Monitoring for Management:
A Monitoring Strategy for Southern California Coastal Wetlands

The Wetland Recovery Project Regional Monitoring Program

Product of
The Wetland Recovery Project Scientific Advisory Panel

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Executive Summary

The Wetland Recovery Project Regional Monitoring Program (WRP RMP) consists of coordinated approaches for coastal wetland monitoring to track progress toward achieving objectives of the WRP's Regional Strategy and to assist interested agencies and implementing organizations in incorporating these approaches into site-specific permit- and funding-required monitoring programs. Comparable monitoring information is essential to assessing whether the goals and objectives of the WRP Regional Strategy are being met, guide future funding decisions, and protect past investments in wetland restoration from more traditional estuarine stressors including hydrological alterations, water quality, and urbanization along with the rapidly advancing impacts of climate change, including sea level rise, increased wave impacts and watershed runoff from storms, and debris flows from fire scared landscapes. This document presents a monitoring plan essential to understanding the health, function, and persistence of coastal wetlands in southern California. The monitoring plan identifies and explains the overarching monitoring framework, questions, elements, and indicators along with establishing standardized SOPs.

The WRP RMP is designed to assess the WRP Regional Strategy Goal 1: Preserve and restore resilient coastal tidal wetlands and associated marine and terrestrial habitats by addressing seven monitoring questions, organized into three categories: extent, condition, and resilience (Table ES- 1).

Table ES- 1. WRP Regional Strategy objectives linked to the WRP RMP monitoring questions.

Category	Monitoring Question	Programmatic Questions **Objectives for Regional Strategy Goal 1:** Preserve and restore resilient coastal tidal wetlands and associated marine and terrestrial habitats.
Extent	1. What is the extent of the region's coastal wetland ecosystems?	Restore Wetland Area Restore Wetland Size Restore Wetland Archetype Distribution Habitat Diversity Wetland Upland Transition Zone Restore Hydrological Connectivity
	2. What changes in ecosystem area and distribution are occurring?	
	3. Where do coastal wetlands support complex habitat diversity and connectivity, and how does it vary by archetype?	
	4. Where do coastal wetlands have space to migrate?	
Condition	5. What is the condition of the region's coastal wetlands?	Wetland Condition
	6. What are the major stressors to the region's coastal wetlands?	
Resilience	7. What is the resilience of the region's wetlands and what is the role of restoration in improving extent, condition, and resilience?	All Objectives

WRP RMP monitoring applies specifically to the Southern California Bight (SCB). There are 118 coastal wetlands of varying sizes along the 700 kilometers of southern California. These wetlands can be categorized into "archetypes", which are representations of a group or class of coastal wetlands similar in form and structure. Regional monitoring will occur across the entire region and all wetland archetypes. The monitoring indicators and sampling frequency may vary depending on archetype and can be utilized at any of the coastal wetlands in the region.

The WRP RMP will include routine mapping of all coastal wetlands in the region. In addition to mapping, three elements of the WRP RMP monitoring effort will include:

1. Core monitoring – Core monitoring is focused on monitoring the WRP Sentinel Site Network at regular intervals to track ecological condition of coastal wetlands through time and evaluate regional trends, with the stated purpose of answering the seven monitoring questions on a five-year cycle.
2. Grant and permit monitoring – This monitoring can leverage and intensify efforts to support the core monitoring by adding indicators, sites (beyond the sentinel sites), higher frequency of monitoring, or increased spatial intensity within sites.
3. Special studies – Special studies provide deeper understanding through targeted investigations of specific sites or functions. These studies can complement the core monitoring.

To answer the seven monitoring questions, monitoring will be conducted at a combination of sentinel and non-sentinel sites using the core, permit/grant, and special studies monitoring elements. Sentinel sites are defined as coastal wetlands that are designated for long-term monitoring to track ecological condition through time, evaluate the effect of regional trends in external conditions/stressors, and track progress toward regional objectives, strategies, or plans. The Sentinel Site Network is composed of 37 coastal wetlands within the region and is comprised of three sentinel site types: Reference, Restoration, and Other Sites of Interest.

The WRP RMP will monitor all sentinel sites on a five-year cycle, and all sites will be monitored in a single year. This is the minimum frequency to ensure that the WRP can answer the seven monitoring questions. More intensive monitoring can be conducted within the sentinel site network based on funding and resources or the permit or grant monitoring requirements of restoration and mitigation projects, or other management programs. Additionally, if a specific site has a targeted stressor concern, then monitoring could be more frequent to adequately assess wetland response to that stressor utilizing standardized SOPs that can be used by practitioners to assess response in a way that can be compared to other regional datasets. In summary, sentinel site monitoring on a five-year cycle will be completed by the core monitoring element, as well as any groups already sampling sentinel sites as part of permit, mitigation, or grant requirements.

A common set of indicators will be monitored over time at the sentinel sites as part of the core monitoring to answer the monitoring questions. Indicators are also recommended for use by grant and permit/mitigation monitoring, recognizing there may be agency specific requirements or constraints related to the selection of specific indicators and their monitoring frequency. These indicators can be summarized, synthesized, and packaged to evaluate ecosystem function following a function-based assessment framework. The WRP RMP includes two classes of indicators (Table ES- 2). First are core indicators that should be monitored across all sites at an ideal rate (dependent on the indicator) to answer the monitoring questions. These indicators should be included in all three monitoring types (core, permit/grant, special studies). If resources are available, then supplemental indicators could be added to the core monitoring. These indicators are typically more time and cost prohibitive. If grant and permit requirements require these supplemental indicators, then the recommended methods should be followed.

Table ES- 2.Core and supplemental indicators for inclusion in the WRP RMP.

Core Indicators	Supplemental Indicators
Habitat and Elevation	Sediment Dynamics
Marsh Vegetation	Mouth Dynamics
Water Quality: Temp., DO, Salinity	Water Quality: Parameters of Concern
Hydrology	Submerged Aquatic Vegetation
Rapid Assessment	Birds
Fish: Minimum sampling	Fish: Extensive sampling
Invertebrates: Macrofauna (> 3 mm)	Invertebrates: Infauna (< 500 um)
Eutrophication: sediment nutrients	Eutrophication: algae

Every five years, following the completion of the core monitoring, a technical report will be produced to report on the current round of monitoring, as well as trend data from prior monitoring. This technical report will include tentative answers to the seven monitoring questions and the evaluation of the progress towards achieving Goal 1 objectives of the WRP Regional Strategy. This report will be critical in guiding the next round of core monitoring by reviewing what components have and have not been successful. With the regular implementation of the WRP RMP, the WRP will be able to track the collective condition of coastal wetlands in the region and how they are responding to climate change stressors and development stressors, as well as provide regulatory and funding agencies, along with landowners and stewards of public trust resources with a means to monitor wetlands in a comparable way, improve access to data via a centralized data repository, and better leverage efforts across programs to improve regional wetland inventories and condition assessments.

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Foreword

The WRP RMP was developed by the Science Advisory Panel with support from a Project Technical Team (Table FW- 1). This document provides a monitoring framework to evaluate the goals and objectives of the WRP-Goal 1 (Restore Coastal Wetlands), including identifying recommended monitoring actions and indicators and proposing a framework for long-term monitoring of sentinel sites. By implementing a structured approach to track ecological conditions, assess restoration outcomes, and measure resilience to physical and environmental stressors, this strategy ensures that monitoring efforts produce meaningful, regionally comparable data. Additionally, it provides guidance on integrating new scientific advancements, adapting to emerging challenges such as climate change, and fostering collaboration among agencies, researchers, practitioners, and stakeholders to enhance the effectiveness of wetland conservation and restoration efforts in the Southern California Bight.

The management of a monitoring program is an ongoing and iterative process. As a result, this is a "living" document with the goal of operationalizing broad concepts and advancing and streamlining decision-making. The WRP expects to produce updated versions of this plan as it is implemented, and lessons are learned from early monitoring efforts.

Table FW- 1. The WRP Project Technical Team and Science Advisory Panel members

Name	Affiliation	Role
Jan Walker	Southern California Coastal Water Research Project	Project Technical Team
Eric Stein	Southern California Coastal Water Research Project	Project Technical Team
Katie Nichols	State Coastal Conservancy	Project Technical Team
Kevin O'Connor	Central Coast Wetlands Group, Moss Landing Marine Labs	Project Technical Team
Megan Hall	California Coastal Commission	Project Technical Team
Corey Clatterbuck	California Coastal Commission	Project Technical Team
Rich Ambrose	University of California, Los Angeles	Scientific Advisory Panel
Kat Beheshti	SONGS Mitigation Program, University of California, Santa Barbara	Scientific Advisory Panel
Caitlin Crain	San Francisco Estuary Institute	Scientific Advisory Panel
Jeff Crooks	Tijuana River National Estuarine Research Reserve	Scientific Advisory Panel
Karina Johnston	University of California, Santa Barbara	Scientific Advisory Panel
Kerstin Wasson	Elkhorn Slough, National Estuarine Research Reserve	Scientific Advisory Panel
Christine Whitcraft	California State University, Long Beach	Scientific Advisory Panel

Glossary of Terms

ACOE or USACE	US Army Corps of Engineers
Bight RMP	Southern California Bight Regional Monitoring Program
CARI	California Aquatic Resources Inventory
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
DiG	WRP Directors Group
EMPA	Estuary Marine Protected Area Monitoring Program
EPA	US Environmental Protection Agency
IM Plan	Information Management Plan
NERR	National Estuarine Research Reserve
OPC	Ocean Protection Council
PTT	Project Technical Team
SAP	Science Advisory Panel
SAV	Submerged aquatic vegetation
SCB	Southern California Bight
SCC	State Coastal Conservancy
SCWRP or WRP	Southern California Wetlands Recovery Project
SDTF	Standardized data transfer formats
SONGS MMP	San Onofre Nuclear Generating Station Mitigation Monitoring Program
SOP	Standard Operating Procedure
WAG	Wetland Advisory Group
WMG	Wetland Managers Group
WRAMP	Wetland and Riparian Area Monitoring Plan
WRMP	San Francisco Wetland Regional Monitoring Program
WRP RMP	Wetland Recovery Project Regional Monitoring Program

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1. Context: The Southern California Wetlands Recovery Project Regional Monitoring Program

Southern California's wetlands historically supported large areas of vegetated and unvegetated tidal marsh; however, in the last 200 years, more than 62% of these wetlands have been lost (Stein et al. 2014). The historical loss and fragmentation of coastal wetlands that has occurred has resulted from the intensive urban development that characterizes southern California. Wetlands have been filled, diked, drained, and broken into pieces to allow for agriculture, grazing, transportation, urban development, and flood protection. For many tidal wetlands, the hydrologic connection to the ocean has been modified as tidal inlets have been dredged, filled and drained to maintain open tidal connections, reduce inlet migration, and address inland flooding. These many wetland stressors have reduced large wetland complexes down to small fragmented systems. These modifications within wetlands and their associated watersheds have not only reduced wetland areas, but the composition of wetland habitat has also changed (Stein et al. 2014). Higher sea levels will result in more wetland loss and habitat type conversion, which will threaten our ability to maintain a network of diverse wetlands along the southern California coast (Doughty et al. 2019).

