predation.
- Hypoxic conditions that develop at depth during closed/perched states do not pose a problem for tidewater goby.
- Closed/perched states provide ideal conditions for rearing of juvenile steelhead trout owing to the availability of food in the channel and also on inundated marshes and vegetated banks. Very high growth rates have been observed in Scott Creek (Bond et al 2008), Russian River (Matsubu et al. 2018) and Pescadero Lagoon (Huber 2018). However, this trophic benefit can be offset by hypoxia, either through removing deep, cool-water habitat (Boughton et al 2017) or through fish mortality during breach events following closure (Huber et al. 2018; Largier et al 2015).
- Benthic hypoxia/anoxia during closed state represents a loss of habitat for flatfish in estuaries.

# Section 3-Data Collection Protocols and Strategies

## Level 1: Landscape Level Protocols

### California's Coastal Confluences Inventory

A comprehensive inventory of California's coastal confluences (Heady et al. 2014) was completed through a state partnership that built off of previous efforts to include additional estuaries identified through National Wetlands Inventory (NWI) and aerial imagery (California Coastal Records Project). Within this inventory and associated geodatabase, we included georeferenced location, other locational information, size, available data, and estuarine classifications previously applied to each estuary. The inventory thus serves as a crosswalk between the CCWG classification, federally accepted marine and coastal habitat classification system, and estuarine classifications previously applied to various West Coast estuaries.

### Regional Footprint of State Park BBE Management

Bar-built estuaries make up 51% (276) of the estimated 539 coastal confluences in California (Figure 8). Of those 276 BBEs, 134 of them are located partially or entirely within a California State Park. The complete inventory and classification of coastal confluences in California is available on the CCWG website[8].

The size distribution of BBEs in State Park Management is representative of the overall population size distribution in California (Figure 9).

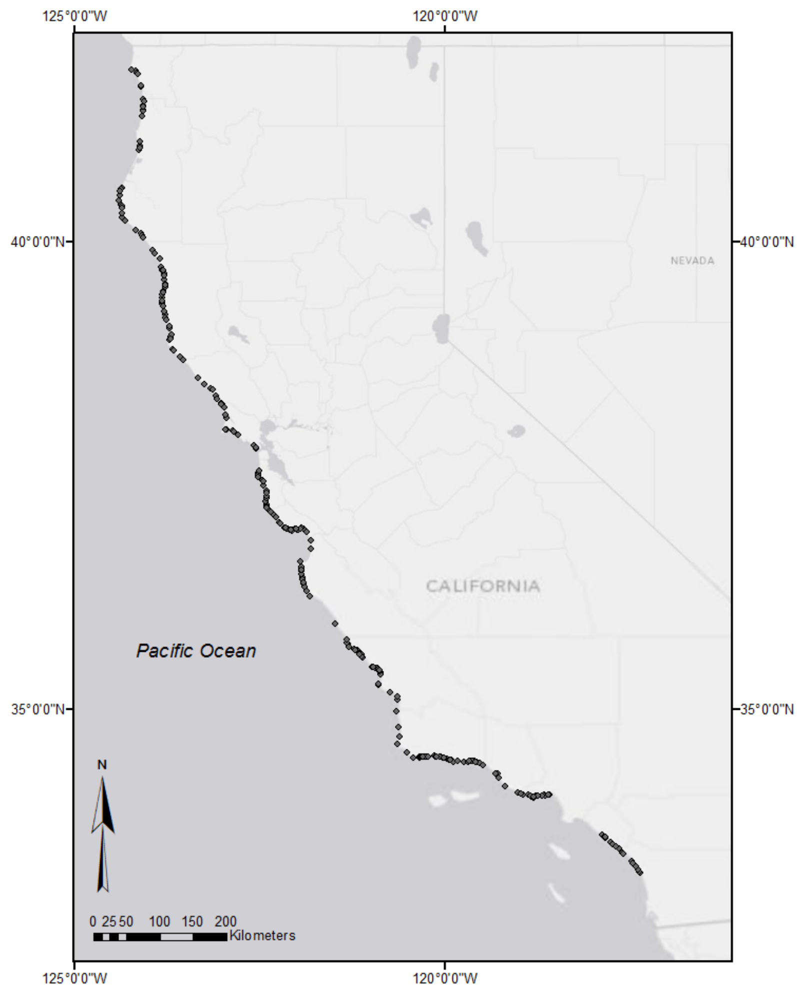



Figure 8. Inventory of all BBEs in California (N=276)

[8] https://www.mlml.calstate.edu/ccwg/wetland-research/

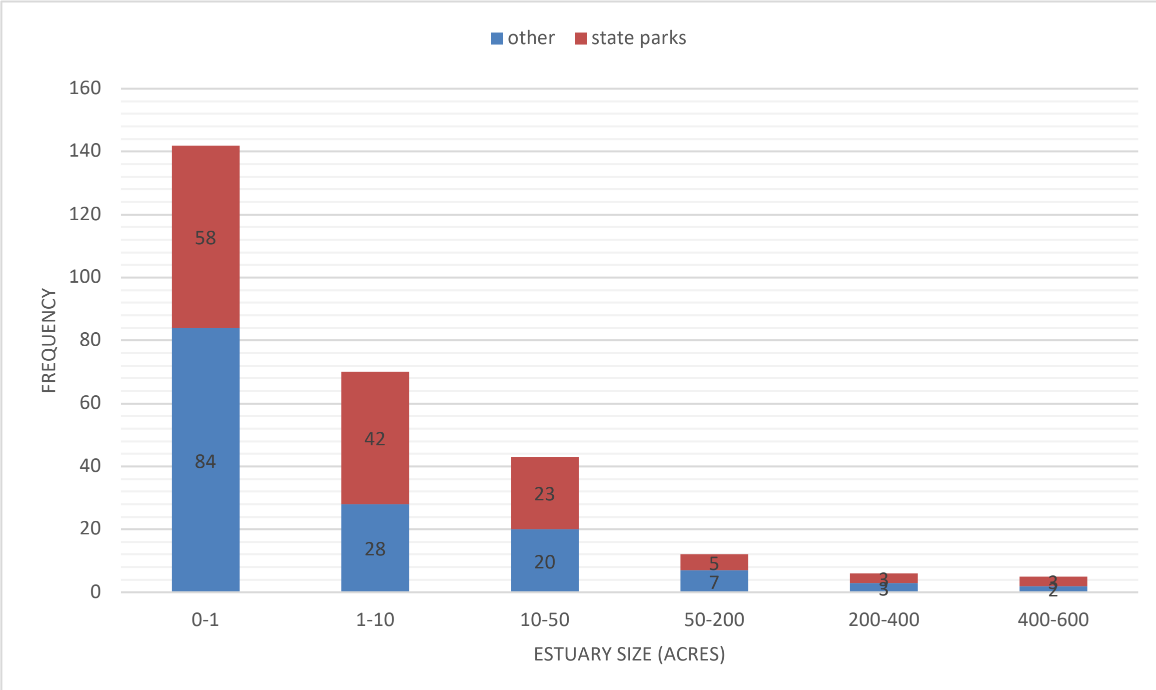



**Figure 9. Size distribution of BBEs in State Park Management (red) and all others (blue).**

## Habitat Change Analysis

According to the often cited US Fish and Wildlife Study (Dahl 1990), 91% of California's wetlands were lost between the 1780's and 1980's. Wetlands continue to be lost, and a recent report on the status and trends of wetlands showed a reduction in net wetland acreage on the Pacific Coast of 5220 acres between 2004 and 2009 (Dahl and Steadman 2013). While this bleak assessment is valuable on the whole, it does not specify whether this loss is evenly distributed among all wetland types, or if some types have seen greater loss than others. Part of what is special about bar-built estuaries is that within a BBE there are diverse set of aquatic habitat types with unique beneficial services to many rare species. The intent of this evaluation was to document the total loss of wetland acreage as well as the conversion habitat classifications within the wetland system. This methodology can be expanded to other systems to assess the loss and alterations of other wetlands throughout the State Parks network. The goal of this standard inventory effort is to answer the following questions:

- What acreage loss or gain (entire wetland and specific habitat classes) has been documented within each region of the state?
- What are key causes of loss (filling, diking, urbanization etc.)?
- What are key watershed impacts on lagoons by region?
- What, if anything, does this tell us about how systems should be managed on an individual or regional level?

The habitat change analysis used 19th century T-sheets[9] (ArcGIS rectified) to compare with current imagery and wetland inventories including the National Agriculture Imagery Program (NAIP)[10] maps and the National Wetland Inventory. At each site, a polygon shapefile was drawn to encompass what we determined was the

[9] Available from: https://shoreline.noaa.gov/data/datasheets/t-sheets.html
[10] Available from: https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/

maximum extent of the specific BBE for both the current and historical condition. Inland extent was determined using multiple lines of evidence including the 10 foot elevation contour, a narrowing of channel width, a change in vegetation type, and in some cases, the inland extent of our inventory was determined by the inland coverage of the 19th century T-sheet maps (especially larger systems). Lateral extent was determined by looking at topographic indicators and the presence of surface waters that are physically/hydrologically connected to the channel. The digital habitat extent polygons were generated by hand saved as "current" and "historical" files.

Using the "cut polygon features" tool, the polygons were cut by tracing habitat boundaries for both the current and historical maps until each specific habitat zone had been delineated (Figure 10). One of the biggest challenges was to craft the habitat type naming convention that would best characterize these systems and document all the habitats, without becoming too specific which made comparison among sites and between centuries difficult and inaccurate. The selected naming convention helped to ensure confident and consistent habitat identification, and accounted for variability among historic T-sheets, made by different people with different expertise. Each individual habitat type was classified and the area for each was calculated in ArcGIS. The four tiers of habitat classification are defined in Table 1. Once the classification of each of the sites was complete for both the current and historical condition, we copied the attribute tables into one large Excel spreadsheet and then uploaded it to R for analysis. We calculated absolute and percent change of habitat for Tier 1 and Tier 2 for each site individually, for each region of the State, and for the State as a whole. Results can be found in Section 4 of this report.

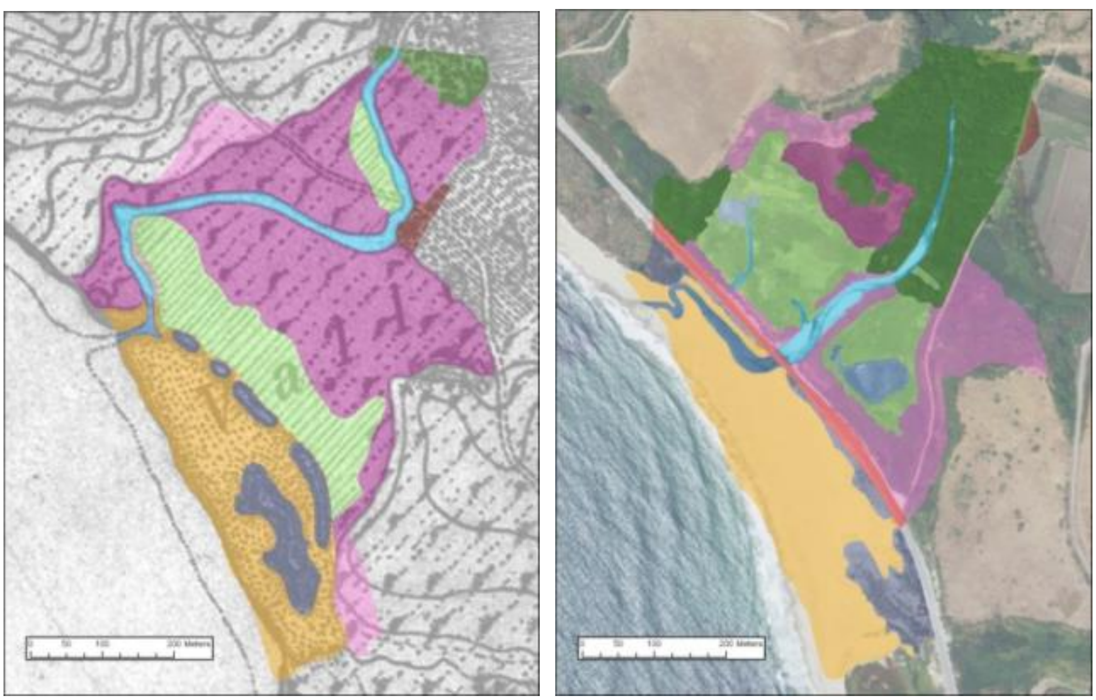


**Figure 10. Historical (left) and current (right) map of habitat types at Scott Creek Lagoon**

## Table 1. CCWG BBE habitat classification system

<table>
<tr><th>TIER 1</th><th>TIERL 2</th><th>TIER 3</th><th>TIER 4</th></tr>
<tr><td rowspan="10">Wetland (W): Regularly or occasionally wet, or with a high water table that supports wetland vegetation. Depending on the salinity gradient these systems would be classified by NWI as Riverine, Estuarine or Palustrine.</td><td rowspan="2">Beach/Berm/Inlet (B): Sandy shoreline between the lagoon mouth and the ocean. At times, the lagoon can pond on this shoreline creating a distinct habitat type. NWI: Unconsolidated Shore (US), typically Sand (2).</td><td>Beach (Be): Non-vegetated, exposed sand.</td><td></td></tr>
<tr><td>Beach Channel/Inlet (I): Area of the beach that contains open water communication between ocean and lagoon. NWI: Marine (M) Intertidal (2)</td><td rowspan="9">Hydrologically Connected (HC): or Hydrologically Isolated (HI): Project specific descriptor for whether existing wetlands are still hydrologically connected to the lagoon, or whether they have been isolated by management actions.</td></tr>
<tr><td rowspan="3">Wetable Lowland: Low lying land that is potentially inundated by lagoon dynamics. NWI: see our Level 3</td><td>Periodically Inundated (PI): Surface water only present during situations with especially high freshwater flows, high tides, or unusually high inundation. Vegetation likely to be a mix of hydrophilic and upland vegetation. NWI: Scrub Shrub (SS) or occasionally Emergent (EM) with modifier Intermittently Flooded (J). *Note: Historical T-sheet sites that do not define the habitat type but are topographically low lying are put in this category by default.</td></tr>
<tr><td>Marsh Plain (M): ground that is regularly, seasonally, or intermittently wetted with either surface water or saturated soils. Supports wetland species of plants. NWI: Emergent (EM) with possible modifiers Temporarily Flooded (A), Saturated (B), Seasonally Flooded/Saturated (C/E), Regularly Flooded (N)</td></tr>
<tr><td>Flats (F): Non-vegetated sand or gravel flats, not including the beach or channel area that are maintained in this state by episodic flows. NWI: Unconsolidated Shore (US) which could be Cobble-Gravel (1), Sand (2),</td></tr>
<tr><td rowspan="3">Open Water (O): Areas experiencing standing or flowing water that are not vegetated. The extent and elevation of actual water may vary within or among days (tidally), seasonally (seasonal tides and stormflows), and interannually. NWI: see our Level 3</td><td>Channel: (C) unvegetated areas of water conveyance. NWI: Riverine or Estuarine (R or E) Tidal (1)</td></tr>
<tr><td>Pond (P): Off-channel areas of still water. NWI: Lacustrine (L), Estuarine (E) Intertidal (2) Unconsolidated Shore (US), or Palustrine (P) Unconsolidated Bottom (UB)</td></tr>
<tr><td>Bars (Ba): Non-vegetated sand or gravel flats, not including the beach, within the greater channel area, that are maintained in this state by episodic flows. NWI: Unconsolidated Shore (US) which could be Cobble-Gravel (1), Sand (2),</td></tr>
<tr><td colspan="2">Altered, Developed or Disturbed (D): Areas that show signs of human disturbance, but inundation is at least partially maintained. NWI: depending upon the level of disturbance NWI may not classify these as wetland.</td></tr>
<tr><td colspan="2">Vegetated Woody (VWo): Vegetated land covered by trees and shrubs that are typically hydrophilic such as willows. NWI: Forested (FO)</td></tr>
<tr><td rowspan="8">Non-Wetland (NW): generally upland or developed land with either impervious or well drained soils, is thereby only wet from storm events, and dries relatively quickly. NWI does not subcategorize these; they are typically defined as "Upland."</td><td rowspan="6">Developed (D): Highly impacted by people, often with hardened or compressed surfaces, and thus the area does not fit the Level 1 definition of "Wetland." It may or may not have been Wetland prior to disturbance.</td><td>Transportation Corridor (TC): Paved and dirt roads, railroad tracks and heavily trafficked paths.</td><td rowspan="8">Not-Applicable (NA): The issue of hydrologic connectivity is not applicable in non-wetland settings</td></tr>
<tr><td>Agriculture (A): farmed agricultural land including grapes, row crops, grains and orchards</td></tr>
<tr><td>Grazing (G): Land used for grazing, including cows, sheep and horses.</td></tr>
<tr><td>Urban (Ur): developed land with a high percentage of impervious surface including residential, commercial and industrial uses.</td></tr>
<tr><td>Parking Lot (PL): Land adjacent to the site that is used solely for parking.</td></tr>
<tr><td>Other (Ot): Non-wetland land that doesn't fit into other categories. NOTE: this could include fallow ag land that is disced, undeveloped bare ground.</td></tr>
<tr><td rowspan="2">Undeveloped (UD): Non-wetland that is allowed to remain in a natural or semi-natural state.</td><td>Vegetated Upland (VUp): Upland land that is typically vegetated with non-wetland species</td></tr>
<tr><td>Dune (Du): Sand dunes, could be vegetated or bare.</td></tr>
</table>

## Landscape and Watershed Stressors

Landscape level investigations of potential stressors can be conducted for each estuary. The watersheds of each estuary can be demarcated using Watershed Delineation Tools in ArcGIS. The predominance of different landform modifications and land cover types that can affect the condition of downstream wetland habitat are calculated for each bar-built estuary. The effects of watershed stressors on downstream BBE resources was studied at four different scales: 1) the entire watershed; 2) a 2 kilometer area surrounding the bar-built estuary; 3) within a 250 meter buffers of all watershed streams; and 4) within a 250 meter buffers of all streams within the 2 kilometer area surrounding the bar-built estuary. These four geographic scales test the significance of various landscape scale stresses on bar-built estuary habitat. Our previous research throughout California has shown these four landscape scales to be useful in highlighting the influence of different stressors on condition and in prioritizing management actions. Specific methods are outlined below.