The Southern California Wetlands Recovery Project (WRP) is a partnership of 18 State and Federal agencies that was formed in 1997 as a regional voice for the valuable yet diminishing coastal wetlands of southern California. These agencies entered into a Working Agreement allowing directors and staff to exercise their respective authorities and coordinate to expand, restore and protect wetlands in the WRP region, which stretches along the coast from the U.S.-Mexico border to Point Conception in Santa Barbara. Representatives from each WRP partner agency form the WRP Directors Group (DiG) and Wetland Managers Group (WMG), made up of staff from each partner agency. The WRP also coordinates with additional public agencies, scientists, and local communities through working groups. These include the Wetland Advisory Group (WAG), which provides local input from on-the-ground land managers and restoration practitioners, and the Science Advisory Panel (SAP), which provides recommendations on specific scientific questions or projects.

WRP priorities are guided by the Wetlands on the Edge: Regional Strategy 2018, which provides guidance for the WRP and its stakeholders to achieve the WRP's four goals:

Goal 1. Preserve and restore resilient coastal tidal wetlands and associated marine and terrestrial habitats.

Goal 2. Preserve and restore streams, adjacent habitats, and other non-tidal wetland ecosystems to support healthy watersheds.

Goal 3. Support education and compatible access related to coastal wetlands and watersheds.

Goal 4. Advance the science of wetland restoration and management in southern California.

The Regional Strategy 2018 includes a set of Quantitative Objectives and Management Strategies to provide numeric targets that help quantify progress towards meeting the WRP's Goals. As a part of the multi-year, collaborative planning process to develop this shared vision for wetland recovery, agencies and scientists *identified a critical need to develop a comprehensive, regional wetland monitoring program* *for coastal wetlands* to evaluate whether the goals and objectives of the Regional Strategy-Goal 1 (Restore Coastal wetlands) are being achieved. This prompted the creation and development of the WRP Regional Monitoring Program by the SAP. The WRP Regional Monitoring Program aims to develop coordinated approaches for coastal wetland monitoring to track progress toward achieving objectives of Goal 1 of the Regional Strategy and to assist interested agencies and implementing organizations in incorporating these approaches into site-specific permit- and funding-required monitoring programs along with general resource management monitoring efforts. The proposed framework establishes a standardized and coordinated technical monitoring toolkit rooted in best available science that practitioners and landowners can use to improve local estuarine management and monitoring practices.

WRP Regional Monitoring Program goals include:

- Track the collective condition of coastal wetlands in the region and how they are responding to current development stressors and future climate change stressors
- Help agencies assess coastal wetland resilience to address climate change effects and develop adaptation strategies
- Provide landowners/resource managers, regulatory and funding agencies and landowners with a means to monitor wetlands in a comparable way, improve access to data, and better leverage efforts across programs to improve regional wetland inventories and condition assessments
- Utilize improved information on wetland condition, resilience, and performance in southern California to help state and federal regulatory programs more effectively manage, preserve, and restore wetlands in southern California.
- Assess progress towards reaching the WRP goals for coastal wetland restoration, which are listed under Goal 1 of the WRP Regional Strategy 2018.

The WRP Regional Monitoring Program development process began in Fall 2022. A Project Team was formed to guide the decision-making process through a consensus-based approach facilitated via conversations among the WRP partner agencies. The Project Technical Team was comprised of members from the California State Coastal Conservancy, Southern California Coastal Water Research Project, California Coastal Commission, and the Central Coast Wetlands Group. The Project Team's initial role was to develop the monitoring framework necessary for the WRP to assess its quantitative objectives for coastal wetland restoration. To accomplish this, the Project Team reconvened the SAP to solicit critical science consultation to collect input on the monitoring framework.

In the development and formation of the WRP Regional Monitoring Program, the SAP provided recommendations on the development and process for establishing a sentinel site network, a monitoring strategy, and an implementation strategy for coastal wetlands in southern California. In addition, the Project Technical Team wrote guidelines for agencies and their permittees and grantees to apply the Monitoring Strategy. The WRP Regional Monitoring Program is described in the following four documents:

1. Development of a Coastal Wetland Sentinel Site Network. Summarizes recommendations for the development and maintenance of a statewide sentinel site network and provides recommendations for southern California sentinel sites (Southern California Wetlands Recovery Project 2024, Walker et al. 2025).

2. **Monitoring for management: A monitoring strategy for southern California wetlands. Provides an overview of the monitoring strategy, monitoring questions, and priority indicators necessary to develop the WRP Regional Monitoring Program.**
3. Applicability of Regional Monitoring for Agencies: Guidelines for Incorporating the WRP Regional Monitoring Program into Agency Programs. Provides agency-specific guidelines for applying the regional monitoring approach to permitted and funded projects.
4. Implementation strategy for the WRP Regional Monitoring Program. Outlines a plan to guide the rollout and coordination of a collaborative coastal wetland monitoring effort across wetlands in southern California.

This document is the monitoring plan listed in item #2 above.

2. Introduction

This document presents a monitoring plan essential to understanding the extent, health, function, and persistence of coastal wetlands in southern California. The monitoring plan identifies and explains the overarching monitoring framework, questions and indicators, and sentinel site network. This comprehensive monitoring plan fills a key recommendation of the Wetland Recovery Project's (WRP) Regional Strategy for wetland recovery by providing a mechanism to evaluate whether the goals and objectives of Goal 1of the Regional Strategy are being achieved.

The WRP Regional Monitoring Program (WRP RMP) is organized into three principal components:

1. Monitoring Framework – The monitoring framework describes the programmatic and monitoring questions, geographic scope, types of monitoring, and the overall programmatic design
2. Assessment Approach – Recommends a master list of core and supplemental indicators, the selection of monitoring stations, and analysis.
3. Data Management – A comprehensive data management strategy to facilitate the integrated analysis of data to answer the WRP RMP questions.

The WRP RMP is designed to enhance understanding of ecosystem processes and conditions through time and in response to certain stressors. The WRP RMP will enhance efficiency and increase the value of monitoring efforts associated with voluntary restoration and compensatory mitigation projects. The primary intent of the WRP RMP is to provide a mechanism to collect regional scientific information and data to evaluate project performance, improve regional assessment, enhance data consistency and increase efficiency (through leveraged efforts) for individual restoration projects. A key component of this strategy is to provide standard methods of data collection, management, and analysis to answer broad regional questions and ensure that project data can be compared over time and space. By reducing the costs, time, effort, and redundancy involved in project monitoring throughout the region, robust monitoring results from the WRP RMP can improve regional efficiency in complying with agency monitoring and mitigation requirements.

This document contains recommendations for how to establish a WRP RMP, which are summarized in Table 1 and discussed in more detail in subsequent sections of the document.

Table 1. Summary of recommendations for a WRP RMP.

RMP Elements	Recommended Agency Action	Document Section
Geographic Scope	This monitoring framework applies specifically to the Southern California Bight	3
Monitoring Elements	1. Core monitoring – This monitoring occurs at the coastal wetland sentinel sites identified by the WRP SAP and is the minimum sampling effort necessary to answer the region's monitoring questions. 2. Grant and permit monitoring – This monitoring can leverage and intensify efforts to support the core monitoring by adding indicators, sites (beyond the sentinel sites), higher frequency of monitoring, or increased spatial intensity within sites. 3. Special studies – Special studies provide deeper understanding through targeted investigations of specific sites or functions. These studies can complement the core monitoring.	3
Monitoring Design	Monitoring will be conducted at a combination of sentinel and non-sentinel sites using the core, permit/grant, and special studies monitoring elements on a 5-year cycle.	3
Assessment Approach	A common set of indicators will be monitored over time . There are two classes of indicators: core indicators that should be monitored across all sites at an ideal rate (dependent on the indicator) and supplemental indicators could be added to the core monitoring. These indicators are typically more time-intensive and costly. Monitoring is based on establishing sampling stations or zones that encompass a variety of habitat types and therefore monitoring can capture multiple functions.	4
Data management	Integrate data with existing data portals, such as the EMPA Monitoring Program	5
Outputs	Status and Trends of the Southern California Bight, Published Dataset, Updated WRP Project Tracking	6

3. Monitoring Framework

The monitoring framework describes the "what, why, how, where, and when" for cost-effective monitoring. The WRP RMP framework is guided by the Wetland and Riparian Area Monitoring Plan (WRAMP). WRAMP is a product of the California Wetland Monitoring Workgroup (CWMW) of the California Water Quality Monitoring Council. WRAMP is a framework to integrate cost-effective project monitoring with ambient (external to project) monitoring in the watershed and regional contexts, based on prioritized management questions.

According to the 10-step WRAMP framework presented below in Figure 1, the programmatic questions and decisions in step 1 have already been laid out in the WRP Regional Strategy. Therefore, the WRP RMP framework will cover the details of monitoring questions (step 2), indicators (step 4), metrics (step 4), data collection (step 5), sampling design (step 6), data management (step 7), and interpretation (step 8). As referenced in step 5, the monitoring framework will be consistent with the three spatial levels of data collection methods: Level 1: assessment using maps to inventory water-related resources, their availability and distribution; Level 2: assessment involving quick, on-the-ground evaluations that provide a snapshot of the overall condition of the wetlands; and Level 3: assessment providing detailed, site-specific measurements focusing on particular aspects of estuarine function.

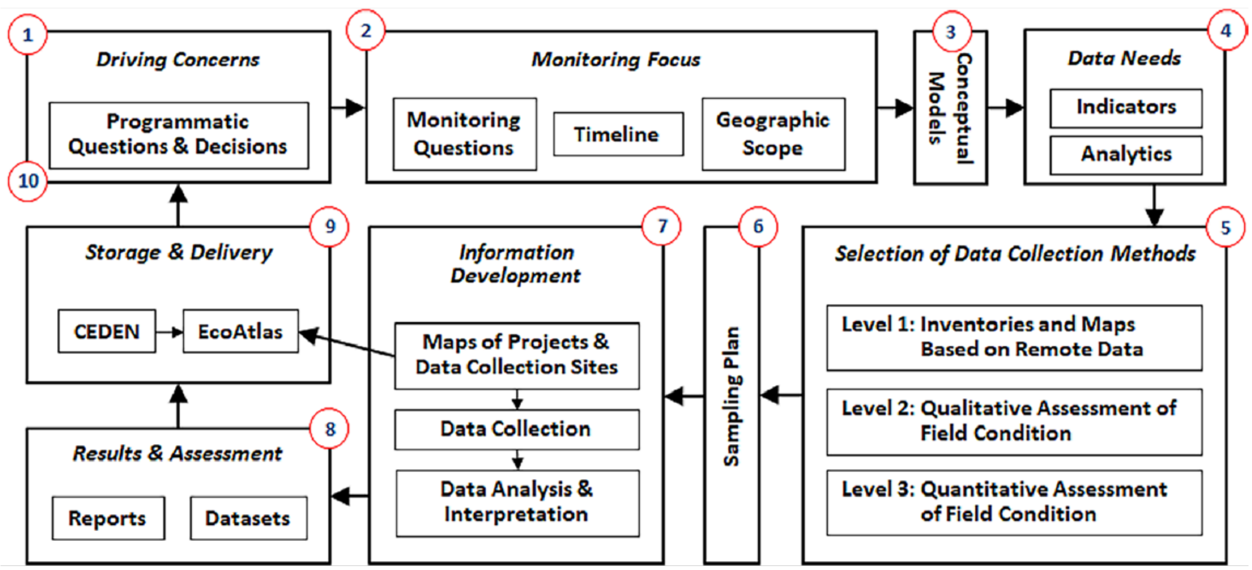

Figure 1. WRAMP Framework (California Wetland Monitoring Workgroup).

For the purposes of the WRP RMP, the three levels of data collection are as follows:

- Level 1: Maps of coastal wetland resources within the California Aquatic Resources Inventory (CARI) made available via EcoAtlas.org along with the coastal wetland archetypes from the WRP Regional Strategy
- Level 2: California Rapid Assessment Method (CRAM) scores available via EcoAtlas.org
- Level 3: The core and supplemental indicators for core, permit/grant, and special studies monitoring described below.

Additionally, details of the WRP RMP monitoring framework benefited from principles and approaches incorporated into existing state and regional monitoring programs (Appendix A. Related Efforts). By aligning monitoring frameworks, the WRP RMP can further help ensure compatibility between programs across the state of California. We briefly describe some central efforts that can support the WRP RMP.

Monitoring Efforts

Estuary Marine Protected Area (EMPA) Monitoring Program

The EMPA Monitoring Program is an ongoing effort to assess the quality and condition of estuaries statewide. The program goals are to monitor California estuaries with a standard, comprehensive function-based assessment framework to determine the health of California's estuaries and the efficacy of MPA designation. Partners in the program have developed an assessment framework, standard monitoring protocols, data structures, and quality control measures. This program is supported by the Ocean Protection Council and California Department of Fish and Wildlife.

The WRP RMP will leverage many of the resources from the EMPA Monitoring Program. The WRP RMP will align with EMPA Monitoring Program by 1) monitoring estuaries following the EMPA standard, comprehensive function-based assessment to determine the health of California's estuaries, 2) incorporating the EMPA ecosystem-function based assessment framework to accommodate different programmatic needs and heterogenous landscapes, and 3) integrating with the EMPA user-friendly data management system to increase transparency, accessibility, and quality control in data collection, upload, and publication. Many members of the SAP and Project Team are principal investigators on the EMPA Monitoring Program. To align with this state effort, the WRP RMP will adopt the assessment framework, indicators, and associated standard operating procedures (SOPs) from the EMPA Monitoring Program, as described below in the Assessment Approach.

Southern California Bight Regional Monitoring Program (Bight)

The Bight Program is an ongoing marine monitoring collaboration that examines how human activities have affected the ecological health of more than 1,500 square miles of southern California's coastal waters. Nearly 100 organizations pool their resources and expertise to support the program, which runs in five-year cycles. The WRP RMP can align the monitoring cycle of the WRP RMP with the Bight five-year cycle. By aligning cycles, more resources can be leveraged to complete the Core Monitoring Element (as described below).

Intensive Ongoing Monitoring

The WRP RMP will also leverage two specific coastal wetland monitoring efforts: the San Onofre Nuclear Generating Station (SONGS) Mitigation Monitoring Program (MMP) led by University of California, Santa Barbara and the Tijuana River National Estuarine Research Reserve monitoring. Both efforts monitor a number of wetlands across the southern California region. In building the WRP RMP, the Project Team and SAP worked closely with these programs to align the program with ongoing long-term monitoring efforts.

Programmatic and Monitoring Questions

The WRP RMP includes seven monitoring questions, organized into three categories: extent, condition, and resilience (Table 2). These monitoring questions are intended to evaluate the objectives of Goal 1 of the WRP Regional Strategy (Table 3), which is to preserve and restore resilient coastal tidal wetlands and associated marine and terrestrial habitats.

To address these objectives, we define three categories of questions:

1. Extent – The total acreage, area, or size of a wetland; Changes in habitat extent will be the complex product of a variety of natural and anthropogenic processes. Fluctuations in extent will vary in magnitude and will likely differ (i.e., gains and losses) in different parts across the coastline.
2. Condition – The status of hydrological, physical, chemical, biological, and ecological indicators of the level of services and beneficial uses of wetland systems. It's important to understand the many stressors that could impact the current and future condition of wetland systems.
3. Resilience - The capacity of natural systems in the coastal environment to resist and recover from disturbances, induced by factors such as sea level rise, extreme events, and human impacts, while maintaining their essential functions. The resilience of the system could impact the ability of the wetland to change in terms of both extent and condition.

Table 2. WRP Regional Strategy objectives linked to the WRP RMP monitoring questions.

Category	Monitoring Question	Programmatic Questions **Objectives for Regional Strategy Goal 1:** Preserve and restore resilient coastal tidal wetlands and associated marine and terrestrial habitats.
Extent	1. What is the extent of the region's coastal wetland ecosystems? 2. What changes in ecosystem area and distribution are occurring? 3. Where do coastal wetlands support complex habitat diversity and connectivity, and how does it vary by archetype? 4. Where do coastal wetlands have space to migrate?	Restore Wetland Area Restore Wetland Size Restore Wetland Archetype Distribution Habitat Diversity Wetland Upland Transition Zone Restore Hydrological Connectivity
Condition	5. What is the condition of the region's coastal wetlands? 6. What are the major stressors to the region's coastal wetlands?	Wetland Condition
Resilience	7. What is the resilience of the region's wetlands and what is the role of restoration in improving extent, condition, and resilience?	All Objectives

Table 3. WRP Regional Strategy Goal 1 Objectives.

Objective	Description
Restore Wetland Area	A. Preserve 8,600 acres (3,480 ha) of existing wetlands. B. Facilitate wetland migration and restoration of 7,700 acres (3,116 ha) after 24 inches of sea-level rise. C. This restoration and facilitation will result in 15,500 acres (6,273 ha) of wetland habitat after 24 inches of sea-level rise
Restore Wetland Size	Increase coastal wetland size in areas where 24 inches of sea-level rise will support wetlands in the future, to more closely approximate historical distribution within each subregion.
Restore Wetland Archetype Distribution	A. Preserve or restore, as appropriate, the historical distribution of archetypes in each subregion. B. Increase and maintain connectivity between historically connected wetland fragments.
Habitat Diversity	Restore or maintain the coastal wetland habitat composition, represented by the historical archetype habitat profiles, in at least 50% of the systems within a given archetype across a subregion.
Wetland Upland Transition Zone	A. Protect all existing natural areas of wetland-upland transition zones up to 1,600 feet (500m) from the marsh edge. B. Increase area of natural wetland-upland transition zone to facilitate marsh migration, so that at least a minimum of 40% of the wetland perimeter is bounded by transition zone that extends inland for at least the full estimated tidal extent under 24 inches (0.6 m) of sea level rise. C. Increase areas of natural wetland-upland transition zone up to 1,600 feet (500m) from the marsh edge, even in areas that are not contiguous with the marsh. D. If the system has a river or creek, then an additional focus should be the creation of adjacent habitat that allows for the upstream migration of wetlands, at least to the head of tide under 24 inches (0.6 m) of sea level rise.
Restore Hydrological Connectivity	A. Restore tidal characteristics (range, extent and residence time) B. Restore freshwater and sediment flow characteristics from watersheds (volume, frequency, and timing) C. Restore or manage sediment inputs to maintain wetland and wetland-upland transition zone elevations sufficient to accommodate 24 inches (0.6 m) of estimated sea level rise. Inputs should be assessed based on total annual volume and magnitude of peak inputs.
Wetland Condition	A. Improve the major attributes of wetland condition, including biology, hydrology, physical structure, and landscape context, as measured by a rapid assessment score, for 100% of systems within each archetype. B. 100% of mature coastal wetlands should achieve and maintain an overall CRAM score ranging from 76–94. C. 100% of future restoration projects should be on or above the Habitat Development Curve based on the project age as the restoration matures.