### *Watershed Delineation*

The delineation of California coastal watersheds was accomplished using ArcGIS in tandem with the ESRI geoprocessing toolbox entitled “Watershed Delineation Tools.” The toolbox contains three tools: 1) Watershed Delineation, 2) iRainDrop, and 3) and iWatershed. Only the Watershed Delineation tool was used during this study to create stream networks and delineate watersheds for all stream links. The Watershed Delineation tool required the use of digital elevation models (DEM’s, 10 m resolution) which were downloaded and clipped according to approximate boundaries of watershed zones. The tool assigns stream networks within a watershed based on a set threshold value; the threshold value defines the minimum number of upland cells from a DEM that are required to empty into the network for the stream to be identified. For this project, the threshold value was set to the default minimum of 10,000 cells. Once the watershed and stream networks were delineated, resulting datasets were run through a series of analysis and overlay tools, organized into a custom ESRI toolset model (Figure 11), to create the following five shapefiles for each of the watershed sites:

1) watershed_WS: polygon of entire watershed.
2) watershed_2k: polygon of watershed buffered 2 km from coastal mouth.
3) 250RWS_clip: 250 m buffer zone of entire watershed stream network, clipped to remain within the boundary of the watershed.
4) 250RWS_2k: 250 m buffer zone of 2km watershed stream network
5) watershed_RWS: polylines of all streams within watershed

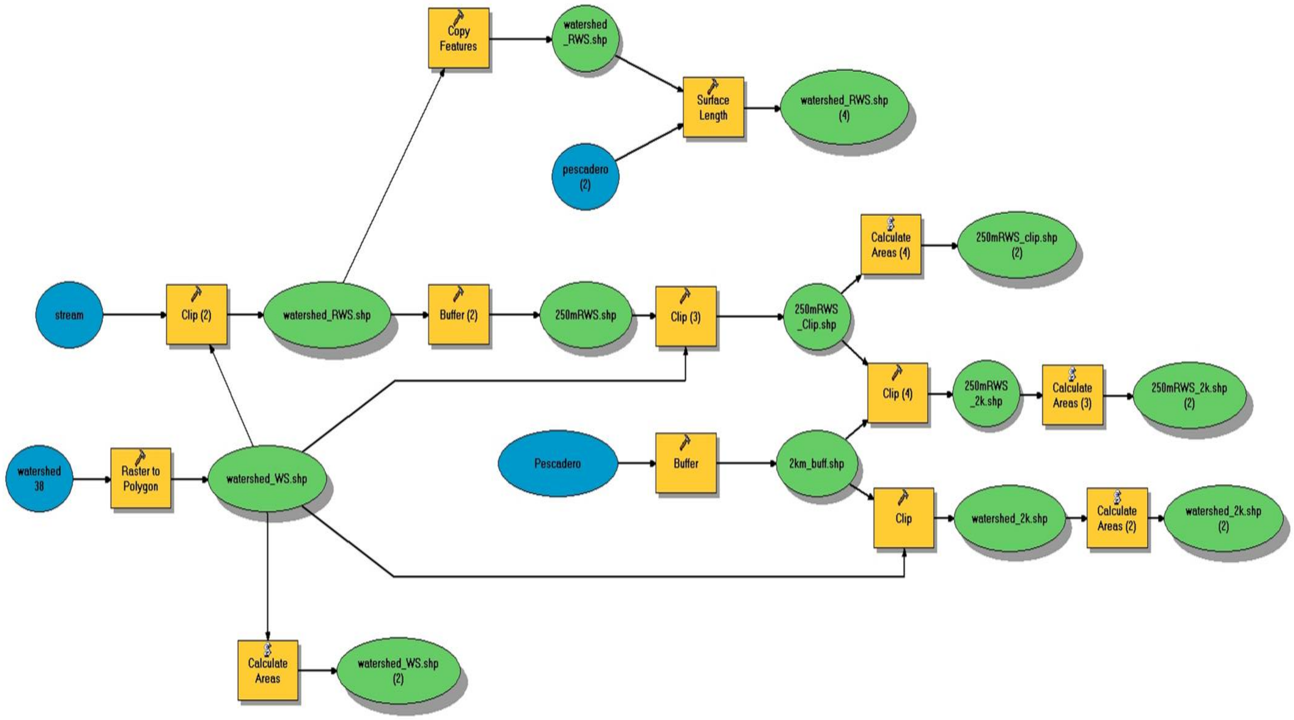



**Figure 10. Customized ESRI toolset model for delineating watershed zones.**

Polygon shapefiles 1-4 listed above were each assigned their corresponding watershed name and alphabetical ID number and merged together to create 4 individual shapefiles, each with the selected watersheds as features. Utilizing overlay and extraction tools in ArcGIS, the above products were used to summarize data from approximately 50 land-based metric datasets. Extracted information was reported numerically in a spreadsheet. Maps of specific watersheds were also presented to show the geospatial extent of each watershed, buffer zone, and stream network (Figure 12).

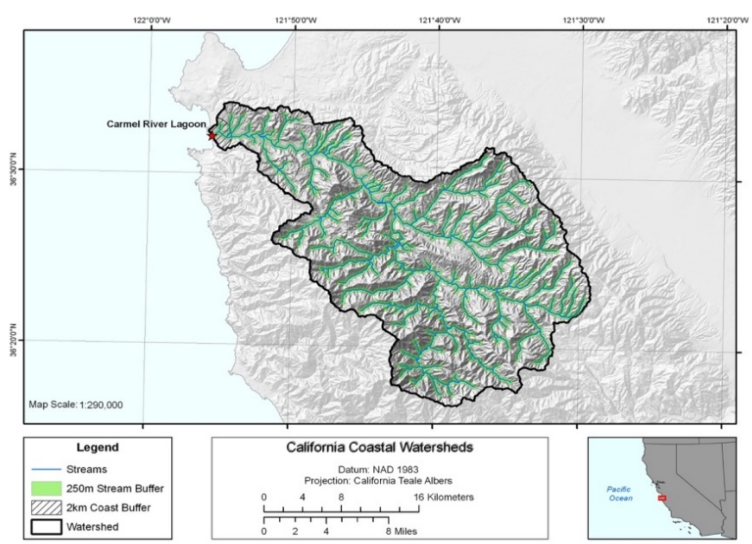



**Figure 11. Example watershed map showing the geospatial extent of each watershed, buffer zone, and stream network.**

## *Data Extraction*

### Raster Datasets:

Five raster datasets were included for data extraction: 30 yr. average monthly precipitation (1971-2000); 30 year average monthly temperature (1971-2000); National Land Cover Database 2011 (NLCD) percent impervious surface; and NLCD land use 2011.

Data from the precipitation and temperature datasets was extracted using Zonal Statistics in tandem with the WS and 2k watershed zones. Data from the NLCD percent impervious surface was first reclassified into categories of 0% imperviousness and 1-100% imperviousness. Zonal Statistics were then applied for extraction from all watershed zones. Data from NLCD land use was reclassified into the following classes: Developed (classes 21-24), Forest (classes 41-43), Shrub/Grassland (classes 52-71), Agriculture (classes 81-82), Wetlands (classes 90 and 95), and Open Water (class 11). The analysis excludes Perennial Ice/Snow (class 12) and Barren Land (class 31). The Tabulate Area tool was then used to cross-tabulate areas between the reclassified land use zones and the watershed zones.

### Feature Datasets:

The following polygon, polyline, and point feature datasets were used for data extraction: geologic units (for calculating naturally occurring soil nitrogen, phosphorous, and sulfur), invasive invertebrates and plants, stream types and length, burn areas (2000 to present), grazing allotments, dams (including drainage areas and storage), mines, EPA 303(d) Listed Impaired Waters, CQWIS discharge sites, and roads. With the exception of the geologic units dataset, all polygon and polyline datasets were processed using the Intersect tool in tandem with the watershed zone files. Segmented polygon and polylines were then recalculated to get accurate areas and lengths and summarized using Summary Statistics. The geologic units dataset required the use of Hawth's Analysis "polygon in polygon" tool to calculate the weighted average of the soil elements within the specified zone. Point datasets of invasive species were buffered and intersected with the stream dataset, and dam and discharge sites were intersected with watershed zones and summarized using Summary Statistics.

## Level 2: Rapid Assessment Protocols and Strategies:

### Introduction to the California Rapid Assessment Method

The California Rapid Assessment Method for Wetlands (CRAM) is a rapid habitat condition assessment. CRAM is a standardized tool for wetland monitoring, developed with support from EPA. CRAM provides a cost-effective assessment tool for wetlands that can be used to assess the condition on a variety of scales, ranging from portions of individual wetlands to assessments of wetland condition throughout watersheds and climatic regions.

It is based on the concept that the structure and complexity of a wetland is indicative of its capacity to provide a range of functions and services. It is designed for assessing ambient conditions within watersheds, regions, and throughout the State. It can also be used to assess the performance of restoration projects. CRAM requires a team of 2-3 trained practitioners less than 3 hours to assess a representative wetland area.

CRAM provides an Index score of the condition of a wetland relative to other wetlands of that type throughout the state. This Index score is calculated as a combination metrics scores based upon visual and easily measured indicators of ecological condition. The metrics assessed in CRAM are similar across various wetland classes but are adapted as necessary to fit the characteristics unique to each wetland type.

CRAM is composed of four main attributes of condition:

1. **Buffer and Landscape Context** - measured by assessing the quantity and condition of adjacent aquatic areas as well as extent and quality of the buffering environment adjacent to the Assessment Area.
2. **Hydrology** - assesses the sources of water, the hydroperiod of the estuary from evidence of alterations to the mouth of the lagoon, and the hydrologic connectivity of rising flood waters in the estuary
3. **Physical Structure** - measured by counting the number of patch types[11] found within the AA and the topographic complexity of the marsh plain.
4. **Biotic Structure** - measures the site on several factors including the number of plant vertical layers, the number of different species that are commonly found in the marsh, the percent of the common species that are invasive, and the horizontal and vertical heterogeneity of the plant communities.

These four attributes are consistent for all wetland modules of CRAM. Each of the four attribute categories is comprised of a number of metrics and sub metrics that are evaluated in the field and scored on a scale of (A)12 to (D)3. The metrics that are measured may vary between wetland types. Each of the four attribute categories are then converted to a scale of 25 through 100, and the average of these four scores is the final CRAM index score, also ranging on a scale from 25 (lowest possible) to a maximum of 100.

The scale of condition categories presented in Table 2 is appropriate for the purposes of evenly distributing CRAM results into quartiles.

[11] A patch is a spatially distinct structural element of a wetland system large enough to serve as a habitat for wildlife, or to serve as an indicator of spatial variations in hydrological or edaphic (soil) conditions within a wetland.

**Table 2. CRAM condition categories and associated index scoring ranges**

| Condition Category | Total CRAM Index Score Range |
|---|---|
| Good | 76-100 |
| Fair | 51-75 |
| Poor | 25-50 |

## Implementation of CRAM

CRAM implementation requires application of the most appropriate wetland type-specific module. There are both field and office components, and one assessment area takes approximately 2-4 hours to complete. Additionally, accurate CRAM assessments require multiple certified scientists who have undergone calibration and training.

Assessments should be repeated prior to management actions (restoration, enhancement, changes in breaching dynamics, etc.) taking place that may affect wetland habitat condition, and then repeated following implementation of the action on a regularly occurring interval to monitor change through time (every other year or so). To track ambient condition through time (unrelated to a specific management action), assessments may be needed on a 3 to 5 year occurrence interval.

For more information on implementation of CRAM, please see the document titled "USING THE CALIFORNIA RAPID ASSESSMENT METHOD (CRAM) FOR PROJECT ASSESSMENT AS AN ELEMENT OF REGULATORY, GRANT, AND OTHER MANAGEMENT PROGRAMS, TECHNICAL Bulletin – Version 2.0", prepared by the California Wetlands Monitoring Workgroup
(https://www.cramwetlands.org/sites/default/files/2019CRAM_TechnicalBulletin.pdf)

## General steps of a CRAM Assessment:

1. Assemble the background information;
2. Classify the wetland;
3. Verify the appropriate season;
4. Sketch the CRAM Assessment Area (AA) (e.g. Figure 13);
5. Conduct the office assessment portion of the AA;
6. Conduct the field assessment portion of the AA (including completing the stressor checklist);
7. Complete the quality control check of the data; and
8. Submit results online.


**Figure 12. Example CRAM assessment areas in the Salinas River Lagoon**

## Special Considerations for Selecting Assessment Areas within Bar-built Estuarine Wetlands

Bar-built Estuarine wetlands often support extensive wetland resources along the flood plain that are often classified separately from the main BBE channel. The National Wetland Inventory classifies wetland resources within the BBE flood plain differently. Deep Channel resources are classified as estuarine or riverine and flood plain resources are often classified as palustrine. All of these wetland features function together to form the BBE complex.

CRAM was created to evaluate the condition of single classes of wetlands within an Assessment Area (AA) and failed to fully qualify the importance of the secondary wetland areas within the BBE flood plain. The BBE CRAM module was modified in several ways to better reflect the importance of these secondary wetland resources and the functions and services they provide (Heady et al. 2015). In addition, land use changes and urban development have impacted or eliminated these floodplain resources and those impacts must be fully characterized. Therefore, some CRAM metrics include characterization of resources (similar to buffer within all classes) outside of the AA. It is a fundamental assumption of the BBE CRAM module that BBEs that function in concert with these secondary floodplain resources provide many additional services and are of better condition than those that have lost those resources.

AA boundaries for the BBE wetland class have been established as the main channel of the system and secondary channels that are hydrologically connected during low water conditions (Figure 14). The condition of floodplain marsh resources that exceed the size limits of the AA are integrated into several metrics and can be assessed separately if necessary. Often it is difficult to establish the upstream limit of the BBE wetland sub-type and as a result, the upstream extent will be determined by the 10-foot contour combined with visual indicators, including a change in wetland type or a significant hydrologic break, such as the presence of tide gates.

Frequently BBE wetlands are small and the AA may encompass the entire wetland. In either case, the AA should include the vegetation near the mouth of the BBE (where cover exceeds 10%) and extend inland to the limits describe above. The main channel and any side channels will be included, and the AA will extend to the top of the banks of these features where a break in slope is observed and include the immediate "riparian" area. The AA can extend across the marsh plain between these features as well. If a distinct break in slope is not observed, the lateral extent of the AA will be determined by the potential for allochthonous input of plant material to the channel.

The AA should not extend above the backshore, as indicated by wrack lines, and transitions from tidal to upland vegetation. The AA should not extend into any hydrologically isolated wetlands on the marsh plain (i.e. perched fresh water ponds). Additionally, the AA should not cross across any channel that is wider than 50 m or that cannot be safely crossed at low tide. The boundary of the AA can extend along the midline of such channels but not across them.


**Figure 13. Example Assessment Area in a Bar-built Estuary.**

## CRAMWETLANDS.ORG and EcoAtlas/Project Tracker

The CRAMWETLANDS.ORG website is the main portal for information on CRAM, data entry, and data reporting. The website offers an easy-to-use data entry interface which ensures that all of the appropriate information associated with CRAM assessments can be captured and utilized to inform decision-makers. It gives practitioners the ability to delineate CRAM assessment areas by drawing on a map, access to a practitioner dashboard where assessments can be created and edited, and an up to date list of all trained practitioners in the state. Users can also generate PDF reports of assessment locations, filter assessments, and download assessment data for analysis. All CRAM data reference in this report is available online at the CRAM website.

All data entered into the CRAM website that are marked as "public" are displayed on EcoAtlas.org. EcoAtlas is a science-based data management and mapping toolset designed to aggregate data from many different sources. Developed in collaboration with a statewide network of Federal, State, Regional, and local public agencies and NGOs, EcoAtlas coordinates natural resource restoration and protection efforts in the context of population growth and climate change. EcoAtlas dynamically displays data made available in public databases, and provides sophisticated analytics to share and visualize information for addressing critical resource management questions. The use of EcoAtlas is expanding as it uniquely enables users to aggregate the best available data for strategic decision support in the landscape, watershed, or regional context.

Project Tracker provides online data entry forms to enable public agencies, restoration managers, and NGOs to map and share information about their on-the-ground landscape, restoration, mitigation and adaptation projects in EcoAtlas and other web-based visualization tools.

## Level 3: Intensive Site Assessment Protocols and Strategies

Unique processes such as beach bar formation, seasonal flooding, and ocean overtopping create variability in surface water elevations and salinity gradients that are unique to these systems. The presence and absence of these events will determine the level of services and condition. Decreases in the level of services and condition often correlate with human management and watershed impacts. Marine or watershed dominance (and the interaction of both systems) can lead to varying salinity and water levels. These variable hydrologic states support a complex set of habitat types and an array of fresh, marine and terrestrial species.

Several Level 3 data collection protocols are described below which were utilized by CCWG to characterize the unique process present in these systems.

### Beach Sediment Characterization

#### *Sample Collection*

Beach sediment samples were collected in 2015. Each sample fit in a small plastic sandwich bag and was collected just under the surface of the sand. Collections took place along 4 transects running perpendicular to the ocean, distributed on each side of the channel between the estuary and the ocean. Each transect included three samples; one at the shore face (A), one at the top of the beach berm (B), and one from the runnel at the back edge of the beach (C) (Figure 15). A Trimble Juno differential GPS was use to collect location and elevation data for each sediment sample.

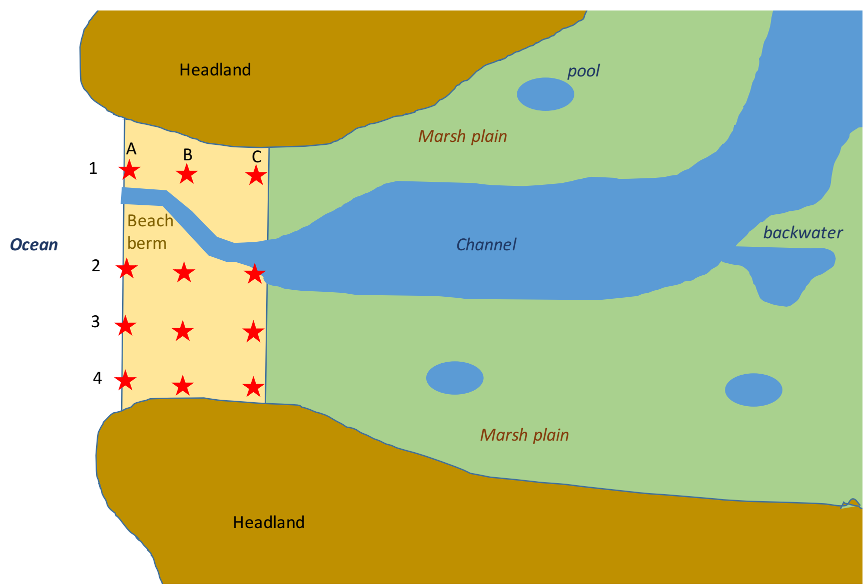



**Figure 14.Example BBE with beach sediment collection locations (red).**

#### *Grain Size Analysis*

The procedures used for the particle size analysis of the sediment samples includes preliminary processing and subsampling, running standards before and after the sediment analysis, repeated grain size analyses for each sample and data export.

Particle size analyses are carried out with a Beckman-Coulter LS 13 320 laser particle size analyzer (LPSA) attached to an aqueous module equipped with a pump and a built-in ultrasound unit. The measured size distributions analyzed is from 0.04 µm to 2 mm. Measurements of such a wide particle size range are possible because the particle sizer is composed of two units: a laser beam for conventional (Fraunhofer) diffraction (from 0.4 µm to 2 mm) and a polarized intensity differential scatter (PIDS) unit, which measures particles based on the Mie theory of light scattering (0.04 µm; Beckman Coulter Inc., 2003).

The sediment samples are subsampled and dispersed in de-ionized water. Subsampling of the solutions for the laser particle analysis is done with a pipette (diameter = >2 mm) while vibrating the flask to resuspend the sediment and ensure random sampling. Increasing amounts of the sediment solution are then added to the aqueous module of the particle sizer until obscuration values of 10%–15% and PIDS obscuration values of 48%–52% are obtained. Obscuration is the percentage or fraction of light that is attenuated because of extinction (scattering and/or absorption) by the particles and is also known as optical concentration.

Instrument settings during operations are as follows:

- Pump speed = 100%.
- Obscuration = 10%–15%
- Duration of each analysis (during which the grain size is averaged) = 90 s.

De-ionized water is used to supply the liquid module. The optical model chosen for grain size determination is the default Fraunhofer model, based on the Fraunhofer theory of light scattering.
Data interpolation and statistical analyses are calculated with the laser particle sizer proprietary software (Beckman Coulter Inc., 2003). Because all samples analyzed tend to log-normal grain size distributions in the 0.04 µm to 2 mm spectrum, geometric rather than arithmetic statistics were applied to the values obtained by the logarithmically spaced size channels of the particle sizer.

**Procedure**

1. Each sample bag/vial is first inspected to assess whether enough material for particle size analysis was present and for the presence of large (>2mm) pebbles, rock fragments, shells and shell fragments and any other component that could not be measured with the LPSA.

2. The second critical step is to resample each sample bag using and objective repeatable method to obtain a representative sub-sample for further processing and LPSA. This is can be done either using a micro splitter or by homogenizing thoroughly the sample in the zip-lock bag and then isolating a portion of the bag which where the sub-sample is finally collected.

3. Very wet samples are partially dried in an oven at 60ºC between 2 and 48 hours depending on the water content. Drying is interrupted once the sample Is semi consolidated, e.g. having a tooth paste-like consistency. The reason for this drying procedure is because during drying the coarser material settles at the bottom; by creating a paste-like substance it is possible to obtain subsamples or 'pie-slices' which include all grain sizes in their 'natural' proportions.

4. Test samples are run before carrying out the samples analyses with LPSA. 3 standards were used: 03 µm (Fluka standard), 15µm (LG control 15), and 35µm garnet standard (Control G35D). The

5. Each dry subsample is analyzed for particle sizes using the LPSA. For the majority of the samples this is done several times and always at least twice: replicates of each respective sample were run until three runs containing mean grain size statistic within 3 um of one another were obtained or until ten replicates of the respective sample are run, whichever came first.

6. The main statistical results are reported for each run as well as average of the multiple runs carried out for each sample. Grain size statistical data include:

| **Parameter** | **Description** |
|---|---|
| Mean grain size (µm) | Mean grain size in micrometers (µm) |
| Median grain size (µm) | Median grain size in micrometers (µm) |
| S.D.: | Standard deviation in micrometers (µm) |
| Variance | Variance |
| Skewness | Skewness |
| Kurtosis | Kurtosis |
| d10 | 10th percentile of particle size |
| d50 | 50th percentile of particle size |
| d90 | 90th percentile of particle size |
| Specific Surf. Area | Specific surface area in micrometers squared ($\mu m^2$) |
| Clay (<4µm) | Percent Clay, particles less than 4 micrometers in size (<4µm) |
| Silt(4µm<<63µm) | Percent Silt, particles from 4 to less than 63 micrometers in size (4µm<<63µm) |
| Sand(63µm<<2000µm) | Percent Sand, particles from 63 to less than 2000 micrometers in size (63µm<<2000µm) |

7. Test samples are run after carrying out the sample analyses with LPSA. 3 standards are used: 03 µm (Fluka standard), 15µm (LG control 15), and 35µm garnet standard (Control G35D).

## Marsh Plain Inundation and Mouth Breaching Dynamics

Temperature/depth loggers, recording data every 15 minutes, were deployed at 26 estuaries in southern, central, and northern California in 2015 (Table 3). In-Situ Rugged Troll 100 data loggers[12] were utilized to collected the temperature and depth data. They were suspended on a stainless steel cable and deployed in a perforated PVC tube attached to a 6 to 9 foot long metal stake which was pounded into the estuary substrate (Figure 16). The location for each logger was selected carefully. A site was chosen which would most likely be inundated when the water in the main channel was low (either due to the mouth being open or due to low flow from the watershed). In addition, the site was usually off the main channel to prevent the logger from being washed out to sea in a strong flow.

| | |
|---|---|
| Example logger in PVC tube suspended on stainless steel cable | Example logger tube deployed in side channel of a BBE to prevent loss from high flows |

[12] https://in-situ.com/products/water-level-monitoring/rugged-troll-100/

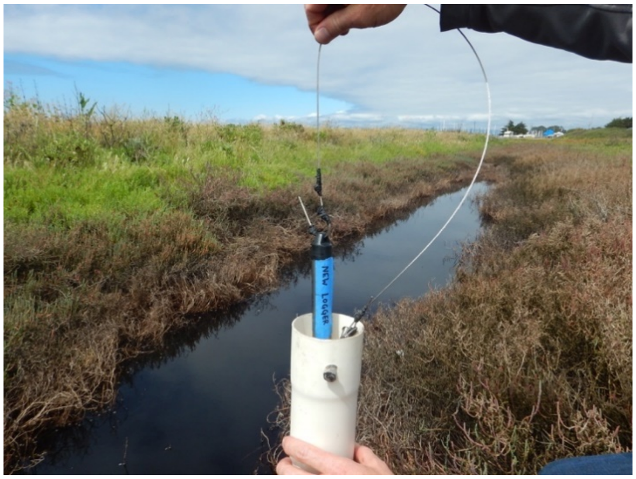


Figure 15. In-Situ logger deployment example.

CCWG worked with State Park District staff along the coast to exchange the loggers each summer. This resulted in a 1 to 3 year data set for many of the original 26 sites (Table 3). Most of the estuaries still have loggers deployed and actively collecting data. CCWG will continue to house the logger data and to work with State Park District staff to annually exchange the data loggers.

Table 3. BBE name and status of temperature/depth logger data collection.

| Site Name | Logger deployed in 2015 for EPA grant? | Years of data collected | Current status (as of January 2020) |
|---|---|---|---|
| 10-Mile River | yes | 3 | in place collecting data |
| Aptos Creek | yes | 0-logger stolen | no logger |
| Arroyo de la Cruz | yes | 4 | in place collecting data |
| Arroyo Grande Creek | yes | 3 | in place collecting data |
| Arroyo Sequit | yes | 3 | no logger |
| Big Sycamore Creek | yes | 2 | in place collecting data |
| Brush Creek | yes | 2 | in place collecting data |
| Carpinteria Creek | yes | 2 | no logger |
| Canada del Capitan | yes | 3 | in place collecting data |
| Fern Canyon (Home Creek) | yes | 4 | in place collecting data |
| Fort Ross Creek | yes | 4 | in place collecting data |
| Laguna Creek | yes | 4 | in place collecting data |
| Lake Davis (Manchester Creek) | yes | 3 | in place collecting data |
| Los Penasquitos Lagoon | Not needed-logger already in place, maintained by CDPR and TRNERR[13] | continuous and ongoing | in place collecting data |
| Malibu Creek | Not needed -logger already in place, maintained by CDPR[14] | continuous and ongoing | in place collecting data |

[13] Visit: http://torreypines.trnerr.org/index.cfm
[14] Contact State Park staff at Malibu Creek State Park for data (818-880-0367)

| Site Name | Logger deployed in 2015 for EPA grant? | Years of data collected | Current status (as of January 2020) |
|---|---|---|---|
| Navarro River | yes | 3 | in place collecting data |
| Ossagon Creek | yes | 4 | in place collecting data |
| Pescadero Lagoon | yes | 2 | no logger |
| Canada del Refugio | yes | 4 | in place collecting data |
| Russian Gulch | yes | 0-logger stolen | no logger |
| Salinas River | yes | 4 | in place collecting data |
| Salmon Creek | yes | 2 | no logger |
| San Jose Creek | yes | 3 | no logger |
| San Mateo Creek | yes | 1 | no logger |
| San Simeon Creek | yes | 3 | in place collecting data |
| Stump Beach Creek | No | 0 | no logger |
| Tijuana River | Not needed-logger already in place, maintained by TRNERR[15] | continuous and ongoing | in place collecting data |
| Villa Creek | yes | 3 | in place collecting data |
| Waddell Creek | yes | 3 | in place collecting data |
| Wilder Creek | yes | 3 | in place collecting data |
| 10-Mile River | yes | 3 | in place collecting data |
| Aptos Creek | yes | 0-logger stolen | no logger |
| Arroyo de la Cruz | yes | 4 | in place collecting data |
| Arroyo Grande Creek | yes | 3 | in place collecting data |
| Arroyo Sequit | yes | 3 | no logger |
| Big Sycamore Creek | yes | 2 | in place collecting data |
| Brush Creek | yes | 2 | in place collecting data |
| Carpinteria Creek | yes | 2 | no logger |
| Canada del Capitan | yes | 3 | in place collecting data |
| Fern Canyon (Home Creek) | yes | 4 | in place collecting data |
| Fort Ross Creek | yes | 4 | in place collecting data |
| Laguna Creek | yes | 4 | in place collecting data |
| Lake Davis (Manchester Creek) | yes | 3 | in place collecting data |
| Los Penasquitos Lagoon | Not needed-logger already in place, maintained by CDPR and TRNERR[16] | continuous and ongoing | in place collecting data |
| Malibu Creek | Not needed -logger already in place, maintained by CDPR[17] | continuous and ongoing | in place collecting data |
| Navarro River | yes | 3 | in place collecting data |
| Ossagon Creek | yes | 4 | in place collecting data |
| Pescadero Lagoon | yes | 2 | no logger |
| Canada del Refugio | yes | 4 | in place collecting data |
| Russian Gulch | yes | 0-logger stolen | no logger |
| Salinas River | yes | 4 | in place collecting data |
| Salmon Creek | yes | 2 | no logger |
| San Jose Creek | yes | 3 | no logger |
| San Mateo Creek | yes | 1 | no logger |
| San Simeon Creek | yes | 3 | in place collecting data |
| Stump Beach Creek | No | 0 | no logger |

[15] Visit: http://trnerr.org/system-wide-monitoring-program/
[16] Visit: http://torreypines.trnerr.org/index.cfm
[17] Contact State Park staff at Malibu Creek State Park for data (818-880-0367)

| Site Name | Logger deployed in 2015 for EPA grant? | Years of data collected | Current status (as of January 2020) |
|---|---|---|---|
| Tijuana River | Not needed-logger already in place, maintained by TRNERR[18] | continuous and ongoing | in place collecting data |
| Villa Creek | yes | 3 | in place collecting data |
| Waddell Creek | yes | 3 | in place collecting data |
| Wilder Creek | yes | 3 | in place collecting data |

These temperature and water depth measurements were supplemented by vegetation surveys linked to topographic data collected using a Trimble Juno differential GPS. Initial vegetation and marsh plain topographic surveys in 2015 were targeted for specific features. The location and elevation of different plant communities, along with different marsh plain elevations and physical features (backwater habitats) were recorded (Figure 17).

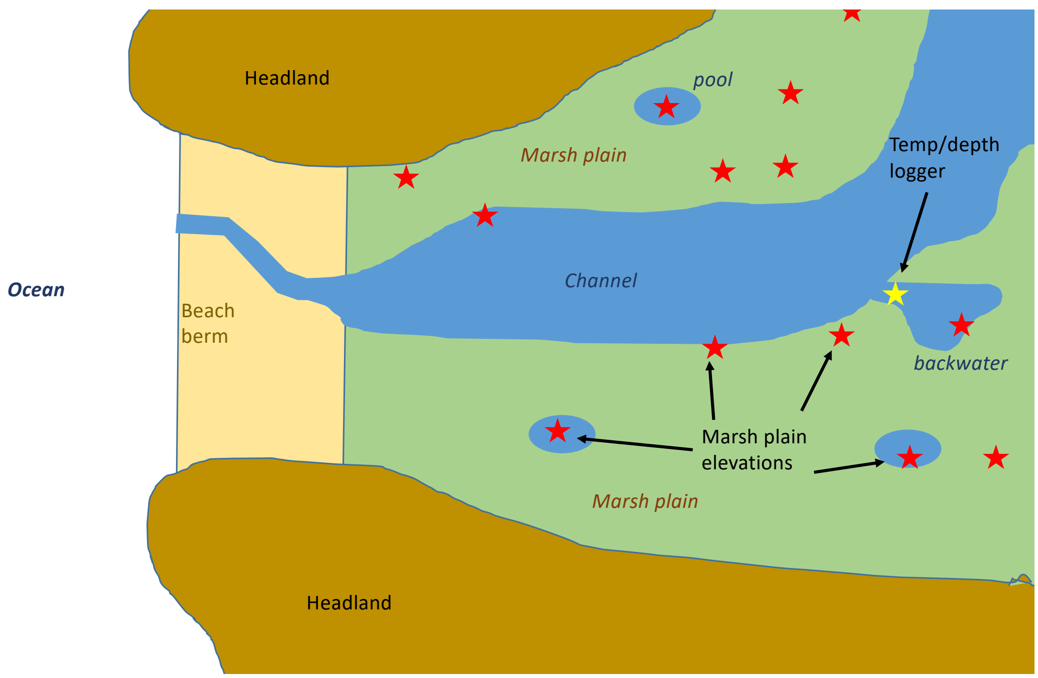



**Figure 16. Example BBE with logger deployment location (yellow), and GPS/topographic monitoring locations (red).**

A return visit to each BBE in 2017 allowed for a more systematic survey of the vegetation community on each marsh plain. At each estuary two to four transects were completed. Each transect was at most 100m long and ran perpendicular to the main channel, starting at the water's edge and extending towards the upland habitat transition zone. A 1-m2 quadrat was laid down every 5 meters along the transect and the elevation was taken at the center of the quadrate using a Trimble Juno differential GPS. Within each quadrat, each plant species was recorded at each of the 9 intercept points. If there were two layers of plants rooted in the substrate, both species were recorded (Figure 18). This combination of data allowed for the assessment of estuary water levels, breeching events, inundation of the marsh at multiple elevations, and characterization of the plant community with different lengths of inundation.

[18] Visit: http://trnerr.org/system-wide-monitoring-program/

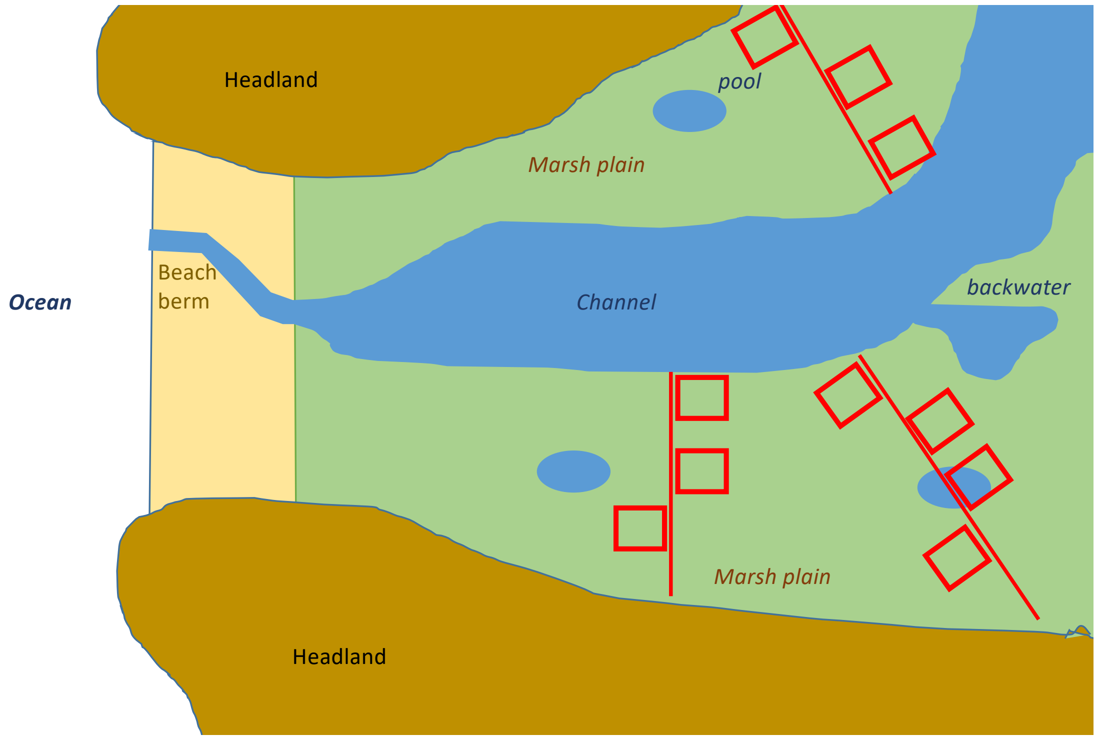



**Figure 17.Example BBE with topographic and vegetation community data collection using quadrates (red squares) along set transects (red lines), from channel edge out to upland transition.**

### *Data Analysis and Reporting*

After a year of deployment, and annually for 2 additional years for some sites, the data was downloaded from the temperature/depth loggers and subsequently re-deployed. Water level over the course of the year was determined by combining the recorded depths with the elevation of the logger. The nature of water level fluctuations allows for the determination of breeching events. Data from the vegetation surveys was used to define minimum, maximum, and average elevations of the marsh—if the water level is above a given elevation then everything below that elevation is assumed to be inundated. Inundation percent of marsh elevations was calculated by combining water levels and topographic data.

The advantages of this monitoring approach of bar-built estuaries is that once a methodology is in place it eases the difficulty of long-term monitoring. Much of the processing, analysis, and figure generation has been automated, meaning that once certain files are updated with new data the analysis can be completed or the figure generated with little hassle.

Once the data was processed and analyzed it was used to create three types of figures: composite graphs of multiple variables for each BBE, marsh plain inundation maps, and vegetation inundation boxplots.

## Special Status Species

An investigation of the California Natural Diversity Data Base (CNDDB), local recovery plans, reports on locations of species status and input from local researchers documented (or assumed high probability) that ten special status species (listed as species of concern or under the state or federal endangered species act) of interest were present within the studied estuaries. All ten of the selected species were reported to be present in one or more of the 30 sites. Pescadero Marsh and Waddell Creek supported the greatest number of special status species. Species presence was recorded for each system with source information references. The species include:

- Snowy Plover
- Coho
- Steelhead
- Western Pond Turtle
- Tidewater Goby
- Red-Legged Frog
- SF Garter Snake
- Saltmarsh Common Yellowthroat
- Monarch Butterfly
- Brackish Water Snail

# Section 4- Statewide Assessment

A data evaluation among BBEs in California is presented below, intended to demonstrate the values of standard data collection techniques which document statewide changes and regional differences in resource condition and documented changes due to management actions.

## Habitat Inventory and Mapping Exercise

For the 66 (30 for the current grant and 36 from previous efforts) bar-built estuaries included in this study, we have seen a loss of 40% of wetland habitat from the T-sheets (ranging from the 1850s-1890s) to the present day (Figure 19). This inventory documents an overall and significant reduction in wetland habitat for the estuaries within California State Parks. Specific types of wetland loss was documented using level 2 habitat type change data (Figure 20). These data demonstrate that the wetland habitat most vulnerable to loss in the past has been wetable lowland (loss of 58%) – marsh and periodically (seasonally) inundated landscapes that support unique habitats and functions that distinguish BBEs as a rare and valuable wetland class. This 58% loss of marsh plain habitat is greater than the loss of similar habitat within the estimated 100 BBE systems studied throughout the State. This great than average loss is likely due to the combine effects of 20th century land use changes combine with site specific alterations completed in the first half of the century to provide coastal access and visitor serving infrastructure. The "habitat' category with the largest increase in acreage is developed lands. This land category includes transportation corridors, urban development, parking lots and agriculture. In the 19th Century these land uses covered less than 1% of the studied BBEs, but now this category makes up 36% of the studied BBEs

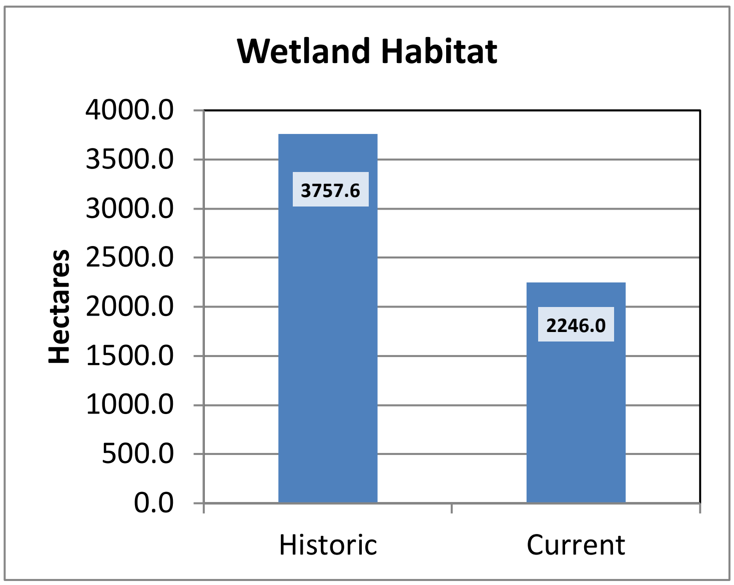



**Figure 18. Statewide wetland habitat change for 66 BBEs in State Park management**

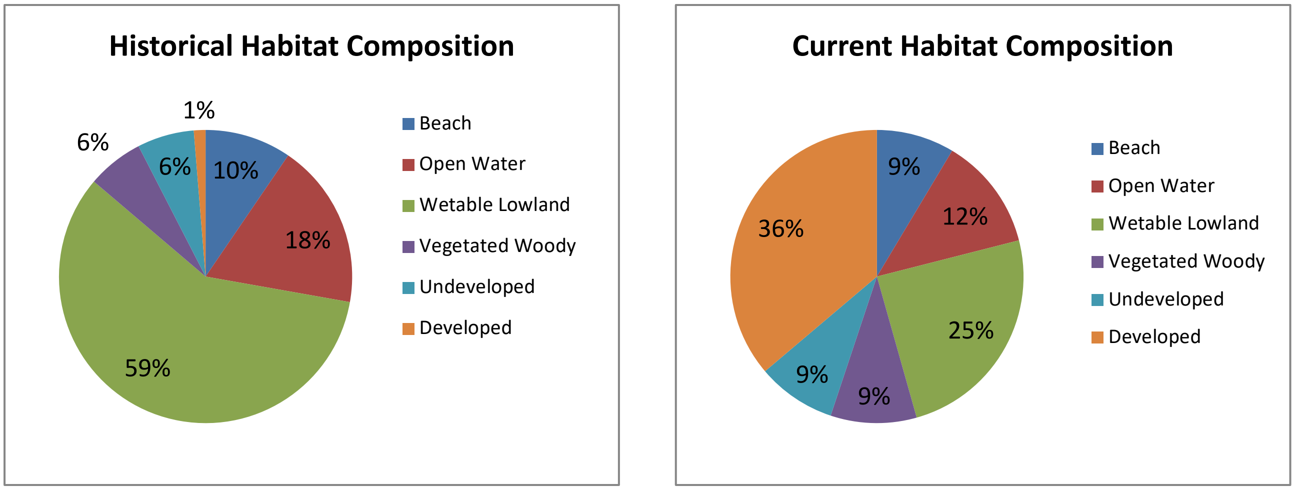



**Figure 20. Statewide change in Level 2 habitat area for 66 BBEs in State Park management**

Further evaluation of habitat changes documents that of the 1485.8 hectares of “developed land”, a majority (74%) is now in agricultural use, followed by urban development (15%), then transportation corridor (5.3%).