The initial monitoring questions within the extent category relate to overarching wetland inventory and landscape level monitoring, while the other questions track the condition and resilience of those wetlands (Table 2). To comprehensively answer these questions, monitoring would ideally occur on an ongoing, annual basis. However, this is not practical in terms of resources and staff capacity. Therefore, the WRP RMP is structured in a more implementable approach anchored in a five-year cycle, which aligns with the Bight Regional Monitoring schedule. Throughout this document, we describe the minimum level of monitoring necessary to answer the seven monitoring questions and provide an evaluation of Goal 1. We recognize that monitoring every five years provides a snapshot in time of the region, rather than the ability to predict specific drivers of change.

Geographic Scope

Monitoring will occur across three different scales. The **wetland scale** represents an entire coastal wetland, where all the tidal and intertidal areas drain through a common inlet to the ocean. Wetlands can be comprised of one or multiple wetland types and can contain various habitat types. The **subregion scale** reflects the major geomorphic processes which drive the coastal landscape: topography, relative exposure to waves, and size of the watershed. The **region scale** refers to the whole Southern California Bight, from Point Conception to the US-Mexico border, which contains a set of coastal wetlands of various sizes and structures that interact ecologically to support regional biodiversity.

This monitoring framework applies specifically to the Southern California Bight (SCB). The physical features, climate, and hydrology of coastal southern California have produced a unique set of physical conditions and a diversity of plants and animals that distinguish the region from any other in North America. Unlike the broad, gradually sloping coastal plains of the Atlantic and Gulf Coasts, southern California has steep coastal mountains that descend sharply to the ocean. Summers are hot and dry in this semi-arid, Mediterranean climate, while winters are cool with rainfall varying in amount and intensity, from droughts to steady rains to torrential downpours. For instance, the San Gabriel and San Bernardino Mountains can experience more rain in a twelve-hour period than anywhere else in the continental United States (Nezlin and Stein 2005).

The SCB can be divided into five subregions - Santa Barbara, Ventura, Santa Monica, San Pedro and San Diego (

). These subregions generally reflect the change between steep, terraced, and flatter stretches of coast (Jacobs et al. 2010). They also reflect changes in orientation from southerly facing, with lower exposure to waves, to westerly facing, with higher exposure to waves. The inland boundaries of the subregions have been defined by watershed boundaries.

Figure 2. Extent of the five subregions of Santa Barbara, Ventura, Santa Monica, San Pedro and San Diego. (WRP Regional Strategy 2018).

Southern California coastal wetlands are complex and highly variable ecosystems and therefore can come in many shapes and sizes. The WRP Regional Strategy identifies 118 individual coastal wetlands in the Southern California Bight (Appendix B. List of Coastal Wetlands). The Regional Strategy then defines coastal wetland "archetypes", which are representations of a group or class of coastal wetlands similar in form and structure. Grouping wetlands into archetypes is useful because it provides a general conceptual model that can be used to explain how a specific group of wetlands function and how they may respond to external pressures or drivers.

The Regional Strategy defines seven archetypes:

- Small Creek – A small inlet with minimal subtidal habitat area, a small area of vegetated marsh at the inlet, and a generally steeper channel slope. These creeks are intermittently open to the ocean throughout the year, creating an estuarine salinity gradient during open periods.
- Large and Small Lagoon – Shallow basins usually created by a beach berm or barrier, which traps the lagoon between the ocean and uplands. Depending on the water level when the inlet closed and the length of closure, areas of ponded water may dry completely to become salt flats. The large lagoons have larger tidal prisms than the smaller lagoons but not necessarily a larger watershed; any river flow may be relatively small and intermittent resulting in more frequent closure of smaller lagoons.
- Intermediate Estuary – Lie between the small creeks and the large river valleys and have significant tidal prism and river flows. When they are closed, water levels within these estuaries are affected by river flow, when present, runoff from the immediate watershed, waves that

overtop the berm, tides which affect groundwater elevations, seepage through the berm from the ocean, evapotranspiration, and overtopping on extreme tides.

- Large River Valley Estuary – Large, depositional river valleys with a primary channel and many secondary channels with adjacent fringing marsh.
- Fragmented River Valley Estuary – A large river valley estuary where remnants of the floodplain have been dissected into smaller, spatially distinct units. The habitats within these fragments will not necessarily reflect the diversity or proportions of habitats of the undisturbed wetlands units.
- Open Bay/Harbor – Tidally dominated estuary with large tidal prisms, small river inputs, large subtidal habitats, relatively little intertidal wetlands and permanently open inlet.

Regional monitoring will occur across the entire region and all seven wetland archetypes. For the purposes of developing a monitoring network, we modified the archetypes to better ensure proportional representation of site monitoring. The SAP excluded Open Bay/Harbors from the sentinel site network and instead defined wetlands inside of larger bays (e.g., Upper Newport Bay, Kendall-Frost Reserve) as a Bay Estuary. The SAP considered the monitoring of harbors a low priority for this monitoring program. However, harbors and bays could be considered in the future, as they are significant sources of invasive species. Additionally, we combined Large River Valley and Fragmented River Valley into a single archetype called River Valley Estuary. The Fragmented River Valleys were once Large River Valleys, so for comparison, those archetypes should be considered together. The monitoring indicators and sampling frequency may vary depending on archetype and can be utilized at any of the 118 coastal wetlands in the region (Figure 3).

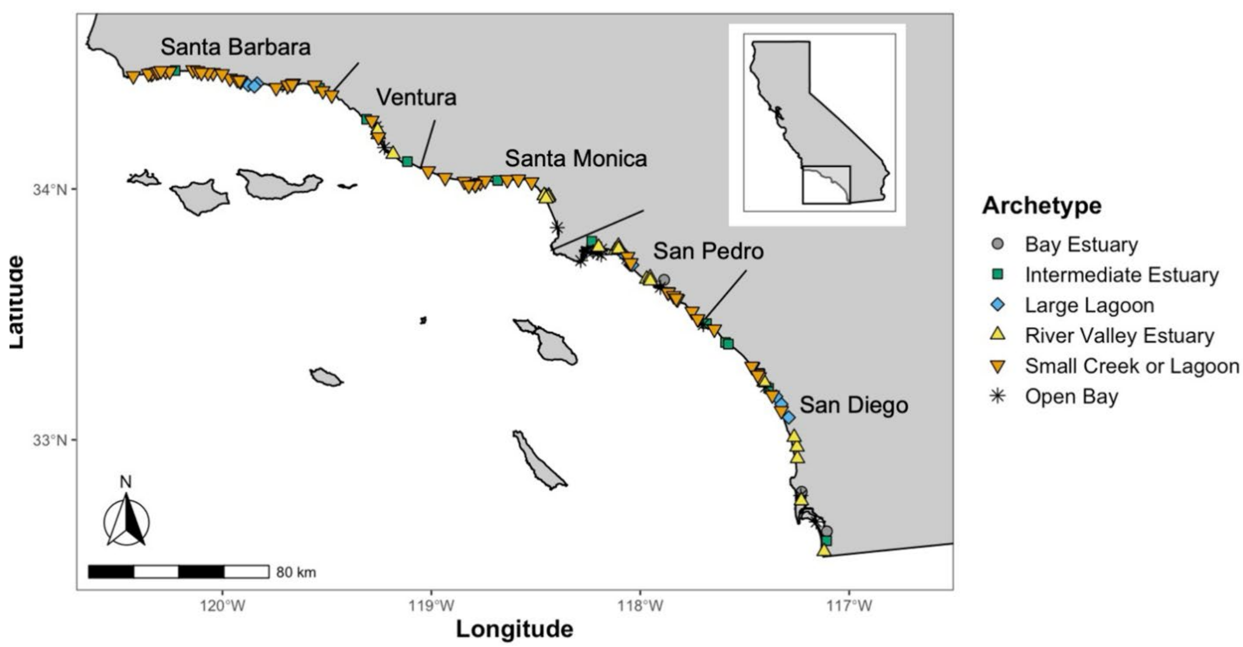

Figure 3. ***Southern California study area showing the location of the 118 coastal wetlands within the five subregions.***

Monitoring Elements

The WRP RMP will include routine mapping of all coastal wetlands in the region. Routine mapping will be done annually, consistent with the Ocean Protection Council (OPC) mapping recommendations (SFEI & SCCWRP 2025). In 2025, OPC convened a series of expert workgroups to develop a program to routinely and comprehensively map the four coastal habitats statewide: coastal wetlands, beaches and dunes, eelgrass, and rocky intertidal. Expert workgroups were convened for each of the four habitats to provide input on mapping approaches and data sources. This information will help inform the development of ongoing mapping efforts that can be applied in a consistent, practical and effective manner. Specifically for coastal wetlands, the expert panel recommended two different approaches (satellite-based mapping vs plane-based mapping) in order to address OPC's mapping goals of tracking overall acreage change. Mapping approaches will be detailed when statewide decisions are finalized.

In addition to mapping, three elements of the WRP RMP monitoring effort (Figure 4) will include:

4. Core monitoring – This monitoring occurs at the coastal wetland sentinel sites identified by the WRP SAP and is the minimum sampling effort necessary to answer the region's monitoring questions.
5. Grant and permit monitoring – This monitoring can leverage and intensify efforts to support the core monitoring by adding indicators, sites (beyond the sentinel sites), higher frequency of monitoring, or increased spatial intensity within sites.
6. Special studies – Special studies provide deeper understanding through targeted investigations of specific sites or functions. These studies can complement the core monitoring.

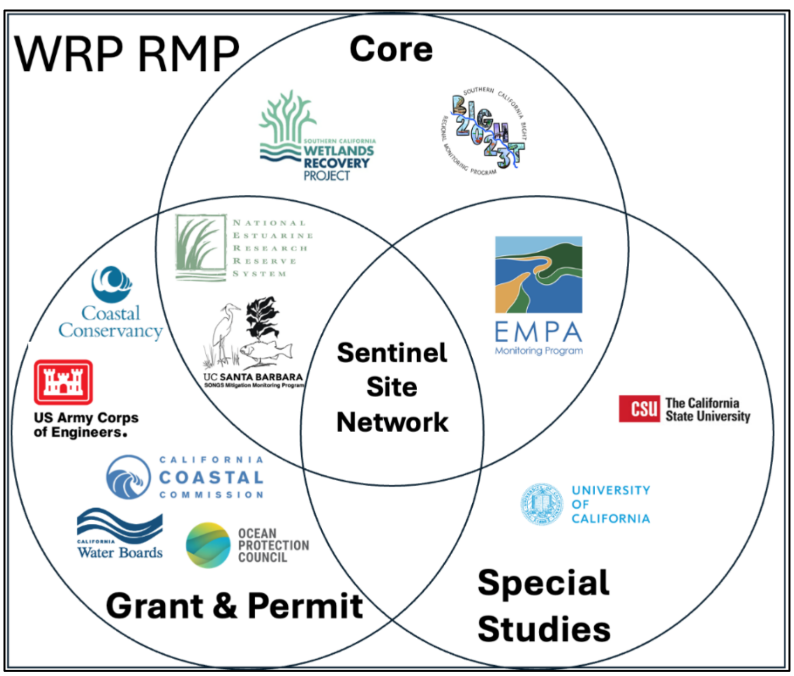

Figure 4. Types of monitoring that can inform the WRP Regional Monitoring Program along with example key entities who may implement each type of monitoring.

Core Monitoring Element

Core monitoring is focused on monitoring the WRP Sentinel Site Network (Southern California Wetlands Recovery Project 2024) at regular intervals to track ecological condition of coastal wetlands through time and evaluate regional trends, with the stated purpose of answering the seven monitoring questions in Table 2 on a five-year cycle. As mentioned above, to comprehensively answer the seven monitoring questions and track both short-term and long-term variability, ideal monitoring should occur on an ongoing, annual basis. However, due to monetary and practical constraints (e.g., resources, staffing), the WRP RMP is structured in a more implementable approach anchored in a five-year cycle.

Sentinel sites are defined as coastal wetlands that are designated for long-term monitoring to track ecological condition through time, evaluate the effect of regional trends in external conditions/stressors, and track progress toward regional objectives, strategies, or plans. They can also be useful in providing context for evaluating long-term efficacy of site-specific and regional restoration and management actions and informing adaptive management programs for coastal wetlands. Sentinel Site monitoring will be the backbone of the WRP RMP program, providing consistent data collection through time.

The Sentinel Site Network is composed of 37 coastal wetlands within the region and is comprised of three sentinel site types (Figure 5) (Appendix C. Sentinel Sites). For more details, see Document #1- Development of a coastal wetland sentinel site network (Southern California Wetlands Recovery Project 2024).

1. Reference – Sites that reflect the least degree of alterations, impacts, or stressors in the landscape, and often the sites used for comparison when assessing restoration or impacted sites.
2. Restoration – Sites that have been or are presently being restored. These sites have undergone large-scale restoration efforts and can be tracked over time to understand their long-term ecological progression. These sites can include both mitigation and voluntary restoration efforts.
3. Other Sites of Interest – This category allows for the inclusion of sites of interest that may not fit into the other categories (e.g., a heavily degraded site, or a site with an established long-term monitoring program).

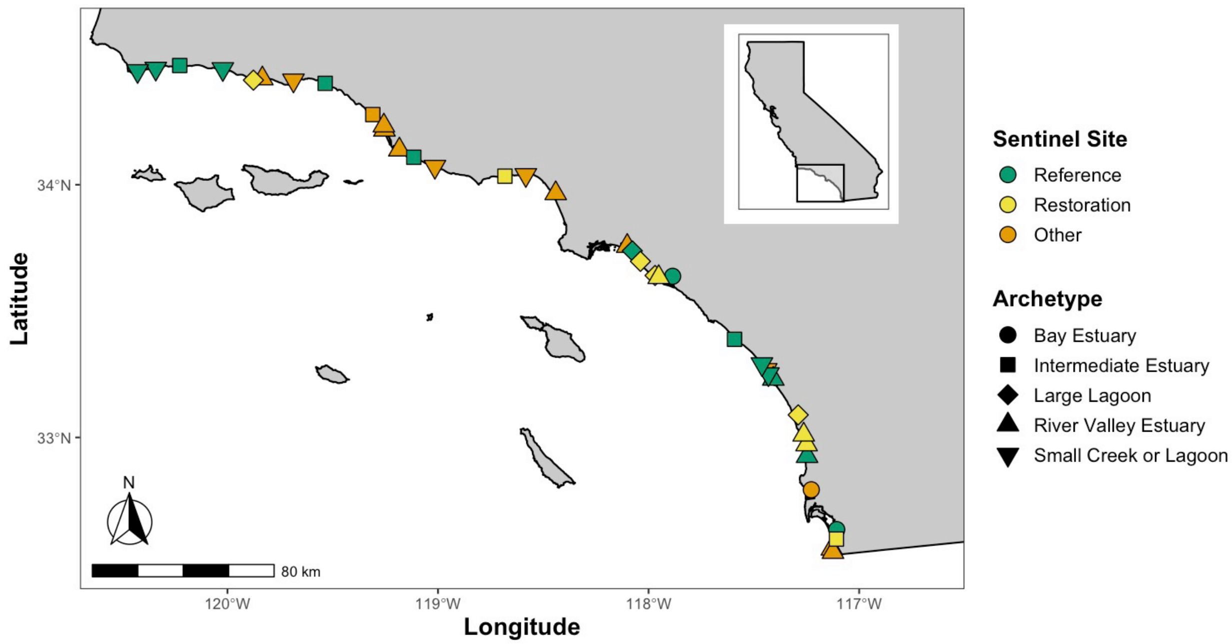

Figure 5. 37 coastal wetlands were designated as sentinel sites. Colors represent the type of sentinel site and shape represents the archetype.

Grant and Permit Monitoring Element

Grant and permit monitoring is the monitoring required in permits or grant conditions for mitigation projects or voluntary restoration projects. By including the recommendations of the WRP RMP's Monitoring Strategy, project specific monitoring can expand and intensify the core monitoring by adding indicators, adding sites both within and outside the sentinel site network, increasing the frequency of monitoring, or increasing the spatial intensity of sampling within sentinel sites.

While the WRP RMP can improve regional understanding of drivers and performance of projects, it may not address all regulatory requirements at a project site, especially those addressing threats to sensitive species and loss of critical habitat. As a result, the monitoring requirements of individual restoration projects might need to be customized, based on the resources affected by the project, for example, when listed species occupy a project site.

Recommendations and guidelines for how agencies can incorporate the WRP RMP and associated tools into project-specific monitoring are outlined in Document #3- *Applicability of Regional Monitoring for Agencies: Guidelines for Incorporating the WRP Regional Monitoring Program into Agency Programs.*

Special Studies Monitoring Element

Special studies can provide additional context and validation for the WRP RMP, including additional targeted monitoring to pilot a new Standard Operating Procedure (SOP), identify target stressors, conduct retrospective trend analyses, understand more detailed aspects of wetland function, test the effectiveness of restoration approaches, or test a research hypothesis. Research institutes or universities could partner with the WRP RMP to conduct special studies and support regional assessment. To participate in a Special Study, partners must utilize the WRP RMP data management system to ensure data sharing and interpretation.

Monitoring Design

To answer the seven monitoring questions, monitoring will be conducted at a combination of sentinel and non-sentinel sites using the core, permit/grant, and special studies monitoring elements. Sentinel sites include the 37 sites selected for monitoring, as described above.

The WRP RMP will monitor all sentinel sites on a five-year cycle[1], and all sites will be monitored in a single year. This is the minimum frequency to ensure that the WRP can answer the seven monitoring questions (Table 2). All monitoring should occur within a single year to ensure that monitoring data are comparable across sites.

More intensive monitoring can be conducted within the sentinel site network based on available resources or the permit or grant monitoring requirements of restoration and mitigation projects, or other management programs. Additionally, if a specific site has a targeted stressor concern, then monitoring could be more frequent to adequately assess site response to that stressor. In summary, sentinel site monitoring on a five-year cycle will be completed by the core monitoring element, as well as any groups already sampling sentinel sites as part of permit, mitigation, or grant requirements.

Non-sentinel site monitoring may also occur due to both permit/grant requirements or special studies. These sites could be either restoration sites or Other Sites of Interest ('opportunistic' sites). Over time, non-sentinel restoration sites could become sentinel restoration sites once performance standards are met and grant/permit requirements are fulfilled. Sites will need to be reviewed to decide whether these types of sites can evolve over time – either graduate into the sentinel site network for continued monitoring or drop off the regional assessment. The restoration site must be successfully restored or on the trajectory to being successfully restored, as defined by the site's proximity to reference standard conditions (Staszak & Armitage 2013, Zedler & Callaway 1999).

To answer the seven monitoring questions, which are grouped into three categories (extent, condition, and resilience), a combination of sentinel and non-sentinel site monitoring will be conducted or leveraged through core monitoring, permit/grant requirements, and special studies. These monitoring question categories are linked to the suggested monitoring frequencies for both sentinel and non-sentinel sites (

Table 4). The resilience category is divided into two components to differentiate the monitoring frequency needed to evaluate resilience towards stressors (e.g., sea level rise) which may act on a longer timeframe, and restoration effectiveness which is on a shorter timeframe and linked to permit/grant requirements. Table 5 outlines the monitoring elements that are recommended to be conducted to complete the necessary monitoring at each site type.