## Regional Habitat Loss

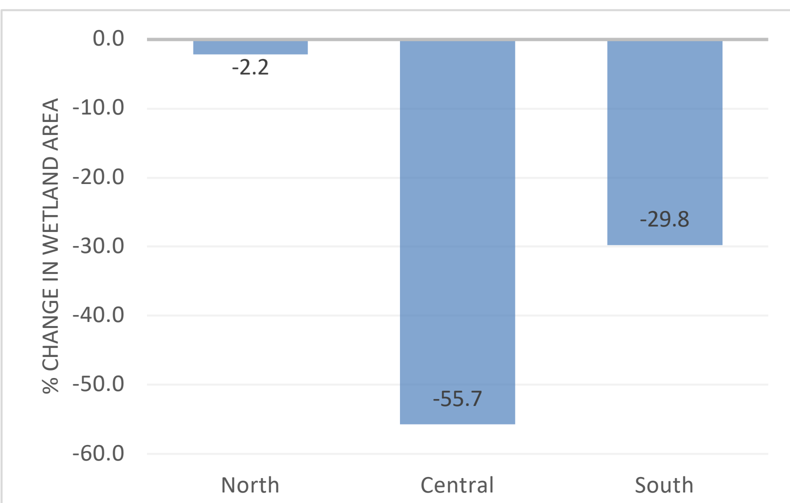



**Figure 21. Regional change in wetland area**

Documenting habitat loss statewide is important for determining future resource management and policy objectives, but is less helpful to local managers in determining regional and park specific priorities. In order to help managers, compare BBEs in their management area with other areas of California, and to help them view their local sites as specific site within a larger ecosystem network.

To investigate regional differences, the State was divided into 3 regions: North, Central and South. Fourteen sites were studied on the North, thirty seven on the Central and fourteen on the South Coast. Total wetland loss was calculated for each of these regions (Figure 21) Northern California sites have lost very little wetland area, central coast (-55.7%) and south coast (-29.8%) BBEs have seen significant loss of in acreage.

The land cover type that replaced wetland area was different between regions (Figure 22). As expected, the Central and South Coasts show loss of wetable lowland being replaced with developed non-wetland. The higher proportion of developed lands found on the Central Coast is likely due to the sites selected for this study, which include several larger South Coast estuaries that are not representative of historical changes to estuaries in this region.

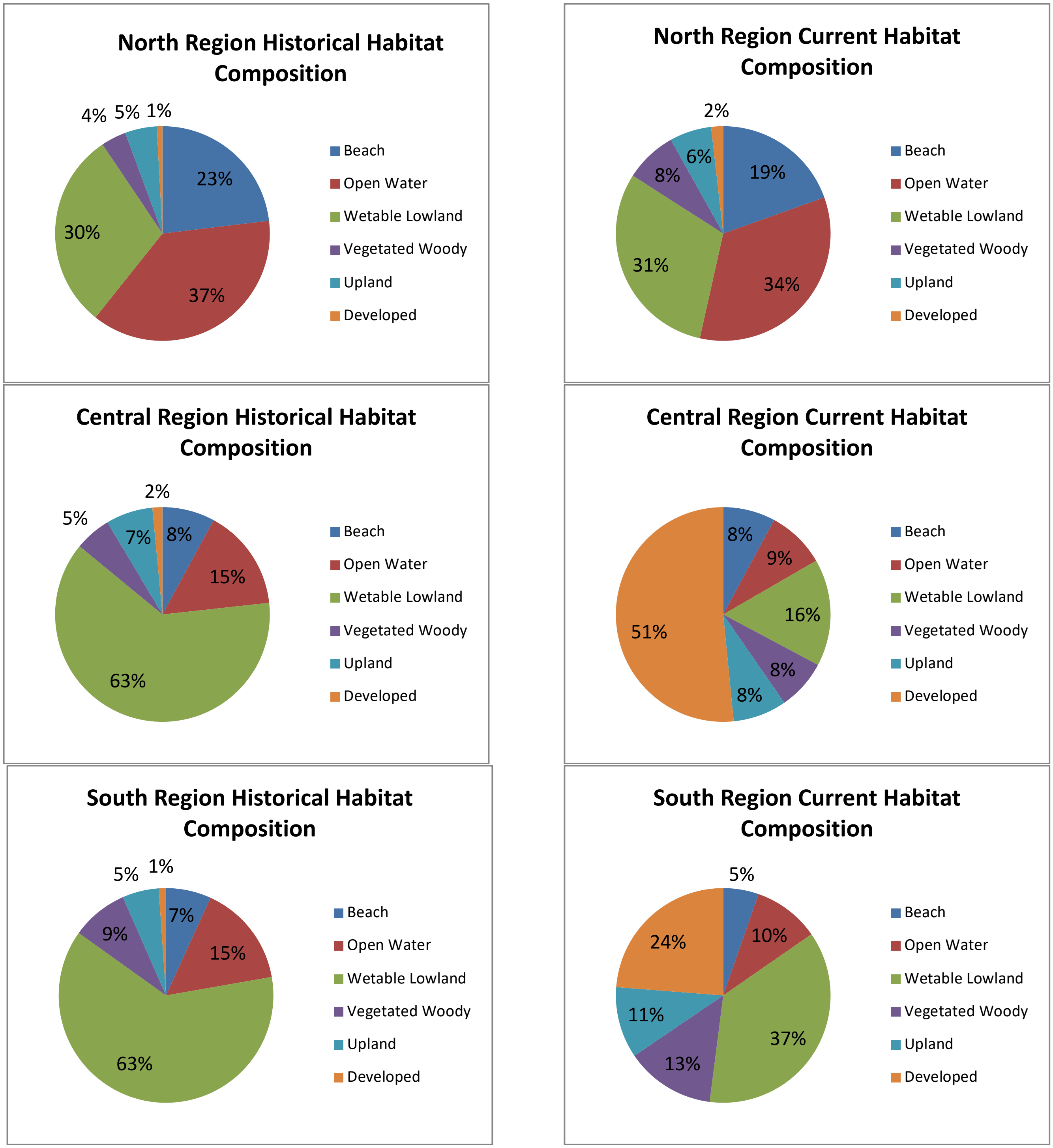



**Figure 22. Habitat change by region.**

## Regional drivers of habitat loss

The main drivers in loss of wetland habitat differed by region of the state. Table 4 shows that the highest development pressure on central coast estuaries over the past 150 years has been agriculture, while for the south coast loss has been due to a combination of urban, agriculture and transportation land uses. For the north coast estuaries, the main land use change, small compared to the other regions, has been for urban purposes. It is important to note that the number of estuaries (sample size) for each region is not equal.

**Table 4. Percent composition of 6 land use types that have led to wetland area loss in BBEs, organized by region.**

| | **Region** | | |
|---|---|---|---|
| **Developed land use type** | **North** (9.5 hectares) | **Central** (1166.7 hectares) | **South** (309.6 hectares) |
| Agriculture | 0.0% | 88.1% | 23.3% |
| Grazing | 12.5% | 0.1% | 0.0% |
| Other | 1.8% | 2.4% | 6.5% |
| Parking Lot | 7.8% | 0.2% | 8.7% |
| Transportation Corridor | 10.2% | 2.1% | 17.3% |
| Urban | 67.6% | 7.2% | 44.2% |

## Site Specific Drivers of Habitat Loss

Even within a region, trends in land form changes are not consistent among sites. For example, Aptos Creek and Laguna Creek (Figure 23) are less than 20 miles apart on the Central Coast and are similar in size. Their historical habitat breakdowns are similar; however, they have both been altered in the subsequent century. Laguna Creek retains significant intact marsh habitat, though in different proportions than historically. The Aptos Creek lagoon has been altered for flood control and urban development in the floodplain. Laguna Creek provides a broader suite of functions due to the access to the floodplain and lack of development but Aptos continues to provide important habitat for migrating steelhead.

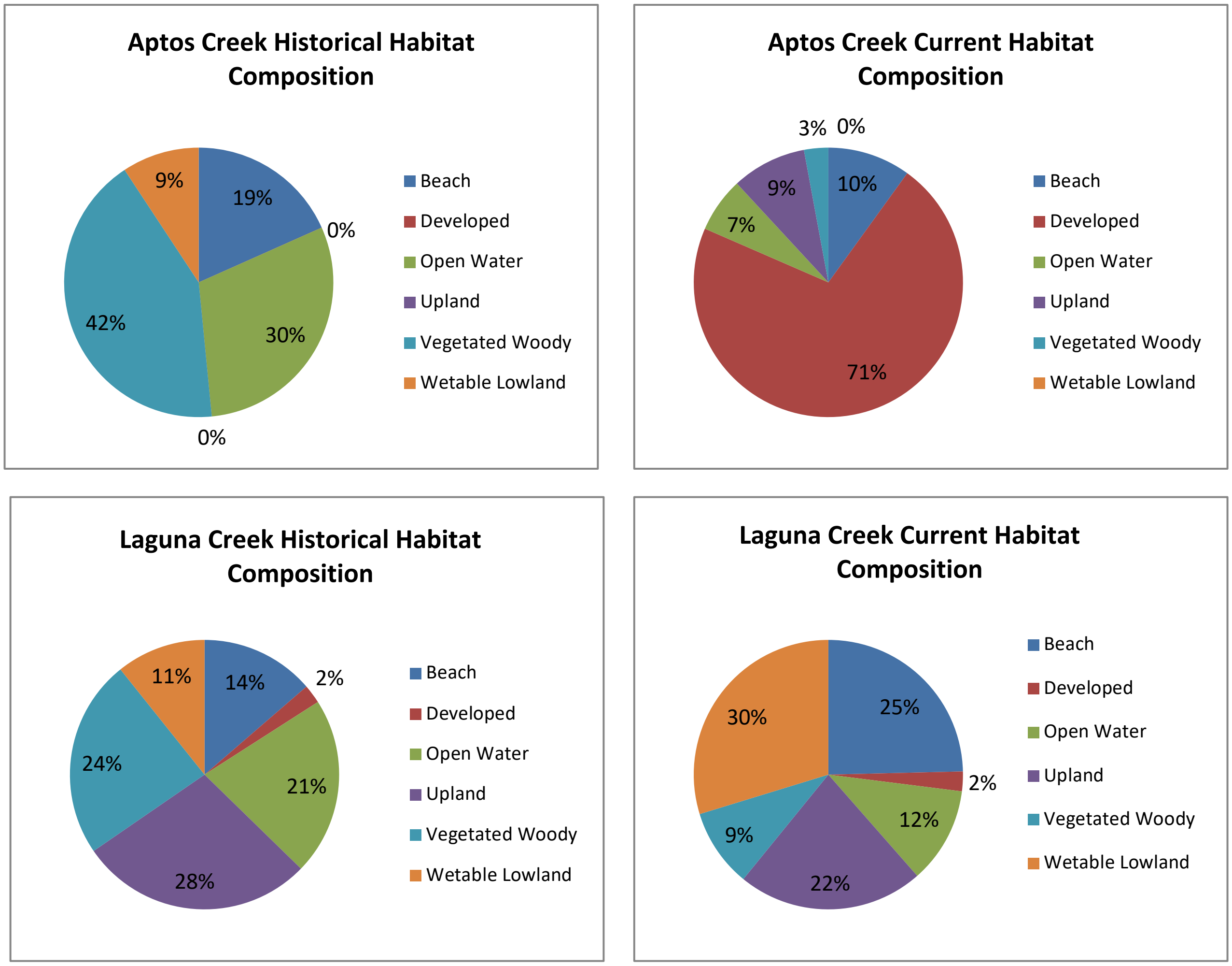



Figure 23. Habitat change by site, two examples from the Central Coast

## Watershed Land Uses and Wetland Stressors

Generalizations on dominant land cover types and potential stressors within the watersheds of the three regions can be made from the watershed landcover GIS analysis. On a watershed scale, urban an impervious surfaces are highest in the southern region, while agriculture is highest on the central coast. The natural land cover of forest and scrub/shrub is a mirror image between the northern and southern regions of the state. High forest cover is shown in the north, while it is low in the south. For scrub/shrub one sees high coverage in the south and low I the north. The central coast region resides I the middle with about equal coverage of both (Figure 24A). When you look at a smaller scale, within 2km of the estuary, the urban pressure on the south coast becomes even more apparent (Figure 24B).

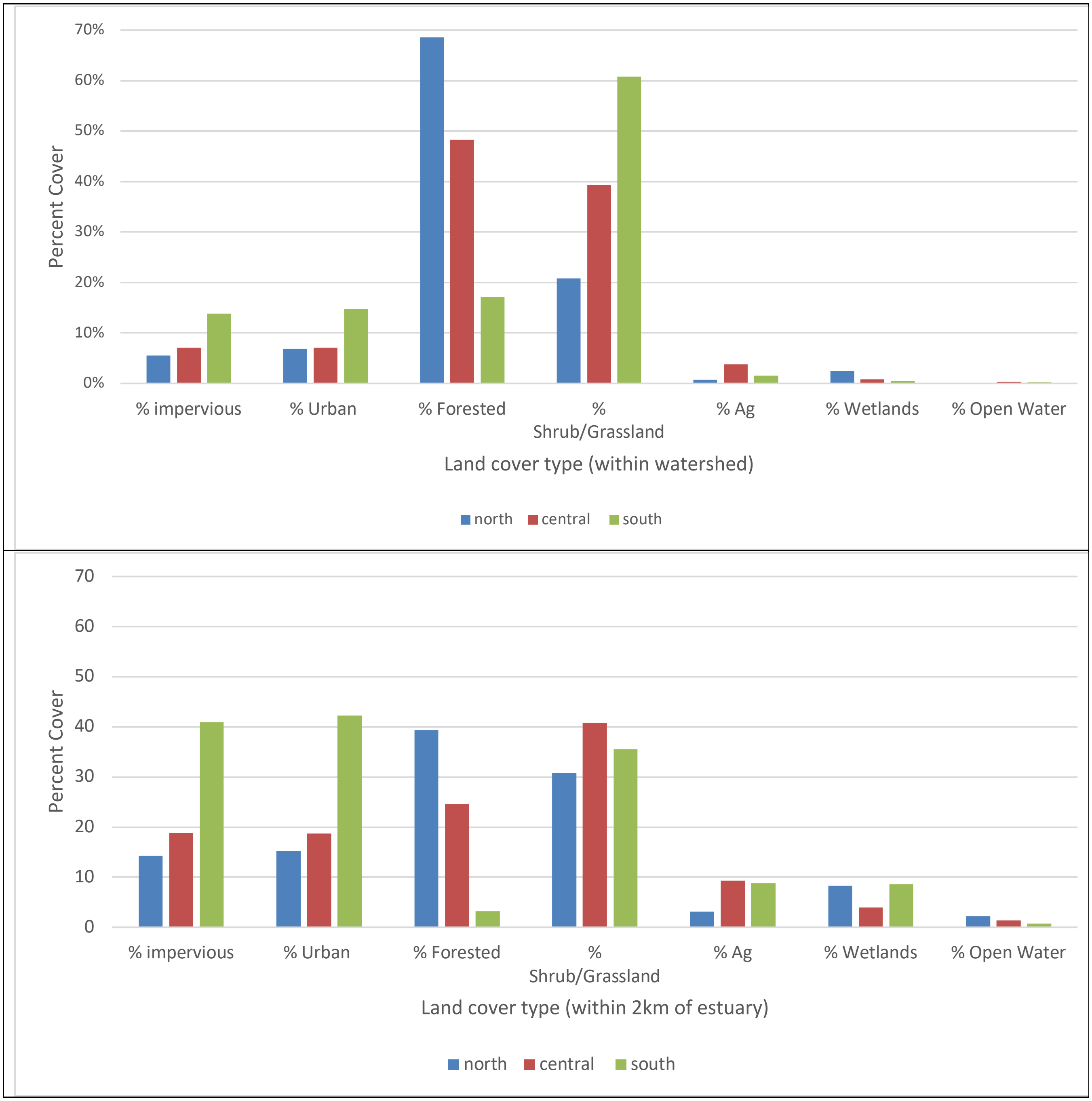



**Figure 24. The average percent over by region of the state of various land use categories for A) the entire watershed and B) within 2km of the estuary.**

## Level 2: Rapid Condition Assessment

### Habitat Condition Assessment Results

CRAM Scores ranged from a low of 37 to a High of 90 points for the 65 sites throughout California, with a median score of 72 (Figure 25). This score distribution does not reflect ambient condition of all California BBE systems, but rather reflects the condition of nearly 50% of all BBEs within State Park lands. No sites were found to have a CRAM index score higher than 90, indicating that none of the selected sites possesses optimal indicators for every metric. Among the 65 sites, at least one site was reported be of each of the four alternate condition categories for each of the 16 CRAM Metrics, suggesting that CRAM adequately represented the full range of condition of BBEs for State Parks.

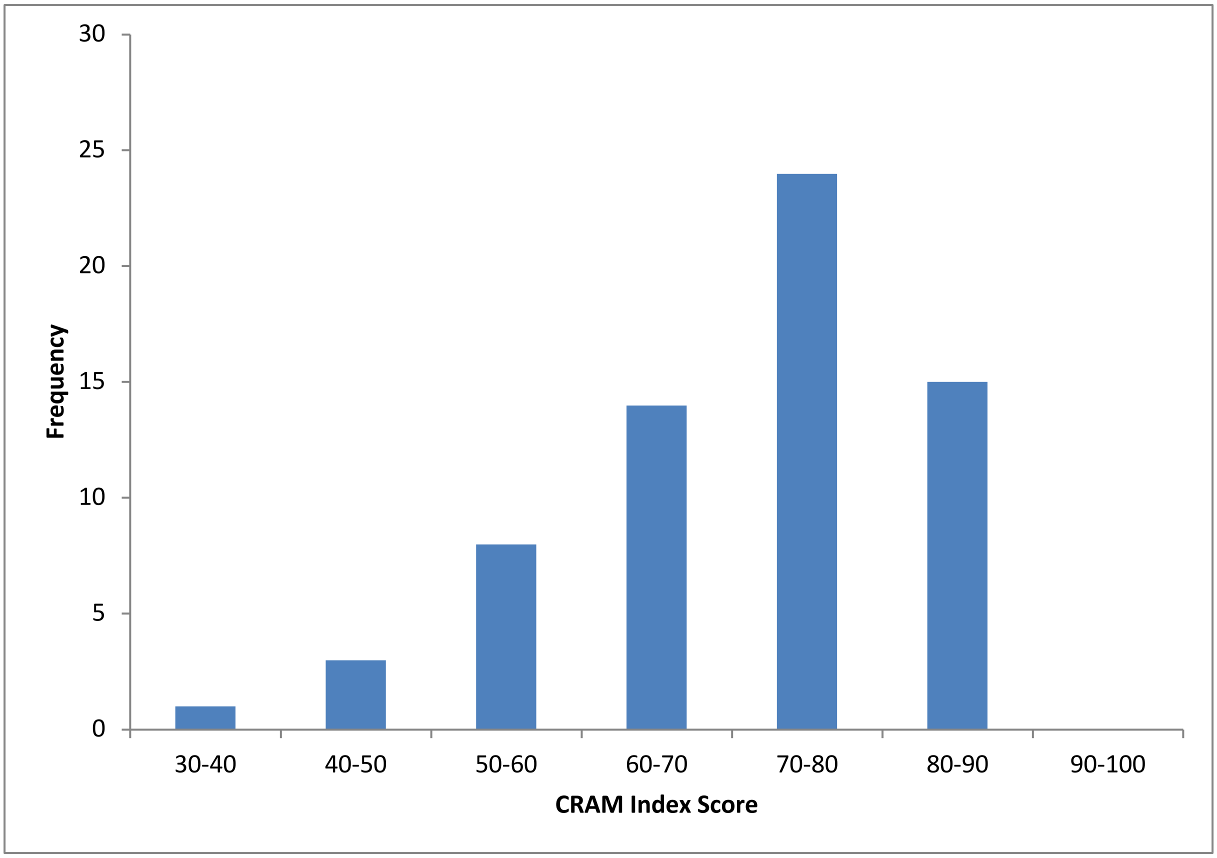



**Figure 25. Histogram of CRAM index scores for 65 bar-built estuaries in California State Parks**

### Range of Scores by Region

The range of scores within each geographic region varied with the Central Coast having the largest range of CRAM Index Scores (37 to 90). All three regions showed similar maximum scores in the upper quartile of condition, meaning they exhibit very high potential for a well function estuary. The South Coast region showed the lowest median score of 69, although it is within the margin of error of the central coast regions median score of 72. The north coast region showed the highest median score of 81 (Figure 26).