[1] A five-year cycle is consistent with existing regional monitoring programs, and therefore likely to be implementable with anticipated funding.

Table 4. Minimum monitoring frequency recommended for each site type to answer the monitoring questions.

Question Categories	Sentinel Sites			Non-sentinel Sites	
	Reference	Restoration	Other	Restoration	Opportunistic
Extent	Mapping per OPC mapping recommendations				
Condition	every 5 years + as required by permits/grants + targeted based on stressor concerns			per permits/ grants	every 5 years + targeted frequency at sites of concern
Resilience: Stressors	every 5 years				every 5 years
Resilience: Restoration Effectiveness		every 5 years + per permits/grants	dependent on site type	per permits/ grants	

Table 5. Monitoring elements recommended to be conducted at each site type.

Monitoring Element	Sentinel Sites			Non-sentinel Sites	
	Reference	Restoration	Other	Restoration	Opportunistic
Core	X	X	X		
Permit/ Grant	X	X	X	X	
Special Studies	X	X	X	X	X

In planning for the five-year cycle, the following will need to be considered:

1. Status of the sentinel site network – The sentinel site network will need to be evaluated holistically to determine if the sentinel sites are in the correct categories (e.g., whether the reference sites are still reference and whether the region has any new restoration sites).
2. Incorporation of project monitoring efforts within sentinel sites – Sites should be considered for incorporation into the program under specific grant and permit required monitoring. These considerations will help allocate resources within the five-year core monitoring. Some permit and grant sites may only monitor a percentage of the RMP indicators, therefore the RMP may need to add additional indicators to these sites during the five-year cycle.
3. New sites – New sites should be considered for addition to the sentinel site network based on funding, ongoing monitoring, and upcoming restoration projects.

The inclusion of existing, ongoing site monitoring will need to be considered for incorporation into the program. The following is recommended:

1. In the short-term (first monitoring cycle), sites with existing monitoring should be included in the WRP RMP, especially if they are sentinel sites, regardless of the indicator method in use. Sites with ongoing monitoring (e.g., the San Onofre Nuclear Generating Station Mitigation Monitoring Program and the National Estuarine Research Reserves) are critical sites for inclusion in the WRP RMP. Due to mitigation compliance requirements, monitoring methods are unable to change. However, methods can be cross-walked between the WRP RMP and other monitoring programs to maximize the utility of the data that is generated. Special studies could further be utilized to evaluate how similar and comparable monitoring methods are.
2. In the long-term, new sites that are added to the sentinel site network should be required to use the preferred methods as outlined in the WRP RMP. As the program grows, there should be an increase in the number of sites using the preferred method. In the future, only sites that use preferred methods will be considered for inclusion in the WRP RMP.

4. Assessment Approach

A common set of indicators will be monitored over time at the sentinel sites as part of the core monitoring to answer the seven monitoring questions. Indicators are also recommended for use by grant and permit/mitigation monitoring, recognizing there may be agency-specific requirements or constraints related to the selection of specific indicators and their monitoring frequency. These indicators can be summarized, synthesized, and packaged to evaluate ecosystem function following a function-based assessment framework (described below).

Indicators

The WRP RMP includes two classes of indicators. First are core indicators that should be monitored across all sites at an ideal rate (dependent on the indicator) to answer the monitoring questions (Table 6). These indicators should be included in all three monitoring elements (core, permit/grant, special studies). We outline the process for selecting these indicators in Appendix D: Indicator Prioritization. The core indicators are described in Appendix E: Core Indicators. If resources are available, supplemental indicators could be added to the core monitoring. These indicators are typically more time-intensive and costly. If grant and permit requirements require these supplemental indicators, then the recommended methods should be followed. The supplemental indicators are described in Appendix F: Supplemental Indicators. At this time the monitoring framework does not include benchmarks for the ideal or target conditions for each indicator. However, where there are established criteria (for example with dissolved oxygen), use those criteria.

Within the monitoring year, the frequency of monitoring will depend on the individual indicator and method (e.g., whether the indicator should be monitored seasonally or at a single time point within the monitoring year). For each indicator in Appendix E and F, we provide tables that describe the minimum and ideal temporal sampling frequency within the monitoring year. Some indicators should be monitored seasonally (e.g., spring and fall), while other indicators should be monitored based on events (e.g., mouth open and closure). All recommendations are for monitoring within a single year.

Table 6. Core and supplemental indicators for inclusion in the WRP RMP.

Core Indicators	Supplemental Indicators
Habitat and Elevation	Sediment Dynamics
Marsh Vegetation	Mouth Dynamics
Water Quality: Temp., DO, Salinity	Water Quality: Parameters of Concern
Hydrology	Submerged Aquatic Vegetation
Rapid Assessment	Birds
Fish: Minimum sampling	Fish: Extensive sampling
Invertebrates: Macrofauna (> 3 mm)	Invertebrates: Infauna (< 500 um)
Eutrophication: sediment nutrients	Eutrophication: algae

Station Monitoring

Regional differences in annual precipitation, watershed and coastal geology, and land use drive tremendous variability in estuarine conditions and functions. Additionally, estuaries are composed of a diversity of habitats or landscape features from salt marsh platforms to intertidal and subtidal channels to seagrass beds. WRP RMP monitoring is based on establishing sampling stations or zones that encompass a variety of habitat types and therefore monitoring can capture multiple functions.

The appropriate selection of sampling locations within each estuary is critical to increase the comparability of the assessment framework and interpretability of the data across estuaries. Site selection could start with stratified random placement or a probabilistic approach that considers placement within the estuary balanced with permission and accessibility for repeated sampling. In the case of a restoration project located within a larger wetland complex, sampling stations should be located within the area of activity. Note that the interpretation of the data is focused on that area rather than the whole system. Monitoring practitioners will need to document the spatial extent of the monitoring effort so it is clear that the stations correspond to a restoration project. Once stations are selected, these areas will be returned to every five-year sampling cycle.

Within these permanent sampling stations, users can concentrate multiple sampling methods (i.e., cluster sampling) in a given area and thereby conduct reoccurring sampling in the same location over time (Figure 6). This approach is favored over distributing measures more diffusely across the site, as concentrating multiple measures will enhance our ability to interpret data and explore interactions between metrics that are necessary for the function-based approach.

The WRP RMP approach to selecting sampling stations within a site should be consistent with the statewide Estuary Marine Protected Area Monitoring Program (EMPA Monitoring Program). The EMPA Monitoring Program created a multi-step process for the selection of sampling stations within each estuary. The overarching goal of this process is to develop a standardized process for the placement of sampling stations, which will allow users to identify and prioritize the main landscape features that will allow them to assess ecological functions, given their specific estuary. The degree of replication needed to accurately capture these processes will vary with the size of the sampling area, but also the diversity of habitats contained within it. The purpose of these sampling stations is to pre-determine the areas for focused or concentrated sampling. Depending on the size of the estuary, two to three sampling stations are selected for focused monitoring efforts within each estuary. For more details on the process, see the Estuary MPA Monitoring Protocol (Walker et al. 2023).

For the WRP RMP, a minimum of three sampling stations per estuary should be used to answer the monitoring questions (Figure 7).

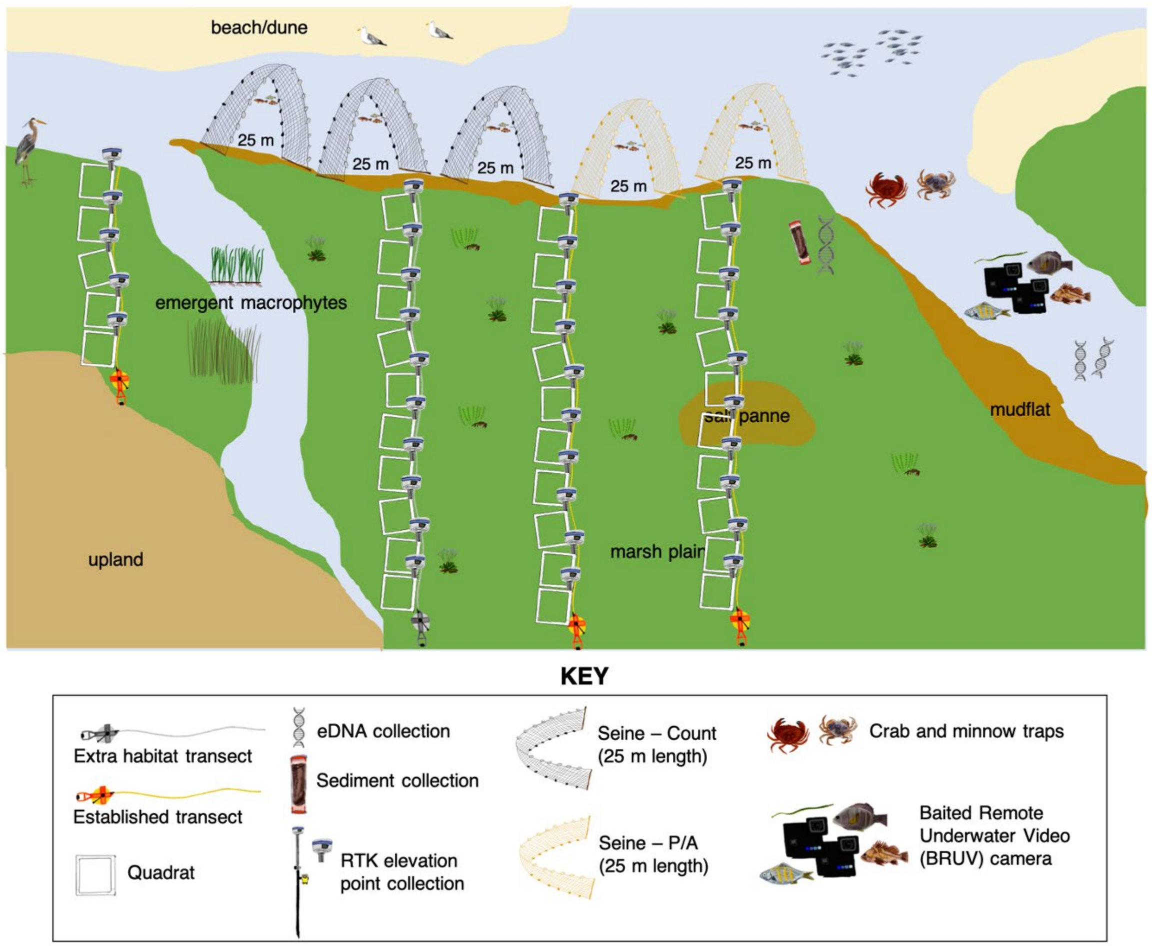

Figure 6. Example of EMPA cluster sampling at a single station. Methods and indicators would vary based on RMP selections.