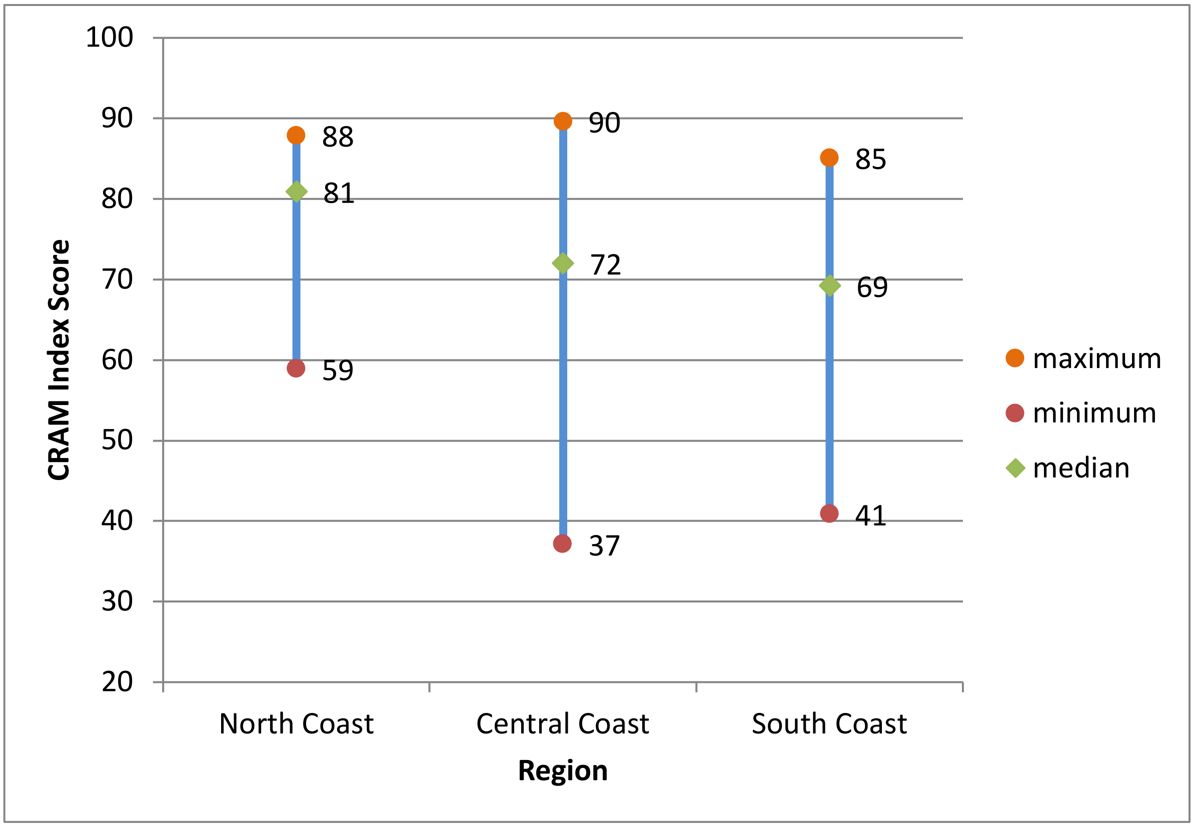



**Figure 26. Maximum, minimum, and median CRAM Index Scores by region of the state.**

Average Attribute scores were found to be higher in the north coast than central or southern California for all but the Biotic Structure Attribute (Figure 27). All supporting data demonstrates that Northern California Lagoons are less impacted from adjacent land uses and subsequently exhibit higher average condition scores. Invasive plants (Ammophila and Spartina) were found to be responsible for low biotic structure of some North Coast Estuaries.

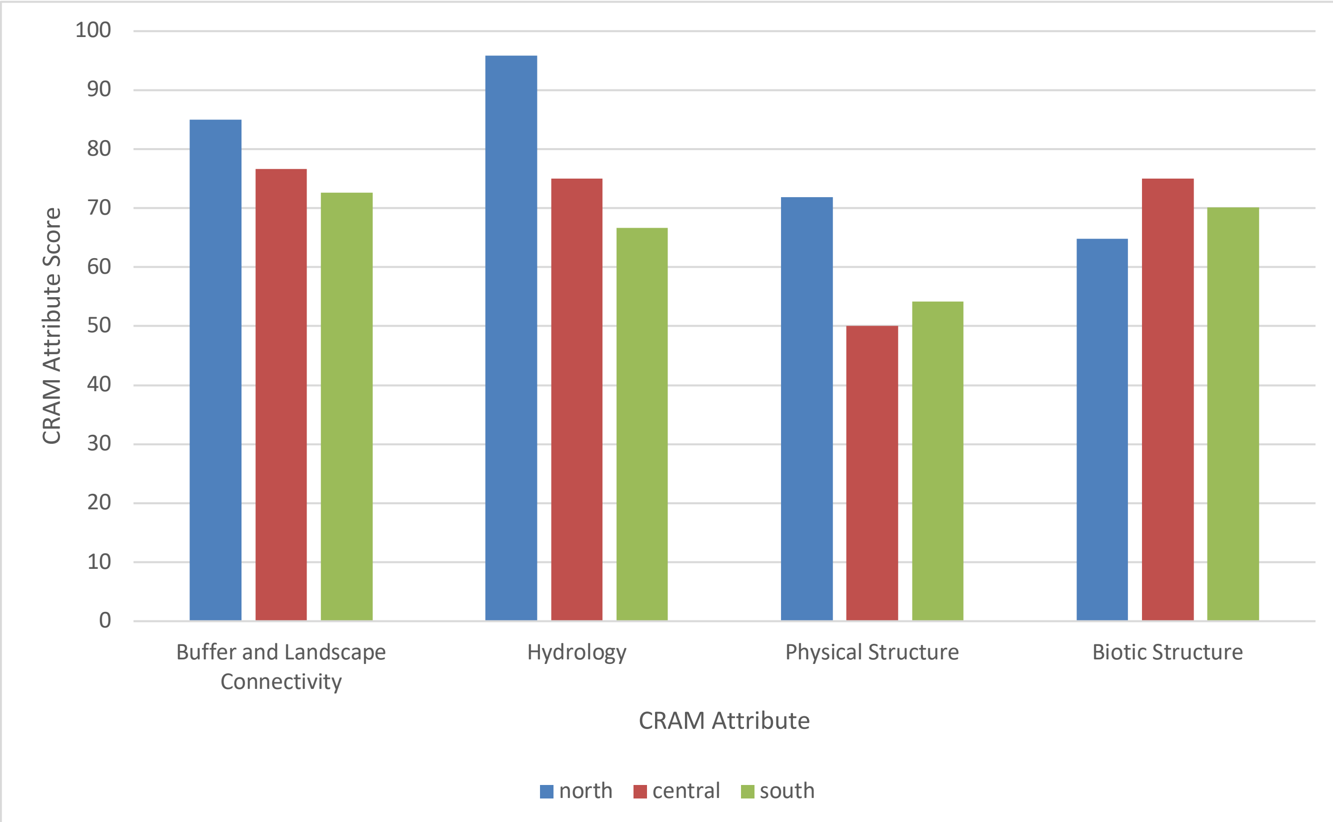



**Figure 27. Median CRAM Attribute Scores by region for 65 bar-built estuaries**

## Comparison of CRAM Metric Results

The most noteable differences among regions for metric scores were greater average condition for Buffer and Hydrology metrics of the lagoons in northern areas (Figure 28). Metrics that pertain to plant species abundance and dynamics are very similar among regions, however invasive species in north coast systems (*Ammophila*) has led to lower median invasive species condition score (yellow circle).

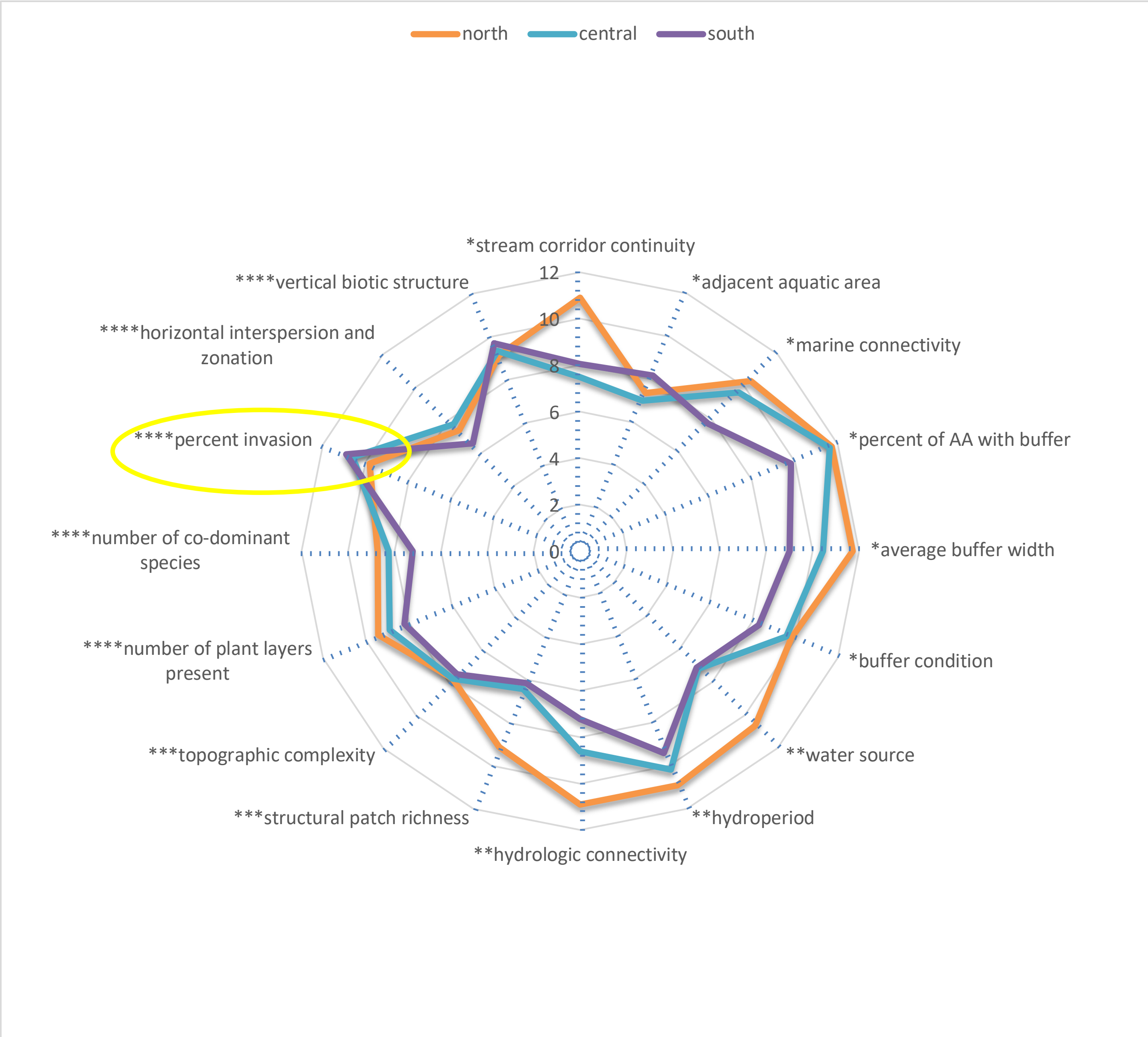



**Figure 28. Average CRAM Metric Scores by region of the state for 65 bar-built estuaries. *=Buffer Attribute, **=Hydrology Attribute, ***=Physical Structure Attribute, ****=Biotic Structure Attribute.**

## Mouth Management and Resulting Impacts on BBE Condition

Mouth management and hydrologic restrictions and alter the habitat condition of BBEs along the coast. These stressors and alterations and alter the natural changes in channel water depth and marsh plain inundation, resulting in changes to the physical and biotic community. Habitat condition assessments were conducted on 65 of the 66 BBEs included in this study. For each of the 65 estuaries, Google Earth, sites visits, and interviews with resource managers were referenced to classify the presence or absence of 1) mouth breaching pressure, 2) the presence of berms or levees resulting in channelization of flow in the estuary, and 3) the presence of mouth constrictions limiting the movement of the mouth of the estuary along the shoreline (Table 5). Where hydrology was restricted or modified in either the channel or at the mouth showed lower CRAM index scores. Breaching pressure had little effect on the CRAM Index score, however it did result in lower Hydrology Attribute scores.

**Table 5. CRAM habitat condition scores at 65 BBE summarized by hydrologic stressors to the estuary**

| **Breaching pressure** | Buffer and Landscape Connectivity | Hydrology | Physical Structure | Biotic Structure | Index Score |
|---|---|---|---|---|---|
| No (n=47) | 74.9 | 80.8 | 58.2 | 70.6 | 71.1 |
| Yes (n=18) | 73.6 | 68.6 | 60.1 | 73.3 | 68.9 |

| **Channelization** | Buffer and Landscape Connectivity | Hydrology | Physical Structure | Biotic Structure | Index Score |
|---|---|---|---|---|---|
| No (n=34) | 81.4 | 88.5 | 63.2 | 72.0 | 76.3 |
| Yes (n=31) | 67.1 | 65.3 | 53.9 | 70.6 | 64.2 |

| **Mouth Constriction** | Buffer and Landscape Connectivity | Hydrology | Physical Structure | Biotic Structure | Index Score |
|---|---|---|---|---|---|
| No (n=42) | 79.8 | 85.2 | 60.2 | 70.9 | 74.0 |
| Yes (n=23) | 65.0 | 63.4 | 56.1 | 72.1 | 64.1 |

## Level 3 Indicators of Condition

### Mouth State and Marsh Plain Inundation Monitoring

Composite graphs were created using the computer code language Python[19]. They are generated for each estuary individually, and pull from a variety of data to show how each parameter changes through time. Parameters include water level, temperature, marsh minimum, maximum, and average elevation (from Trimble Juno GPS points), mean higher high water elevation (from NOAA), flooding periodicity, river gage height (from the USGS when available), rainfall (from NOAA's GHCN), significant wave height (from CDIP), and dominant wave direction (from CDIP). Coupling all this data into a single figure for each estuary provides a broad and exhaustive summary of the system and some of its closely linked drivers (Figure 29).

[19] Python code for generating Composite Graphs is available from CCWG.

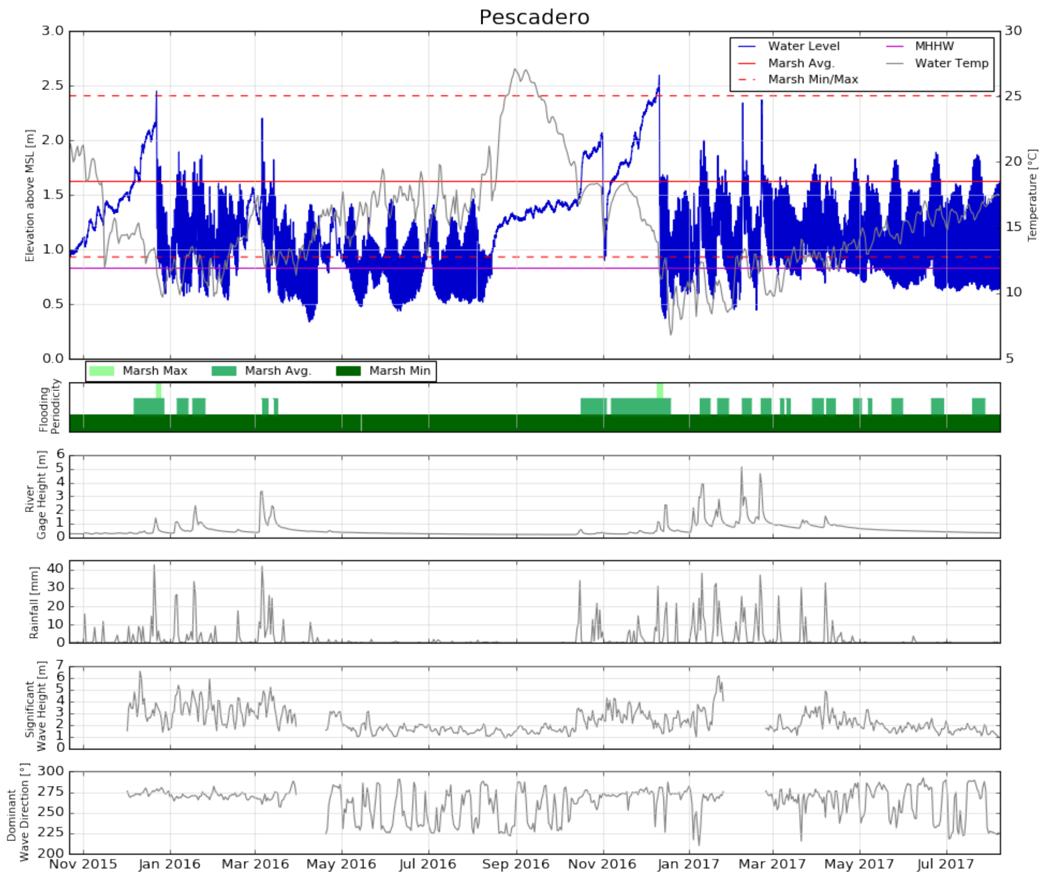



Figure Information: Water temperature, & dominant wave direction are daily mean values. River gage height & significant wave height are daily maximum values. River gage height data publically provided online by the USGS (Station: 11162500). Rainfall data publically provided online by NOAA's GHCN (Station: USC00043714). Wave data publically provided online by CDIP (Station: 142 - SAN FRANCISCO BAR, CA).

**Figure 29. Pescadero Lagoon composite information graph from November 2015 through September 2017.**

## Marsh Plain Inundation Maps

Inundation maps, constructed using ArcGIS for each estuary, show marsh inundation percent spatially. Here, topographic data collected during vegetation surveys was accompanied by LiDAR data provided online by NOAA. Water level data was used to calculate inundation percent for all topographic points (Figure 30). These maps allow for the evaluation of what portions of the marsh may be more susceptible to water level changes. These changes come at varying temporal scales, from episodic breeches to long-term changes in sea level due to glacial extent.

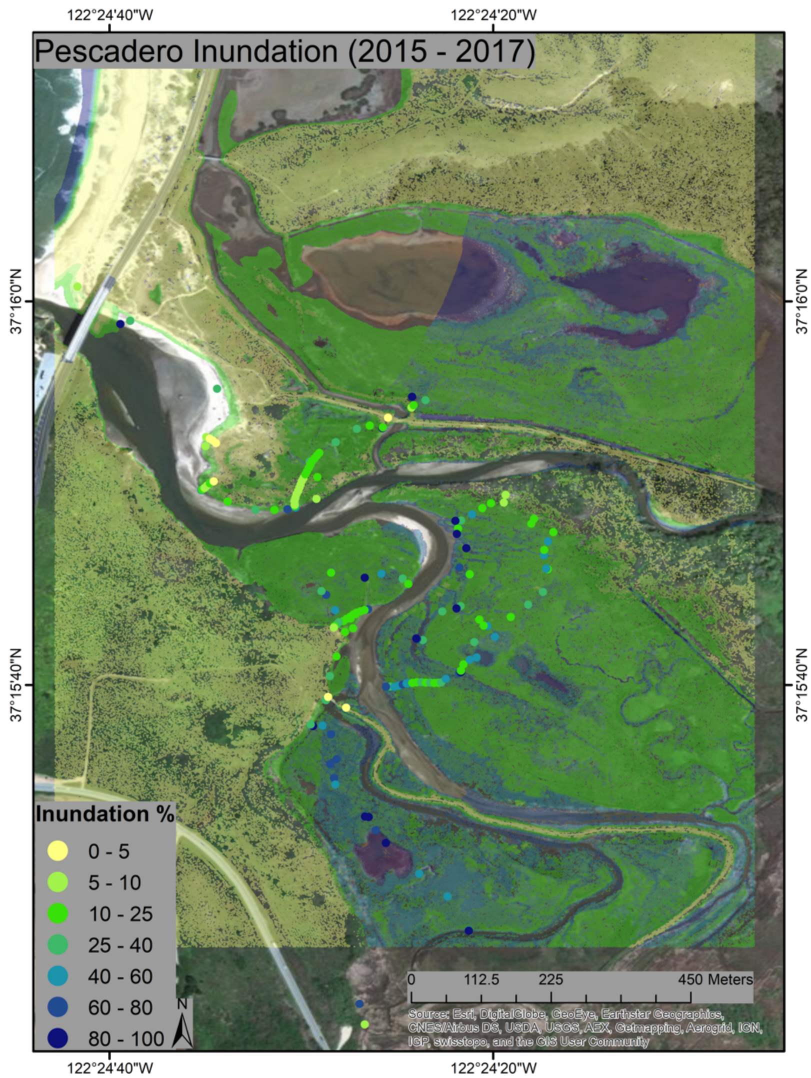



Figure 30. Pescadero Lagoon composite inundation map for November 2015 through September 2017.

## Vegetation Inundation Boxplots

While the former figures were created for each estuary, the vegetation inundation boxplots were made by grouping data from all systems using the computer coding language Python[20]. The categorical data consisted of estuary plant species while the quantitative data included inundation percent and elevations, differentiated by region (southern, central, and northern California) and year. Not only does this method allow for the comparison of averages, but also the spread of the data (Figure 31). For example, does one plant species experience more inundation than another, and is that reflected by the average value or the bulk (spread) of the data?

[20] Python code for generating vegetation box plots is available from CCWG.

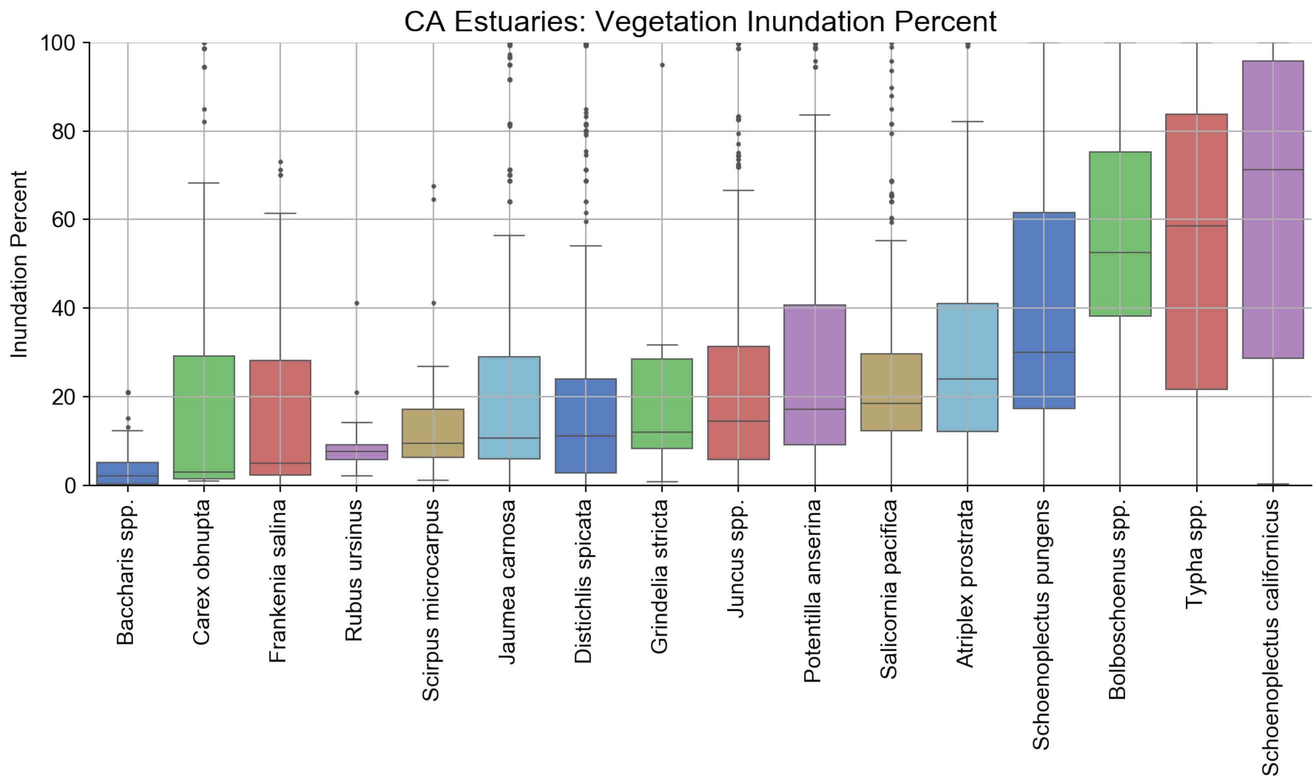



**Figure 31. Average percent of time sixteen common plant species found in BBEs are inundated. Data was pooled from all 26 BBEs that were monitored water level data during this project in California.**

## Sediment Grain Size Results

We found a range in mean grain size from 185um at Arroyo Grande Creek up to 893.8um at Fort Ross Creek (Table 6). Sites along the north coast region of the state showed a higher, but not statistically different, average grain size (506um), as compared to the central and south coast regions, (410um and 406um respectively).

**Table 6. Mean beach grain size for 25 BBEs along the coast of California, sorted by mean grain size.**

| System Name | Region | Mean Grain Size (µm) | Sediment Size Class* | Range of Sediment Size Class** | Percent >2mm |
|---|---|---|---|---|---|
| Arroyo Grande Creek Lagoon | central | 185.58 | Fine Sand | N/A | 0 |
| Los Penasquitos | south | 196.42 | Fine Sand | N/A | 0 |
| Ten Mile River | north | 273.94 | Medium Sand | N/A | 0 |
| Tijuana River Estuary | south | 324.46 | Medium Sand | Fine/Medium Sand | 0 |
| Carpinteria Creek | south | 324.99 | Medium Sand | Fine/Medium Sand | 0 |
| Villa Creek Lagoon | central | 335.03 | Medium Sand | Fine/Medium Sand | Trace Amounts |

| System Name | Region | Mean Grain Size (µm) | Sediment Size Class* | Range of Sediment Size Class** | Percent >2mm |
|---|---|---|---|---|---|
| Waddell Creek | central | 362.36 | Medium Sand | N/A | 0 |
| Malibu Lagoon | south | 365.29 | Medium Sand | N/A | 0 |
| Wilder Creek | central | 386.63 | Medium Sand | N/A | 0 |
| Salmon Creek | north | 386.97 | Medium Sand | Medium/Coarse Sand | Trace Amounts |
| Arroyo Sequit | south | 413.78 | Medium Sand | Medium/Coarse Sand | Trace Amounts |
| Lake Davis | north | 450.08 | Medium Sand | Medium/Coarse Sand | Trace Amounts |
| Pescadero Lagoon | central | 451.29 | Medium Sand | N/A | 0 |
| Laguna Creek | central | 458.43 | Medium Sand | Medium/Coarse Sand | 0 |
| Aptos Creek | central | 467.78 | Medium Sand | Medium/Coarse Sand | Trace Amounts |
| San Simeon | central | 471.03 | Medium Sand | Medium/Coarse Sand | 16.09 |
| Stump Beach | north | 473.28 | Medium Sand | Medium/Coarse Sand | 3.78 |
| Ossagon | north | 479.09 | Medium Sand | Medium/Coarse Sand | Trace Amounts |
| Brush Creek | north | 499.76 | Medium Sand | Medium/Coarse Sand | 1.62 |
| Fern Canyon | north | 531.71 | Coarse Sand | Medium/Coarse Sand | Trace Amounts |
| Big Sycamore Canyon | south | 539.93 | Coarse Sand | Medium/Coarse Sand | Trace Amounts |
| Navarro River | north | 569.57 | Coarse Sand | Medium/Very Coarse Sand | 16.02 |
| Salinas River Estuary | central | 573.41 | Coarse Sand | Medium/Coarse Sand | Trace Amounts |
| San Mateo Lagoon | south | 681.67 | Coarse Sand | Coarse/Very Coarse Sand | 8.78 |
| Fort Ross Creek | north | 893.82 | Coarse Sand | Coarse/Very Coarse Sand | 28.18 |
| *Relative to mean grain size of entire system | | | | | |
| **Considers entire range of mean grain sizes from each sample within the system | | | | | |

Knowledge of the sediment grain size can help with the interpretation of temperature/depth logger data. In general, sites with larger grain size my exhibit more leakage of ponded water behind a closed beach berm from the estuary to the marine environment, or lack ponding all together. For example, Fort Ross Creek (Figure 32) with a mean grain size of 893.8um, showed little if any ponding of water behind the beach berm during rainfall events. Fresh water flowed from the estuary quickly into the marine environment.

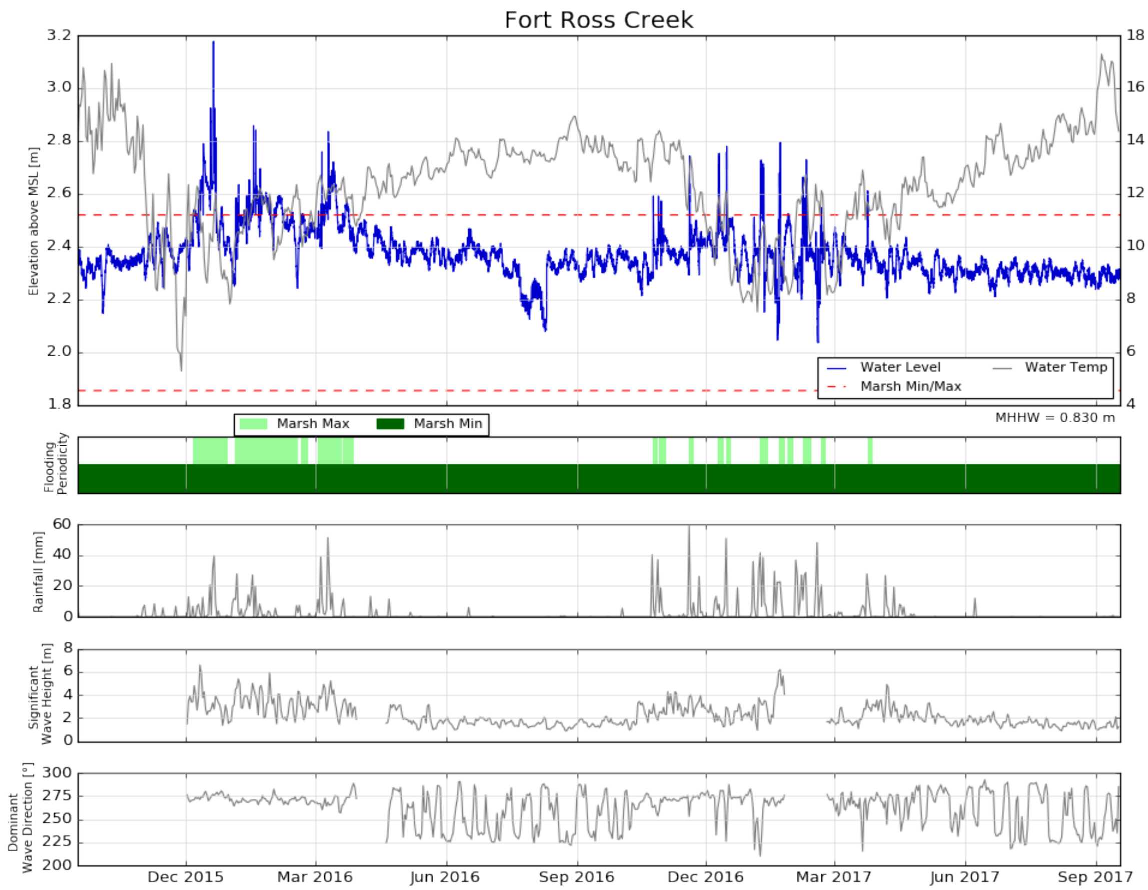



Figure Information: Water temperature, & dominant wave direction are daily mean values. Significant wave heights are daily maximum values. Rainfall data publically provided online by NOAA's GHCN (Station: USW00093245). Wave data publically provided online by NOAA (Station: 142 - SAN FRANCISCO BAR, CA).

**Figure 32. Fort Ross Creek composite information graph from November 2015 through September 2017**

Compare this with Carpinteria Creek (Figure 33) with a mean grain size of 324.99um. This BBE shows extended periods of ponding behind the beach berm, and only drains when a breach occurs during a rain event in February, 2017. Slow leakage can be observed throughout all of 2017 and the water level gradually decreases.

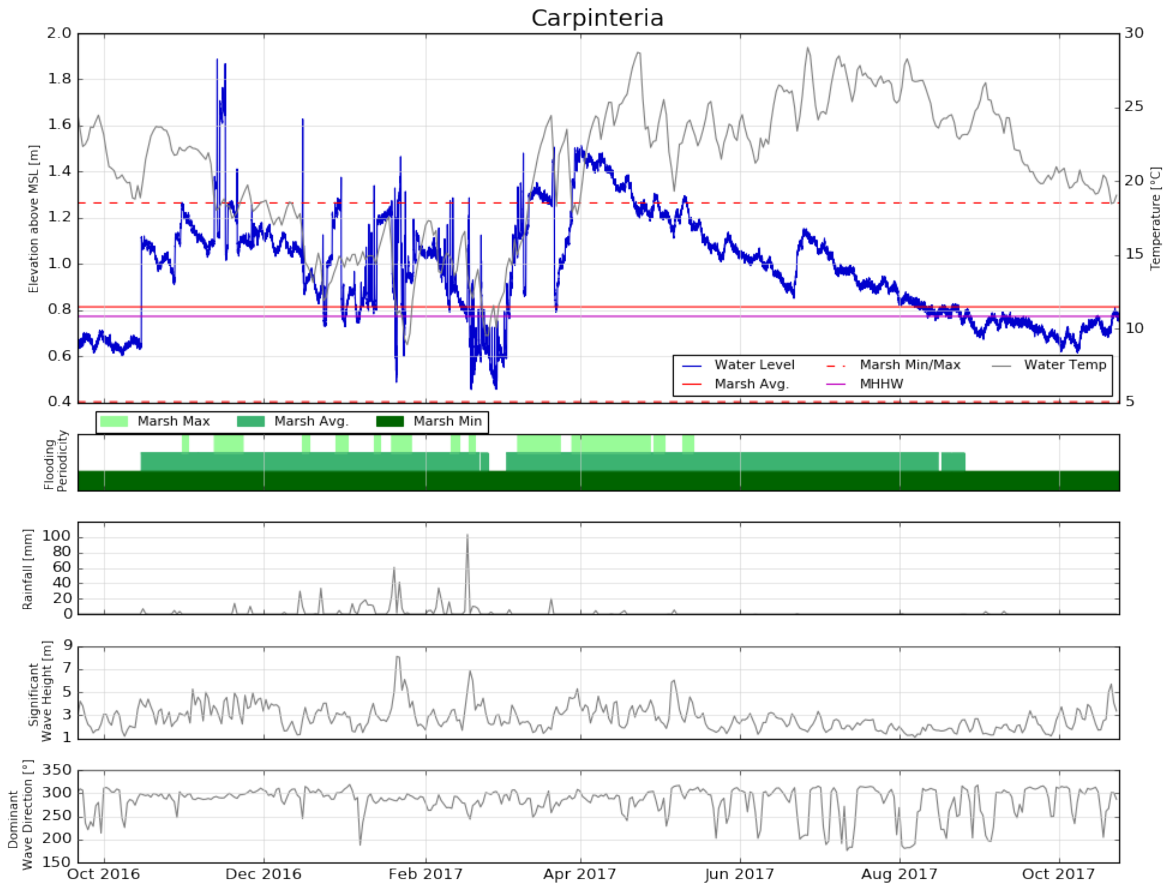



Figure Information: Water temperature, & dominant wave direction are daily mean values. Significant wave heights are daily maximum values. Rainfall data publically provided online by NOAA's GHCN (Station identifier: USW00053152). Wave data publically provided online by NOAA (Station: 071 - HARVEST, CA).

**Figure 33. Carpinteria Creek composite information graph from October 2016 through October 2017**

While the porosity of the beach berm is a main factor in influencing the formation and maintenance of a ponded system behind the beach berm, other factors include freshwater inputs, evaporation, water extraction, and adjacent land use, amongst others.

## Special Status Species

Results of BBE special status species presence is presented in Table 7 below. A complete version of the table with refences to documentation of species presence is available on the CCWG website.

**Table 7. Presence of ten special status species in estuaries assessed for this project. P=present in estuary, W=present in watershed, HP= Not observed, but high potential for presence based on habitat, E=extirpated.**

| System Name | Snowy Plover | Coho | Steelhead | Western Pond Turtle | Tidewater Goby | Red-Legged Frog | SF garter snake | common yellowthroat | monarch | brackish water snail |
|---|---|---|---|---|---|---|---|---|---|---|
| Ossagon Creek | | | P | W | | | | | | |
| Fern Canyon | | P | P | W | | | | | | |
| 10 Mile River | | P | P | | P | | | | | |
| Navarro River | | | P | W | | W | | | | |
| LAKE DAVIS/Manchester | | | | W | P | P | | | | |
| Brush Creek | | | P | W | P | W | | | | |
| Stump Beach | | | | W | | W | | | W | |
| Fort Ross Creek | | | | W | | W | | | P | |
| Russian Gulch (Sonoma) | | | | W | | W | | | E? | |
| Salmon Creek | P | | | W | P | W | | | W/E? | E |
| Pescadero Marsh | P | P | P | P | P | P | P | P | W | P |
| Waddell Creek | P | P | P | P | P | P | P | W | W | |
| Laguna Creek | P | | P | W | P | W | | W | W | |
| Aptos Creek | | | P | W | P | W | | W | W | |
| Wilder Creek | P | | | W | P | W | | W | W | |
| Salinas River Estuary | P | | W | W | P | W | | | | |
| San Jose Creek | | | P | | | W | | | W | |
| Arroyo de la Cruz | | | P | P | HP | W | | | W | |
| San Simeon | P | | P | P | P | P | | | P | |
| Villa Creek Lagoon | P | | P | P | P | W | | | W | |
| Arroyo Grande Creek Lagoon | P | | P | | P | W | | | W | E |
| Canada Del Refugio Creek | | | | P | P | W | | | P | |
| Canada Del Capitan Creek | | | | W | | W | | | W | |
| Carpinteria Creek | E | | | W | P | W | | | P | |
| Big Sycamore Canyon | | | | | HP | W | | | P | W |
| Arroyo Sequit | | | P | | HP | W | | | W | W |
| Malibu Lagoon | P | | P | | P | W | | | W | W |
| San Mateo Lagoon | | | P | E | P | W | | | P | |
| Los Penasquitos | P | | | W | HP | | | | W | P |
| Tijuana River Estuary | P | | | W | | | | | W | P |

# Section 5- Resource Management Prioritization Using Standard Data Collection Protocol

## Site Prioritization

CCWG used the compiled BBE survey data to create a set of three Management Prioritization Strategies to aid California State Parks to prioritize ecosystem-based habitat restoration efforts on the California coast. Each of the prioritization strategies accounts for various combinations of 1) current estuarine condition, 2) level of watershed stress, 3) current support of special status species, and 4) restoration opportunities and resiliency to sea level rise. These data can be used in combination, or as stand-alone tools, depending on the focus and goals of the user. These strategies are intended to provide decision makers with means to integrate diverse habitat information systematically to ensure funding dollars support strategically located projects that provide the greatest overall benefit to BBEs as a population.