Figure 7. Example lagoon (Batiquitos Lagoon in San Diego County, CA) with three monitoring stations.

Analysis Framework

The WRP RMP will follow an ecosystem-function based approach aimed at assessing estuary function, condition, and health to provide data that can be easily compared across systems and between monitoring programs within the region. The WRP RMP will leverage the EMPA function-based approach to complement the WRP RMP data analysis (Stein et al. 2023). Focusing an assessment framework on ecological functions allows for the creation of linkages between assessment results and ecological services, and designated beneficial uses for each estuary. Furthermore, an assessment framework built to evaluate ecological functions will have greater application flexibility within a highly heterogeneous state, like California. The species of plants and animals that are the components of and are used as indicators of ecological functions may change between subregions and estuarine types, but the focal estuarine functions should remain constant. Flexibility of the function-based approach will ultimately allow for comparative assessment across estuary types, while accounting for regional differences and anthropogenic impacts. This will ultimately allow for the assessment of management actions and protected area designations.

Answering the seven monitoring questions and comprehensively assessing ecosystem function will depend on the consistent use and application of monitoring indicators and methods. In some instances, sites with existing, ongoing monitoring may consider switching methods to better align with the WRP RMP. However, whether a site should switch methods should be thoroughly considered due to the potential loss in trend data. Switching to a new method consistent with the WRP RMP sites would increase data comparability across the region. However, by switching methods, the site could lose the critical ability to document trends within the site. If resources are available, rather than switching methods, we recommend layering on new methods (e.g., layering on additional vegetation transects). The majority of core indicators are typically monitored using consistent and common methods throughout the region (e.g., water quality, eutrophication, rapid assessment); therefore, many programs that monitor these indicators will already have comparable data. However, the most problematic indicators are the biotic indicators that require consistent methods and replication to accurately evaluate abundance metrics (e.g., fish). Therefore, the WRP RMP will have to acknowledge the limitations in comparing sites with disparate data within the analysis framework that use these indicators with different methods.

Following the completion of the first WRP RMP monitoring cycle, the analysis framework will be evaluated and expanded based on the available monitoring data.

5. Data Management

A comprehensive data management strategy facilitates the integrated analysis of data to answer the WRP RMP questions. Acquisition and management of high-quality data are paramount. A key component and investment of the WRP RMP will be in a data management system that can assure data quality and clarity of interpretation. One option is to integrate the WRP RMP data with existing data portals.

Attributes of a Data Management System

An informative and useful data management system should have the following attributes:

1. An information management (IM) plan - IM plays a vital and fundamental role in maintaining a high level of data quality assurance and quality control from field collection through laboratory analysis to data submission and subsequent data analysis.
2. Standardized data transfer formats (SDTF) – SDTF allows a diversity of organizations to collect data and then upload data to a common database. Standard formats allow ease in data compilation, download, and analysis.
3. Data checkers - Data checkers include logic checks, completeness checks, range checks, syntax checks, duplicate checks, qualifier checks, checks for calculated parameters, and QA/QC checks. This prevents common errors on the data upload side and expedites the data submittal process, allowing for more rapid access to the final dataset.
4. Public access – Clean, formatted data should be accessible to the public. As part of the IM plan, a data policy should be included on how and when data becomes accessible.

Option to Integrate with the EMPA Portal

One option for the WRP RMP is to integrate their data with existing data portals, such as the EMPA Monitoring Program. The EMPA Monitoring Program is a cooperative, integrated state and regional monitoring program with many participating agencies. The EMPA program utilizes standardized data transfer formats (SDTF) to upload data to a common database using the EMPA data portal. To this end, the program has worked to improve IM by providing updated MS Excel templates for all SOPs, as well as including data checks in the data portal to ensure the final dataset is complete and of the highest quality. In addition to data upload, the EMPA portal also provides access to publicly available data. The EMPA database is currently a public database. Therefore, once data are submitted into the portal, it becomes readily available and searchable.

Data are served up in three ways:

1. Individual datatype retrieval: Data can be retrieved at the individual project level on an annual basis as datasets are published to ArcGIS.
2. Query tool: Data can be retrieved across all projects and datasets using categorical searches spanning multiple datatypes.
3. ERDDAP Server: Continuous water quality data can be retrieved via the NOAA ERDDAP Data Server.

There are many benefits for the WRP RMP integrating with the EMPA Program:

1. Data are currently managed by a southern California entity (SCCWRP).
2. Data infrastructure and support are set up and have been readily tested for the last five years.
3. Southern California Bight data utilizes the EMPA portal for data storage.

However, if the WRP RMP decides to integrate with the EMPA data management system, there could be some challenges, and additional functionality will need to be incorporated into the system.

1. The EMPA data portal is not funded in the long term.
2. Data are immediately public upon submission to the EMPA portal. If project data needs to be private until further approval, then new features will need to be integrated into the portal.
3. The WRP RMP is expecting a variety of methods to be used in the first few cycles of data collection. If methods differ from the EMPA, then data templates and tables will need to be updated to build in flexibility for method discrepancies.
4. With the incorporation of more sites and projects, project level metadata will need to be properly catalogued to increase transparency across all data and ensure proper use of the data.

External Data Sources

A critical decision that the WRP RMP has to make is whether or not to pull ongoing monitoring data from external sources into the internal RMP data management system. Some of the annual and long-term monitoring data collected throughout the region is publicly available via external sources, while other monitoring data are only accessible via request (Table 7).

Table 7. External sources of ongoing monitoring data.

Monitoring Program	Data Access	Sites
The Nature Collective	Available upon request	San Elijo Lagoon
California Estuary Marine Protected Area Monitoring Program (EMPA)	Publicly available – EMPA portal	Goleta Slough Ventura River Malibu Lagoon Newport Bay Bolsa Chica Seal Beach Batiquitos Lagoon
National Estuary Research Reserve System (NERR)	Partially publicly available – ERDDAP Server Available upon request	Tijuana River Estuary Los Pensaquitos Lagoon
Southern California Bight Regional Monitoring Program (Bight)	Publicly available – EMPA portal	Varies on a five-year cycle
San Onofre Nuclear Generating Station Mitigation Monitoring Program (SONGS MMP) - UC Santa Barbara	Publicly available – EDI server	San Dieguito Wetlands Tijuana Estuary Los Penasquitos Lagoon Carpinteria Salt Marsh Mugu Lagoon

WRP Project Tracking

A key goal of the Monitoring Program is to track the WRP's progress in achieving Goal 1 objectives of the Regional Strategy. The WRP's Work Plan includes high priority preservation, acquisition, restoration, and enhancement projects for wetlands and streams in the coastal watersheds of southern California that will accomplish the Goals and Objectives of the Regional Strategy. The WRP has a preliminary visualization tool built within EcoAtlas.org to help represent the progress of WRP Work Plan projects for Goal 1 and includes current or completed projects as of 2018.

With the potential to integrate all WRP RMP data into a single data management system, these preliminary visualizations could be built out to include additional project tracking and functionality. A future goal of the WRP RMP is to create a broader data management and project tracking platform to better visualize the condition and health of wetlands in the SCB.

6. Outputs

As part of the WRP RMP, there will be a series of technical outputs.

1. Status and Trends of the Southern California Bight – Every five years following the completion of the core monitoring, a technical report will be produced on both the current round of monitoring and trend data from past monitoring. This report will include a report and initial answers on the seven monitoring questions and the evaluation of the objectives of Goal 1 of the WRP Regional Strategy. This report will be critical in guiding the next round of core monitoring.
2. Published Dataset – Monitoring data collected during the monitoring cycle will be verified and published alongside the Status and Trends report.
3. Updated WRP Project Tracking – Following each cycle, the WRP project tracking and dashboard will be updated to reflect the Status and Trends report. This dashboard will effectively communicate key messages from the Status and Trends report.
4. As the data management system is developed data dashboards will become available allowing for the display of interim data and summaries between 5-year reporting cycles.

In addition to technical reports, the WRP RMP monitoring plan will be re-evaluated following each five-year cycle. This document is considered a living document and therefore will continue to be revised and updated as the program progresses. Specifically, the following will be continued to be refined:

1. Refinement of the monitoring plan and core monitoring elements
2. Revisions to sampling methods based on field experience
3. Refinement of the analytical and data visualization products

7. References

Doughty, C. L., Cavanaugh, K. C., Ambrose, R. F., & Stein, E. D. (2019). Evaluating regional resiliency of coastal wetlands to sea level rise through hypsometry-based modeling. *Global Change Biology*, *25*(1), 78-92.

Heimhuber, V., Vos, K., Fu, W., & Glamore, W. (2021). InletTracker: An open-source Python toolkit for historic and near real-time monitoring of coastal inlets from Landsat and Sentinel-2. *Geomorphology*, *389*, 107830.

Jacobs, D., Stein, E. D., & Longcore, T. (2010). Classification of California estuaries based on natural closure patterns: templates for restoration and management.

Lynch, J. C., Hensel, P., & Cahoon, D. R. (2015). The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics. *USGS Report*, 8.