## Description of Prioritization Methods

### Initial Steps

The three methodologies were used to develop to prioritize BBE restoration and management actions. The Threshold Evaluation Method reviewed each site based on a set of minimum qualifications, and iteratively removed sites that did not meet these requirements. The second prioritization method used graphical analysis of Condition-Vulnerability Evaluation. Each site was graphically represented based on current wetland condition (CRAM) and the watershed and adjacent stress posed to the site by current land use. The third method utilized the Recovery Potential Screening (RPS) Tool developed by USEPA designed to “compare watersheds and plan efforts for greater likelihood of restoration and protection success”.

All of the information collected for this study was compiled within a single data file including columns for CRAM Attribute and Index scores, all watershed land use and stressors based on three different watershed “influence buffers”, data from the wetland habitat change analysis, and a tally of special status species present at each site. Several additional columns were added to assist in the prioritization of the estuaries, including:

- Opportunity/space for restoration of wetland area (value of 0, 1, or 2, with 2 having the highest potential for restoration of wetland area)
- Capacity to migrate inland in response to sea level rise (yes or no)
- Occurrence of artificial breaching (yes or no)
- Presence of off-channel habitats (yes or no)
- Presence of anthropogenic channelization of the main channel (yes or no)
- Presence of mouth constriction preventing mouth migration (yes or no)

### Prioritization #1: Threshold Evaluation

The Threshold Evaluation Method, modeled after efforts by the Nature Conservancy to assess conservation efforts in west coast Estuaries (Gleason et al., 2011), used numerous criteria to screen sites and remove those that did not meet those thresholds. The Threshold Evaluation Method intended to select sites that would benefit from restoration efforts that would lead to an “ecologically significant” improvement in California BBE condition. Specifically, wetlands were selected to meet a minimum size with all sites of less than 1 hectare removed. Sites were prioritized that had lost more than 50% of marsh plain habitat (wetable lowland: area seasonally inundated by lagoon water elevation dynamics) and that had space for marsh plain restoration and the capacity to migrate inland in response to sea level rise. Finally, sites were prioritized that supported selected special status species. This process resulted in the list of sites being cut from 65 coastal confluences to 8 sites of interest. This method could be modified to prioritize a different subset of thresholds to prioritize a different set of restoration goals.

### Prioritization #2: Condition-Vulnerability Evaluation

The Condition-Vulnerability Evaluation method, based on the EPA's Healthy Watersheds Initiative (Ode et al., 2014), used the habitat condition data and the watershed stressor data to generate a habitat "condition-vulnerability" graph. Sites self-selected into one of four quadrants based on vulnerability and health thresholds, each leading to a call for different management actions:

- Low vulnerability/low health: implement habitat restoration actions
- Low vulnerability/ high health: ensure proper management plans and ongoing actions are taking place
- High vulnerability/high health: emphasize protection of resources and address buffer stress
- High vulnerability/low health: low priority sites

The CRAM Index score was used for the site "condition score", while the "vulnerability score" was calculated as the total percent cover of Impervious surfaces, Urban land cover, and Agricultural land cover (within a 250-meter wide buffer along all streams within 2 kilometers of the estuary) within the watershed. The resulting vulnerability score was then "corrected" for on-site stresses through use of correction factor of 1.2 if there was the presence of anthropogenic channelization in the main channel, and/or the presence of mouth constrictions preventing mouth migration. Each sites condition and vulnerability scores were graphed and a final subset of sites was selected that also met the following criteria:

- Presence of space for restoration of wetland area (value of 1 or 2 in the database)
- Marsh migration is possible due to sea level rise
- Presence of tidewater gobies and/or steelhead
- 50% Estuary in public or land trust ownership

This process resulted in the list of sites being cut from 65 coastal confluences to 15 sites of interest.

### Prioritization #3: EPA Decision support tool

The Recovery Potential Screening (RPS) Tool was developed by the U.S. Environmental Protection Agency (EPA) (www.epa.gov/rps) to enable restoration planners to systematically compare relative differences in the restorability of water bodies or watersheds using GIS data and other georeferenced monitoring information. The tool is used to compare differences among watersheds or streams based on assessments of ecological capacity, stressor exposure, and social context. These three indices are combined to obtain an overall recovery potential integrated (RPI) score, which summarized the restorability of each BBE as compared with the others in the state. Originally developed to support the prioritization of restoration projects as part of Total Maximum Daily Load (TMDL) and impaired waters listing programs, the tool can also support a variety of other prioritization efforts.

CCWG used an early version of the tool which allows the user to use field data collected to estimate ecological capacity, stressor exposure, and social context. To evaluate ecological capacity and BBE management opportunities we used the following parameters:

- CRAM Index score
- CRAM attribute scores (4)
- watershed size
- estuary area size
- presence of space for restoration of wetland area

- % Shrub/Grassland- with in 2km of estuary
- % Natural Forested- within a 250 m buffer of streams within 2km of estuary
- % Natural Forested- whole watershed

For the stressor exposure we used the following parameters:

- Density of all roads (km/km2) for the whole watershed
- within a 250m buffer of streams within 2km of estuary:
    - % Impervious surface
    - % Urban Land cover
    - % Agricultural Land cover
- presence of channelization within the estuary
- presence of a mouth constriction

For the social context metric, we ranked sites based on the percent of the estuary and watershed that are in public/protected ownership

The EPA RPS Tool resulted in three ranked lists of sites, based on Ecosystem Index, Stressor Index and a combined Restoration Priority Index, of which the top eight from each list are presented.

## Results

### Prioritization #1: Threshold Evaluation

The threshold evaluation method resulted in prioritization of the following 8 sites, presented here in order of CRAM Index Score:

| System Name | Region | Index Score |
|---|---|---|
| Canada de la Gaviota Creek | South | 85 |
| Arroyo Grande Creek Lagoon | Central | 71 |
| San Gregorio Creek | Central | 70 |
| Big Sycamore Canyon | South | 70 |
| Frenchman's Creek | Central | 65 |
| Pilarcitos Creek | Central | 60 |
| Arroyo Sequit | South | 59 |
| Yankee Jim Gulch | Central | 56 |

### Prioritization #2: Condition-Vulnerability Graph

The Condition-Vulnerability Evaluation method resulted in the following list of sites, grouped by proposed management action:

Habitat restoration actions (low vulnerability/poor or fair estuary condition): Figure 34, green points

- Waddell Creek
- Pescadero Marsh
- Yankee Jim Creek

- Pomponio Creek

Address stress in buffer (high vulnerability/good estuary condition): Figure 34, orange points

- Gaviota Creek
- San Simeon Creek

Ensure proper management is in place (low vulnerability/ good estuary condition): Figure 34, yellow points

- Villa Creek
- Baldwin Creek
- Arroyo de la Cruz

Lower priority sites (high vulnerability/ poor or fair estuary condition): Figure 34, red points

- Frenchman's Creek
- Arroyo Grande Creek
- Carmel River
- Pilarcitos Creek
- Arroyo Sequit
- San Gregorio Creek

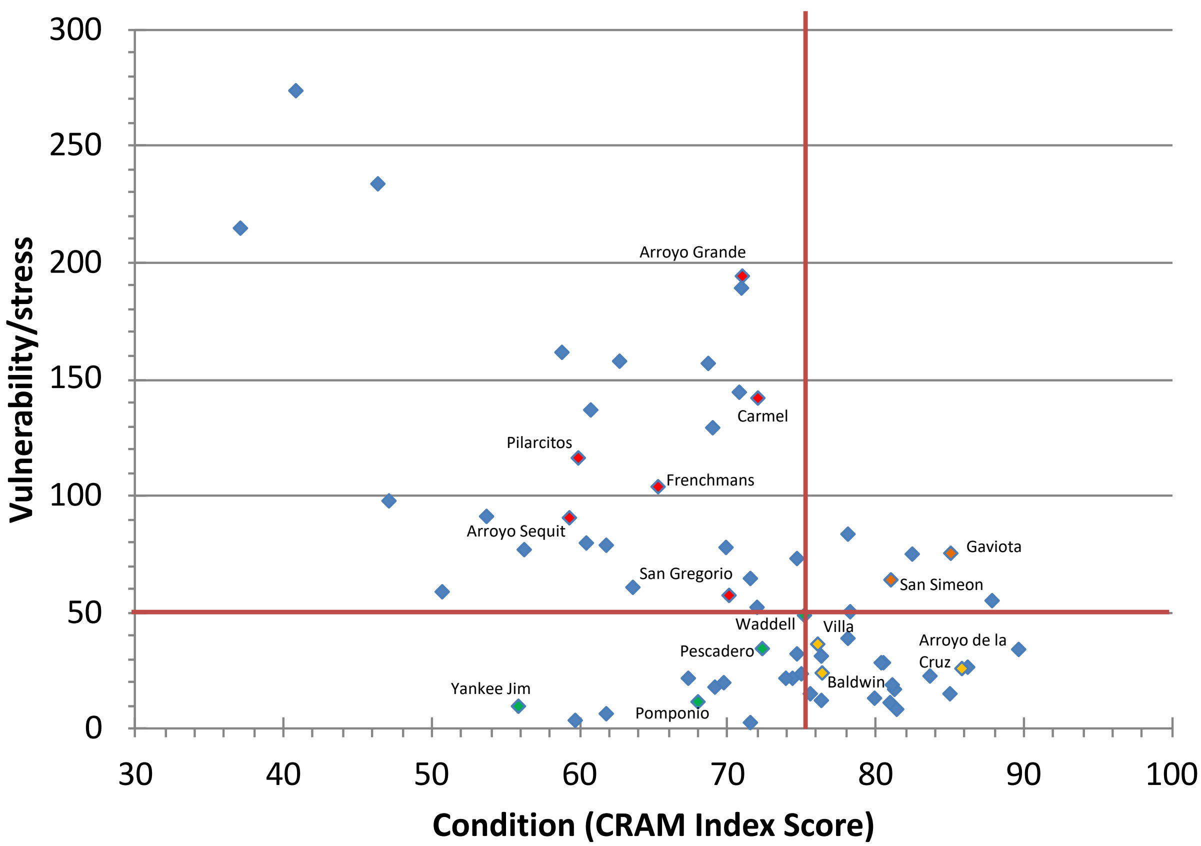



Figure 34. Results of Health-Vulnerability graph prioritization.

### Prioritization #3: EPA Decision support tool

The Recovery Potential Screening (RPS) Tool resulted in the following list of sites, ranked in order and group by Index output from the RPS tool (Table 8).

**Table 8. Results of EPA RPS Tool for State Park BBEs.**

| Ecosystem Index Rank (best condition) | Stressor Index Rank (least stress) | Restoration Priority Index Rank |
|---|---|---|
| 1. Russian River | 1. Fern Canyon | 1. Fern Canyon |
| 2. Laguna Creek | 2. Martini Creek | 2. Martini Creek |
| 3. Ten Mile River | 3. Coon Creek Lagoon | 3. Coon Creek Lagoon |
| 4. Arroyo de la Cruz | 4. Ossagon Creek | 4. Fort Ross Creek |
| 5. Alder Creek | 5. Garrapata (aka Joshua Creek) | 5. Ossagon Creek |
| 6. Scott Creek | 6. Fort Ross Creek | 6. Arroyo de la Cruz |
| 7. Brush Creek | 7. Russian Gulch (Sonoma) | 7. Stump Beach |
| 8. Baldwin Creek | 8. San Jose Creek | 8. Russian Gulch (Sonoma) |

## Prioritization Support Tool

The three prioritization methods relied on various amounts of the data collected for these sites. Prioritization #1 uses only GIS-based data to narrow the number of sites down to five. It is a relatively simple process and the cutoffs for each data type can be set and any desired point. In addition, more screening levels can be added that meet the needs of the party interested.

Prioritization 2 incorporates site-specific field data on marsh condition as well as stress in the watershed. This allows for a ranking based on condition and stress. Additional threshold data were used (restorable area, habitat migration, etc.) to further reduce the list of sites.

Prioritization 3 attempts to rate ecological condition, stress and social context independently using multiple factors, and then combine them to come up with a more holistic ranking of priority sites for management action.

The results of each prioritization method were combined to identify common themes among methods and sites.

## Prioritization of Sites for Restoration Actions

A summary table of all three site prioritization methods and the CRAM Index score was compiled. Sites that were identified within multiple prioritization methods and that have higher CRAM Index scores were highlighted (Table 9). This “preponderance of priorities” evaluation identified 9 BBEs in California that will benefit from timely management action, including:

1. Arroyo de la Cruz
2. Gaviota Creek
3. Baldwin Creek
4. Arroyo Grande
5. San Gregorio Creek
6. Frenchman’s Creek
7. Pilarcitos Creek

8. Arroyo Sequit
9. Yankee Jim Gulch

**Table 9. Summary and combination of all three prioritization schemes.**

| System Name | Index Score | Prioritization 1 | Prioritization 2 | Prioritization 3 | Total |
|---|---|---|---|---|---|
| Arroyo de la Cruz | 86 | | 1 | 1 | 2 |
| Canada de la Gaviota Creek | 85 | 1 | 1 | | 2 |
| Baldwin Creek | 76 | | 1 | 1 | 2 |
| Arroyo Grande Creek Lagoon | 71 | 1 | | 1 | 2 |
| San Gregorio Creek | 70 | 1 | | 1 | 2 |
| Frenchmans Creek | 65 | 1 | | 1 | 2 |
| Pilarcitos Creek | 60 | 1 | | 1 | 2 |
| Arroyo Sequit | 59 | 1 | | 1 | 2 |
| Yankee Jim Gulch | 56 | 1 | 1 | | 2 |
| Ten Mile River | 88 | | | 1 | 1 |
| Laguna Creek | 85 | | | 1 | 1 |
| Russian River | 84 | | | 1 | 1 |
| Ossagon Creek | 81 | | | 1 | 1 |
| Russian Gulch (Sonoma) | 81 | | | 1 | 1 |
| San Simeon | 81 | | 1 | | 1 |
| Coon Creek Lagoon | 81 | | | 1 | 1 |
| Brush Creek | 81 | | | 1 | 1 |
| Alder Creek | 80 | | | 1 | 1 |
| Fort Ross Creek | 80 | | | 1 | 1 |
| Stump Beach | 76 | | | 1 | 1 |
| Villa Creek Lagoon | 76 | | 1 | | 1 |
| Garrapata (aka Joshua Creek) | 76 | | | 1 | 1 |
| Waddell Creek | 75 | | 1 | | 1 |
| San Jose Creek | 75 | | | 1 | 1 |
| Scott Creek | 74 | | | 1 | 1 |
| Pescadero Marsh | 72 | | 1 | | 1 |
| Carmel River Lagoon | 72 | | | 1 | 1 |
| Fern Canyon | 72 | | | 1 | 1 |
| Big Sycamore Canyon | 70 | 1 | | | 1 |
| Pomponio Creek | 68 | | 1 | | 1 |
| Martini Creek | 62 | | | 1 | 1 |

## Assessment of Selected Sites

### *Habitat Loss and Recovery*

Six of the nine sites showed a loss of wetland habitat from the 1850's, while eight of the sites show a greater than 50% loss of wetable lowland (Table 10). Of those eight sites, four of them (San Gregorio, Yankee Jim, Baldwin and Pilarcitos) have the opportunity and space for wetland restoration (a value 2 (good) in Table 10). Potential habitat restoration actions include:

- San Gregorio: reconnect the marsh that is located to the area east of Highway 1 and north of the main cannel with the estuary, as is shown in historical maps. Address the breaching pressure through improvement of beach access when the beach berm is closed.
- Yankee Jim Gulch: Create some backwater habitat for fish refuge and remove the cement channel along with some fill associated with HWY 1.
- Baldwin Creek: remove the barriers between the ponds and the creek channel on the west side of the estuary to return that area to estuarine functions.

- Pilarcitos Creek: restore/improve backwater habitats for steelhead and create scour pools in the lower channel

**Table 10. Habitat change analysis results for the 9 priority sites.**

| System Name | Historic Wetland area (hectares) | Currect Wetland area (hectares) | Wetland Area % Change | % change wetable lowland | opportunity /space for wetland restoration | SLR Marsh Migration possible? | Breaching pressure | off-channel habitats | Channelization | Mouth constriciton |
|---|---|---|---|---|---|---|---|---|---|---|
| San Gregorio Creek | 13.3 | 9.1 | -31.4 | -56.5 | 2 | Y | Y | Y | Y | N |
| Yankee Jim Gulch | 1.9 | 1.6 | -17.9 | -96.0 | 2 | Y | N | N | Y | N |
| Baldwin Creek | 16.5 | 15.1 | -8.5 | -48.4 | 2 | Y | N | Y | Y | N |
| Arroyo de la Cruz | 14.0 | 13.0 | -7.5 | small increase from 0 | 2 | Y | N | N | N | N |
| Pilarcitos Creek | 8.4 | 8.6 | 1.3 | -73.0 | 2 | Y | N | N | N | N |
| Arroyo Sequit | 16.0 | 4.2 | -73.6 | -100.0 | 1 | Y | N | N | Y | Y |
| Canada de la Gaviota Creek | 7.2 | 4.3 | -40.3 | -70.0 | 1 | Y | Y | Y | N | Y |
| Arroyo Grande Creek Lagoon | 126.2 | 84.3 | -33.2 | -86.9 | 1 | Y | Y | Y | Y | Y |
| Frenchmans Creek | 0.8 | 1.1 | 28.2 | -85.1 | 1 | Y | Y | N | Y | N |

## Management Opportunities and General Priority Actions

### *Wetland Habitat Condition-CRAM*

Low CRAM Attribute scores can be improved by eliminating the current or historical stress on that system. The main stressors leading to lower CRAM attribute scores at sites along the coast were as follows:

Buffer and Landscape Context:

- Passive recreation
- Transportation corridor
- Active recreation (off-road vehicles, mountain biking, hunting, fishing)
- Urban residential land use

Hydrology:

- Non-point source discharges

Physical Structure:

- Grading/compaction
- Engineered Channel (riprap, armored channel bank, bed)
- Trash/refuse

Biotic Structure:

- Lack of treatment of invasive plant species adjacent to AA or buffer
- Excessive human visitation

Categories of actions that could be taken to mitigate the impacts of identified stressors on current wetland condition include: 1) enhancing buffer, 2) public education, 3) restoration of natural physical structure, and 4) restoration of hydraulic processes in the estuary. Enhancements to the buffer area between the estuary and adjacent land uses may reduce the effects urban and agricultural land uses, reduce the effects of non-point source discharges, reduce the impact of invasive plant species, and mitigate the impacts of a major transportation corridor (Hwy 1). Expanded education programs and better management of public access can reduce the trampling and recreational impacts in the estuary. The restoration of natural physical structure in the estuary through the removal or mitigation of engineered channels and restoration of compacted areas (trails, parking lots, etc.) can enhance the overall physical condition of these estuaries. Finally, changes or upgrades to culverts and reductions in water extraction activities within the watershed can benefit estuarine hydrology.

### *Watershed Stressors*

The watershed stressor correlation analysis revealed that expanding the width of protective buffers along streams within 2 km of the estuary may lead to an increase in wetland condition as represented by the CRAM Index and CRAM Buffer and Hydrology Attribute Scores. Restoring forested riparian zones may also lead to an increase in the Biotic Structure Attribute Score of the estuary.

### *Wetland Habitat Loss and Change*

The habitat loss and change assessment found the greatest change in open water, wetable lowland and vegetated woody (riparian) acreage, with much of that area being converted upland and “developed” land use (buildings, parking lots, agriculture, etc.). Given the obvious importance of these habitat types on the overall condition of the estuarine ecosystems and the flora and fauna that rely up on them, efforts should be made to restore and enhance these habitat types (including removal of limited value development) where possible.

# Section 6- Recommendations for Improved Management

The following are examples of critical questions that need attention to allow science-based decisions on managed breaching for specific systems:

1. What water level is required in a BBE prior to a breach occurring for a breach to be effective, including deep scour or partial scour scenarios? See Stretch and Parkinson (2006).
2. What are the conditions that lead to the development and persistence of hypoxia and temperature effects within bottom waters, and how are these conditions impacted by natural or artificial breaches? See Largier et al (2018). How does this change with seasons and other controls on light levels at depth? Once hypoxia is established in a given system, will it become more severe or will it dissipate if the mouth is or is not breached?
3. What is the relationship between lagoon hydrology and morphology? See Cooper (2001). What is the distribution of inundation conditions (depth, duration, seasonal timing) under which present marshes developed? What is the feedback of managed breaching on the frequency/timing of natural breach events?
4. How has closure probability changed with water extraction, local land development, shifts in water runoff associated with climate change, ocean conditions, sea level rise, and channel modification? See Van Niekerk et al (2005). How is closure probability expected to change with sea level rise and alterations in sediment supply associated with climate change and watershed management?
5. What types of breach events will lead to significant flushing of estuary fish and/or plankton populations? How does this alter prey availability or predation pressure on critical populations?
6. How will a proposed breaching regime alter the seasonal cycle of marsh inundation and desiccation? How will this alter the marsh community and potential for accretion under sea level rise?

These scientific analyses can inform improved management. In addition to modeling and field studies, much can be learned from strategic monitoring of estuaries before, after and during breaching. Permit conditions can ensure that we learn from each managed breaching event, whether it works as anticipated or not. This is the basis for the recommendations in the next section.

## Learning through Monitoring

A better understanding of the effects of managed breaching (direct and indirect; anticipated and unanticipated) can be advanced by requiring monitoring as a condition of a breach permit – so that the effects of breaching will be better known, providing an empirical basis for minimizing adverse impacts to both special status species and their habitat features. Monitoring requirements could also be placed on a biological opinion's incidental take permit under the Endangered Species Act, when incidental take is expected due to a managed breach. An example of a long-term collaborative monitoring program that informs sand barrier management is at Los Peñasquitos Lagoon. The Los Peñasquitos Lagoon Foundation and California State Parks have worked directly with staff at the Pacific Estuarine Research Lab to adaptively manage the inlet using continuous data sets from a monitoring program initiated in 1987 to achieved desired management outcomes.

There are a number of cost-effective data collection protocols that will improve breaching decisions. Ideally, both managed and natural breaches will be monitored to improve our understanding of BBE responses and the function of BBEs under different management approaches. Dependent on the management objectives and potential effects of breaching, a subset of these monitoring efforts could be used. These monitoring recommendations assume that ancillary data on external forcing are available, such as river flow, tides, and offshore wave conditions. If these data are not available, then they should be included in a monitoring program.

- *Water Level and Photographic Records:*
  Mouth state and closure duration are key considerations for management of BBEs. Mouth state can be determined from water level and photo documentation. Documenting water elevation in relation to channel depth, marsh plain elevation and off-channel water depth is important for understanding the effect of mouth state on diverse estuarine habitats. Placement of low-cost pressure sensors within BBEs should be a standard practice in all managed systems. In addition, automated cameras can be placed at the mouth of key BBEs to track mouth migration, wave overtopping and breach events. Example key parameters for characterizing the abiotic and biotic state of BBEs are listed in Tables 11 and 12.

- *Morphology Surveys:*
  The height of the sand barrier can be monitored through simple horizon-sighting techniques during a closure episode, so that the natural-breach water level is known. Further, through pre- and post-breach morphological surveys of the sand barrier (and channel depth), scouring efficacy can be related to pre-breach water-level head and post-breach accretion in the mouth channel (and also reveal seasonal changes). While estimates of channel depth and width can be obtained from water-level records and photographs, morphological surveys provide a more complete view of sand barrier modification through breaching. Morphology surveys should include the upper extents of marshes and floodplains that can be inundated by the highest water levels as well as sand dunes adjacent to the estuary mouth, which can play a key role in closures and water level maxima.

- *Stratification and Water Quality Records:*
  Salinity, temperature and dissolved oxygen can be monitored through deployment of time-series sensors at representative sites that capture temporal variability. Periodic water chemistry transects (profiles at a set of stations), and water nutrient and toxicity samples will help document spatial patterns in water chemistry, including identification of refugia for species escaping poor water quality. These data can also be used to track changes in stratification, which is a primary determinant of water quality in the lower layer. Data during closure events and before/after breach events allow assessment of the spatial extent and temporal duration of water quality effects of breaching.

- *Marsh plain and Submerged Aquatic Vegetation (SAV) Condition Surveys:*
  Marsh and channel SAV species distribution, abundance, diversity and elevation can be surveyed and related to water elevation data within the estuary. Long-term surveys are more important than pre- and post-breach surveys because marsh plant and SAV communities will likely not be affected by a single manual breaching effort. It is also important to note that in the absence of site-specific monitoring data on water depth and water quality, vegetation can tell stories about lagoon hydrology (depth/duration/frequency of inundation, salinity), especially over the long-term. Long-term surveys of plant composition are critical for assessing breaching protocols (e.g., routine breaching that maintains water level below natural peaks) – including the potential for secondary impacts to the marsh communities or subtidal communities (De Decker 1987). Site-specific information on species distribution relative to marsh plain elevation can help minimize impacts to marsh communities by determining the minimum water elevation needed to flood specific plant communities (and the maximum water elevation to avoid flooding of other land uses).

- *Fish and other faunal surveys:*
  Monitoring of fish and other fauna during open/closed states and immediately post-breach is needed to assess impacts of breaching. Surveys can document both immediate effects of breaching on various species

as well as longer term effects on resident populations. Population studies should be conducted to assess the additive effects of multiple managed breaches on species like steelhead and tidewater goby as well as species of concern (e.g., frogs, turtles, birds). Emerging monitoring techniques involving the use of sampling for DNA markers (eDNA) in the water column may increase the efficiency of monitoring for fauna in BBEs.

- *Soil data collection:*
    - accretion surveys (SET station or feldspar markers)
    - Carbon content of soils
    - Salinity and reduction horizons

**Table 11. Example Key parameters for characterizing the abiotic state of BBEs**

| | |
|---|---|
| **State of BBE** | |
| Mouth state | The elevation of the sand barrier determines if the mouth is considered fully open, partially open (muted tides), closed, or perched. |
| Stratification state | Whether the water body is vertically mixed, weakly stratified, or exhibits intense 2-layer stratification. |
| Water balance | Positive (filling): more freshwater enters from runoff than leaves by evaporation and seepage through barrier.<br>Negative (draining): less freshwater enters from runoff than leaves by evaporation and seepage through barrier. |
| **Abiotic Conditions in BBE** | |
| Water level | Measure of the daily average and daily range of water level in the estuary. |
| Stratification | Strength and depth of interface (pycnocline) in the water column. |
| Light depth | Penetration depth of photosynthetically active radiation (PAR) in water column, often measured as secchi depth. |
| Temperature | Depth-averaged or upper & lower layer temperatures (daily average; daily range). |
| Salinity | Depth-averaged or upper & lower layer salinity (daily average; daily range). |
| Oxygen | Depth-averaged or upper & lower layer dissolved oxygen (daily average; daily range). |
| Redox state of sediments | Index of oxygen demand at sediment interface |
| Turbidity | Depth-averaged or upper & lower layer turbidity. |
| Volume of water | Total volume or layer volumes when stratified. |
| Area of photic bed | Area of benthic habitat exposed to PAR |
| Area of inundation | Area of marsh plain inundated by water |

Table 12. Example Key parameters characterizing the biotic state of BBEs.

| **Biotic Conditions in BBE** | |
|---|---|
| Special Status Species | Surveys of species including fish, turtles, frogs, snakes, birds, etc. |
| Habitat Condition Score | California Rapid Assessment Method for Wetlands (CRAM) |
| Marsh plain inundation | Interpretation of extent and duration of wetted marsh based on water level in channel and marsh plain elevation |
| Soil condition | Salinity and moisture content |
| Vegetation community | Composition and richness (Environmental Protection Agency's Environmental Mapping and Assessment Program) |
| Phytoplankton community | Daily average and daily range of primary production and chlorophyll a; species composition and richness |
| Submerged aquatic vegetation community | Composition, richness, density, distribution, etc. |
| Invertebrate community | Benthic community composition and richness<br>Water column community composition and richness |
| Fish Community | Surveys of species including salmonids, goby, flatfish |
| Marine subsidy | Role and magnitude of marine subsidies (e.g. kelp over wash) in estuary productivity |

## Processed-based Approach to Management

The material in this report underscores the need for BBE management that seeks to identify and characterize the spatial and temporal variability in the drivers that govern responses in lagoon hydrology, morphology, and ecology. Anything less risks unintended consequences that can jeopardize ecological services. In the longer term, based on our best professional judgment, our recommendations are to:

1. Identify ecological costs and benefits of different estuary states and of different breaching protocols to allow for informed decisions on tradeoffs when management actions are taken.
2. Adopt a regional approach to maintaining habitat diversity by ensuring a diverse combination of BBEs systems thrive (i.e., the regional portfolio approach).
3. Understand the dynamic processes that control observed conditions in BBEs (based on field data).
4. Develop quantitative conceptual models that capture the processes and environmental variability of BBEs across seasons – and use these models to inform management decisions.
5. Identify ecosystem functions and services provided by a specific BBE and determine how they are changed by mouth management practices. Further, anticipate future changes in the processes that underpin ecological functions and services – including changes due to watershed management, coastal management and climate change.
6. Develop monitoring programs and data/indicators to inform management decisions.

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# Appendix

## Appendix 1. Bar-built estuaries assessed using CRAM by CCWG

| System Name | latitude | longitude | STATE PARK |
|---|---|---|---|
| Alder Creek | 39.010928 | -123.694174 | Yes |
| Ano Nuevo Creek | 37.116168 | -122.306268 | Yes |
| Aptos Creek | 36.969083 | -121.906540 | Yes |
| Arroyo Burro Creek | 34.402783 | -119.742704 | |
| Arroyo de en Medio | 37.493356 | -122.459853 | |
| Arroyo de la Cruz | 35.709976 | -121.310251 | Yes |
| Arroyo del Puerto | 35.643394 | -121.189012 | Yes |
| Arroyo Grande Creek Lagoon | 35.099651 | -120.628900 | Yes |
| Arroyo Sequit | 34.044800 | -118.934000 | Yes |
| Baldwin Creek | 36.966551 | -122.123871 | Yes |
| Big Sycamore Canyon | 34.071200 | -119.014800 | Yes |
| Brush Creek | 38.975010 | -123.710420 | Yes |
| Canada Del Capitan Creek | 34.457993 | -120.022125 | Yes |
| Canada del la Gaviota Creek | 34.471095 | -120.226358 | Yes |
| Canada Del Refugio Creek | 34.463073 | -120.069754 | Yes |
| Canada Verde | 37.429793 | -122.439485 | |
| Carmel River Lagoon | 36.537025 | -121.926700 | Yes |
| Carpinteria Creek | 34.390581 | -119.519862 | Yes |
| Cascade Ranch lagoon | 37.136912 | -122.338198 | Yes |
| Coon Creek Lagoon | 35.259387 | -120.894464 | Yes |
| Corcoran Lagoon | 36.960155 | -121.984244 | |
| Cottaneva Creek | 39.736225 | -123.829697 | |
| Creek mouth (not named) | 35.682715 | -121.286337 | Yes |
| Creek Mouth (SW Pigeon Point) | 37.172831 | -122.367781 | |
| Dairy Gulch | 36.954973 | -122.091463 | Yes |
| Deverough Slough | 34.410609 | -119.881545 | |
| Drakes Beach Parking Lot | 38.027179 | -122.962481 | |
| Fern Canyon | 41.401885 | -124.069822 | Yes |
| Fort Ross Creek | 38.512065 | -123.243698 | Yes |
| Frenchmans Creek | 37.480522 | -122.451132 | Yes |
| Garapatta (aka Joshua Creek) | 36.417528 | -121.915336 | Yes |
| Garcia River | 38.954465 | -123.733362 | |
| Gazos Creek | 37.165406 | -122.361532 | Yes |
| Gualala River | 38.769004 | -123.535056 | |
| Horseshoe Pond | 38.031355 | -122.951689 | |
| Jalama Creek | 34.512160 | -120.502960 | |
| Laguna Creek | 36.981959 | -122.154706 | Yes |
| Lake Lucerne | 37.225296 | -122.408244 | Yes |
| Las Flores Creek | 33.290500 | -117.464500 | |
| Little Cayucos Creek Lagoon | 35.448083 | -120.903955 | Yes |
| Little Pico Creek | 35.633861 | -121.163824 | |
| Lobitos Creek | 37.376291 | -122.408785 | |
| Lombardi (aka Needle Rock Pt. Lago | 36.962172 | -122.112941 | Yes |
| Los Penasquitos | 32.931100 | -117.256500 | Yes |
| Malibu Lagoon | 34.032580 | -118.680582 | Yes |
| Malpaso Creek | 36.481497 | -121.937551 | |
| Manchester (aka Lake Davis) | 38.992402 | -123.702229 | Yes |
| Martini Creek | 37.552697 | -122.513264 | Yes |
| Mattole Lagoon | 40.300331 | -124.354233 | |

| System Name | latitude | longitude | STATE PARK |
|---|---|---|---|
| Montara State Beach/Unknown | 37.548186 | -122.513917 | Yes |
| Morro Creek Lagoon | 35.376438 | -120.862777 | |
| Natural Bridges | 36.950400 | -122.057712 | Yes |
| Navarro River | 39.191729 | -123.761392 | Yes |
| Old Creek | 35.435132 | -120.887565 | Yes |
| Ormand Beach | 34.133854 | -119.182646 | |
| Ossagon Creek | 41.445072 | -124.063914 | Yes |
| Pajaro Creek Lagoon + Watsonville | 36.845486 | -121.805342 | Yes |
| Pescadero Marsh | 37.266964 | -122.412417 | Yes |
| Pilarcitos Creek | 37.473298 | -122.446340 | Yes |
| Pomponio Creek | 37.299207 | -122.405677 | Yes |
| Pudding Creek | 39.459011 | -123.809414 | Yes |
| Redwood Creek | 41.290178 | -124.092694 | Yes |
| Redwood Creek (Muir Beach) | 37.860177 | -122.576516 | |
| Rodeo Valley | 37.831587 | -122.537609 | |
| Russian Gulch (Sonoma) | 38.466777 | -123.156974 | Yes |
| Russian River | 38.451856 | -123.129877 | Yes |
| Salinas River Lagoon | 36.749967 | -121.803637 | Yes |
| Salmon Creek | 38.354760 | -123.066863 | Yes |
| San Antonio Creek | 34.799764 | -120.619904 | |
| San Gregorio Creek | 37.322115 | -122.403684 | Yes |
| San Jose Creek | 36.523579 | -121.926258 | Yes |
| San Juan Creek | 33.461974 | -117.684101 | Yes |
| San Lorenzo River | 36.964670 | -122.012561 | |
| San Luis Obispo Creek Lagoon | 35.179062 | -120.738022 | |
| San Mateo Lagoon | 33.386000 | -117.593900 | Yes |
| San Pedro Creek | 37.596290 | -122.505746 | |
| San Simeon | 35.595538 | -121.125933 | Yes |
| San Vicente Creek | 37.524167 | -122.517590 | |
| Santa Clara | 34.229306 | -119.264097 | Yes |
| Santa Margarita Lagoon | 33.233200 | -117.412400 | |
| Santa Maria River Lagoon | 34.969177 | -120.646808 | |
| Santa Ynez River Estuary | 34.692213 | -120.602947 | |
| Scott Creek | 37.040615 | -122.229145 | Yes |
| Soquel Creek Lagoon | 36.971695 | -121.952391 | |
| South Spring Bridge gulch | 37.200728 | -122.404582 | Yes |
| Spring Bridge Gulch | 37.205231 | -122.404414 | |
| Stump Beach | 38.581552 | -123.336087 | Yes |
| Ten Mile River | 39.553683 | -123.767189 | Yes |
| Tennessee Valley | 37.841619 | -122.551360 | |
| Tijuana River Estuary | 32.555300 | -117.118200 | Yes |
| Topanga | 34.038021 | -118.582986 | Yes |
| Torro Creek Lagoon | 35.412542 | -120.873242 | |
| Tunitas Creek | 37.359027 | -122.401126 | |
| Usal Creek | 39.831250 | -123.849180 | Yes |
| Ventura River Estuary | 34.276010 | -119.308057 | Yes |
| Villa Creek Lagoon | 35.460383 | -120.970822 | Yes |
| Waddell Creek | 37.096149 | -122.278222 | Yes |
| Whitehouse Creek | 37.146109 | -122.347079 | Yes |
| Wilder Creek | 36.954057 | -122.077634 | Yes |
| Yankee Jim Gulch | 37.192886 | -122.398311 | Yes |
| Younger Lagoon | 36.949290 | -122.067562 | |

## Appendix 2. CDPR staff trained in CRAM

| Last | First | email |
|---|---|---|
| Barve | Nita | Nita.Barve@parks.ca.gov |
| Cowman | David | david.cowman@parks.ca.gov |
| Gerlach | John | john.gerlach@parks.ca.gov |
| Gordon | Spencer | Spencer.Gordon@parks.ca.gov |
| King | Jamie | Jamie.King@parks.ca.gov |
| LeFer | Danielle | Danielle.Lefer@parks.ca.gov |
| Porteur | Jason | Jason.porteur@parks.ca.gov |
| Reilly | Timothy | timothy.reilly@parks.ca.gov |
| Rischbieter | Doug | Doug.Rischbieter@water.ca.gov |
| Sheridan | Brooke | Brooke.Sheridan@parks.ca.gov |
| Valerio | Katrina | Katrina.Valerio@parks.ca.gov |
| West | Dave | David.West@parks.ca.gov |

## Appendix 3. Land-based metrics used for watershed stressor analysis

| Metric | Source | GIS Operations |
|---|---|---|
| Buffered Area | National Elevation Dataset 10 meter DEM | Watershed delineation, clipped buffers, tabulated areas |
| NLCD Landuse | National Land Cover Database (NLCD) 2011 Land Cover; includes Developed (classes 21-24), Forest (classes 41-43), Shrub/Grassland (classes 52-71), Agriculture (classes 81-82), Wetlands (classes 90 and 95), and Open Water (class 11). Excludes Perrenial Ice/Snow (class 12) and Barren Land (class 31). | Raster reclassification and tablulated areas |
| Impervious | National Land Cover Database (NLCD) 2011 Percent Developed Imperviousness | Raster reclassification and tablulated areas |
| Roads | CA Roads dataset | Reclassification to paved and unpaved roads, tabulate lengths |
| Dams | National Inventory of Dams (NID) database | Tabulate count, and sum drainage area based on NID database |
| Mines | USGS Mines database | Tabulate count |
| 303d | EPA 303(d) Listed Impaired Waters database | Tabulate count |
| Fires | CAL FIRE database of fire history (wildfire and prescribed) | Merged all fires since 2000 and tabulated areas |

## Appendix 4. Sources of information for Special Status Species

See associated Excel File, which can be found on the CCWG Website: www.centralcoastwetlands.org

## Appendix 5. Site-specific BBE Data summary pamphlets

Please visit the CCWG Website: www.centralcoastwetlands.org to download these files

## Appendix 6. Site-specific BBE Composite data graphs

Please visit the CCWG Website: www.centralcoastwetlands.org to download these files