Nezlin, N. P., & Stein, E. D. (2005). Spatial and temporal patterns of remotely-sensed and field-measured rainfall in southern California. *Remote Sensing of Environment*, *96*(2), 228-245.

Page, M., Schroeter, S., Reed, D., Steele, M., Ambrose, R., Raimondi, P., & Schmitt, R. (2022). Monitoring Plan for the SONGS' Wetland Mitigation Project. *Report to the California Coastal Commission*.

Payne, S. A., Alvarez, K., Bruce, M., Darling, R., Gunnerson, A., Ly, R., ... & Lee, C. (2025). Bar-Built Estuary Breach Detection with Remote Sensing: an Automated Tool to Inform Management Practices. *Estuaries and Coasts*, *48*(5), 119.

San Francisco Estuary Institute (SFEI) and Southern California Coastal Water Research Project (SCCWRP). 2025. Tracking Coastal Habitat Change Over Time: Combined Habitats Whitepaper. SFEI Publication No. 1246. SCCWRP Publication No. 1438. Richmond, CA. April 2025, pp. 69.

Southern California Wetlands Recovery Project. 2018. Wetlands on the Edge: The Future of Southern California's Wetlands: Regional Strategy 2018. Prepared by the California State Coastal Conservancy, Oakland, Ca.

Southern California Wetlands Recovery Project. 2024. Assessing Wetland Recovery: Building Capacity for Assessing Wetland Recovery Efforts in Supporting Regional Wetland Health and Resiliency - Development of a Coastal Wetland Sentinel Site Setwork. Prepared by the Wetland Recovery Project Scientific Advisory Panel.

Stein, E. D., Cayce, K., Salomon, M., Bram, D. L., De Mello, D., Grossinger, R., & Dark, S. (2014). Wetlands of the Southern California coast: Historical extent and change over time. *Southern California coastal water research project technical report*, *826*, 1-50.

Stein, E.D., Walker, J., O'Connor, K., Clark, R., Whitcraft, C. 2023. Development of a Statewide Estuary Monitoring Program to Evaluate California's Estuarine Marine Protected Areas-Estuary Marine Protected Area Program Overview. A report prepared for the California Ocean Protection Council and the California Department of Fish and Wildlife. 12pp.

Walker, J. B., O'Connor, K., Wasson, K., Crain, C., Johnston, K. K., Ambrose, R. F., ... & Stein, E. D. (2025). Sentinel site networks as a mechanism to evaluate progress toward meeting restoration goals in altered and unaltered landscapes. *Restoration Ecology*, e70062.

Walker, J., Stein, E.B., O'Connor, K., Clark, R., Whitcraft, C., Garcia, S., Hughes, B., Cooper, A., Jacobs, D., Abrecht, M., Largier, J., Roettger, R., Christina, T. 2023. Estuary Marine Protected Area Monitoring Protocol. A report prepared for the California Ocean Protection Council and the California Department of Fish and Wildlife. 29pp.

Zedler, J. B., Callaway, J. C., & Sullivan, G. (2001). Declining Biodiversity: Why Species Matter and How Their Functions Might Be Restored in Californian Tidal Marshes: Biodiversity was declining before our eyes, but it took regional censuses to recognize the problem, long-term monitoring to identify the causes, and experimental plantings to show why the loss of species matters and which restoration strategies might reestablish species. *BioScience*, *51*(12), 1005-1017.

Appendix A. Related Efforts

Details of the WRP RMP monitoring framework benefited from principles and approaches incorporated into existing state and regional monitoring programs. By aligning monitoring frameworks, the WRP RMP can further help ensure compatibility between programs across the state of California.

Program	Description
California Estuarine Marine Protected Area Monitoring Program (EMPA)	The EMPA Monitoring Program is an ongoing effort to assess the quality and condition of estuaries statewide. The program goals are to monitor California estuaries with a standard, comprehensive function-based assessment framework to determine the health of California's estuaries and the efficacy of MPA designation. Partners in the program have developed an assessment framework, standard monitoring protocols, data structures, and quality control measures.
San Francisco Wetland Regional Monitoring Program (WRMP)	The WRMP delivers coordinated regional monitoring of the San Francisco Estuary's wetlands to (1) inform science-based decision-making for wetland restoration and adaptive management and (2) increase the cost-effectiveness of permit-driven monitoring associated with wetland restoration projects.
National Estuary Research Reserve System (NERR)	The National Estuarine Research Reserve System is a network of 30 coastal sites designated to protect and study estuarine systems in collaboration with and service to surrounding communities. Established through the Coastal Zone Management Act, this partnership program between NOAA and the coastal states supports ecosystem health and the interconnectedness of people and the environment. Specifically, the NERR water and vegetation monitoring protocols were critical in selecting WRP RMP methods.
University of California, Santa Barbara San Onofre Nuclear Generating Station (SONGS) Mitigation Monitoring Program	Long-term, independent monitoring and evaluation of the SONGS mitigation projects is a condition of the coastal development permit issued by the California Coastal Commission (CCC) for the operation of SONGS Units 2 and 3. The Permit requires Southern California Edison (SCE) as majority owner and operating agent of SONGS to design and build mitigation projects that adequately compensate for the adverse effects of the power plant's once-through seawater cooling system on living marine resources. UCSB scientists working under the direction of the Executive Director of the CCC are responsible for designing and implementing monitoring programs aimed at determining the effectiveness of these mitigation projects (e.g., San Dieguito Wetlands Restoration Project).
Southern California Bight Regional Monitoring Program (Bight)	The Bight Program is an ongoing marine monitoring collaboration that examines how human activities have affected the ecological health of more than 1,500 square miles of southern California's coastal waters. Nearly 100 organizations pool their resources and expertise to support the program, which runs in five-year cycles.

Appendix B. List of Coastal Wetlands

#	Name	Latitude	Longitude	Archetype	Subregion
1	Agua Hedionda	33.142021	-117.324750	Large lagoon	San Diego
2	Alamitos Bay	33.755467	-118.119313	Fragmented river valley estuary	San Pedro
3	Aliso Canyon Creek	33.267526	-117.441430	Small creek	San Diego
4	Aliso Creek Estuary	33.511760	-117.751739	Small creek	San Pedro
5	Anaheim Bay	33.738227	-118.077213	Large lagoon	San Pedro
6	Andree Clark Bird Refuge	34.420890	-119.660884	Small lagoon	Santa Barbara
7	Arroyo Burro Creek Estuary	34.403292	-119.742917	Small creek	Santa Barbara
8	Arroyo de las Aguas	34.459693	-120.340422	Small creek	Santa Barbara
9	Arroyo el Bulito	34.462770	-120.333899	Small creek	Santa Barbara
10	Arroyo Hondo	34.474000	-120.141157	Small creek	Santa Barbara
11	Arroyo Paredon Creek	34.413385	-119.558183	Small creek	Santa Barbara
12	Arroyo Quemado	34.470447	-120.118961	Small creek	Santa Barbara
13	Arroyo San Augustin	34.459312	-120.353902	Small creek	Santa Barbara
14	Arroyo Sequit	34.045057	-118.934156	Small creek	Santa Monica
15	Ballona Creek	33.972220	-118.437876	Fragmented river valley estuary	Santa Monica
16	Ballona Lagoon	33.973860	-118.460001	Fragmented river valley estuary	Santa Monica
17	Ballona Wetlands	33.965679	-118.441208	Fragmented river valley estuary	Santa Monica
18	Batiquitos Lagoon	33.089201	-117.289564	Large lagoon	San Diego
19	Bell Canyon Creek	34.429782	-119.912799	Small creek	Santa Barbara
20	Big Sycamore Canyon	34.071399	-119.014819	Small creek	Santa Monica
21	Bolsa Bay	33.697996	-118.047555	Large lagoon	San Pedro
22	Bolsa Chica Channel	33.730056	-118.060026	Small creek	San Pedro
23	Bolsa Chica Lagoon	33.696750	-118.038774	Large lagoon	San Pedro
24	Buck Gully	33.589732	-117.868414	Small creek	San Pedro
25	Buena Vista Lagoon	33.172943	-117.350048	Large lagoon	San Diego
26	Cabrillo Marina	33.714413	-118.285060	Open bay/harbor	San Pedro
27	Canada de Alegria Creek	34.470029	-120.272037	Small creek	Santa Barbara
28	Canada del Agra Caliente Creek	34.469009	-120.252444	Small creek	Santa Barbara
29	Canada del Agua	34.465574	-120.314897	Small creek	Santa Barbara
30	Canada Del Coral Creek	34.463006	-120.045186	Small creek	Santa Barbara
31	Canada del la Gaviota Creek	34.471690	-120.226662	Intermediate estuary	Santa Barbara
32	Canada del Refugio	34.463604	-120.069578	Small creek	Santa Barbara
33	Canada del Santa Anita	34.467419	-120.306326	Small creek	Santa Barbara
34	Canyon de las Encinas	33.115825	-117.324804	Small creek	San Diego
35	Carpinteria Creek	34.390875	-119.519524	Small creek	Santa Barbara
36	Carpinteria Salt Marsh	34.400983	-119.535765	Intermediate estuary	Santa Barbara
37	Channel Islands Harbor	34.164835	-119.224798	Open bay/harbor	Ventura
38	Cockleburr Canyon	33.250841	-117.430963	Small lagoon	San Diego
39	Creek at Corona Del Mar Beach	33.587745	-117.865676	Small creek	San Pedro

#	Name	Latitude	Longitude	Archetype	Subregion
40	Damsite Canyon	34.450291	-120.426704	Small creek	Santa Barbara
41	Dana Point Harbor	33.459181	-117.698185	Open bay/harbor	San Diego
42	Del Rey Lagoon	33.961404	-118.451378	Fragmented river valley estuary	Santa Monica
43	Devereux Lagoon	34.413813	-119.876743	Large lagoon	Santa Barbara
44	Dominguez Channel	33.791434	-118.232261	Intermediate estuary	San Pedro
45	Dos Pueblos Canyon Creek	34.440671	-119.964201	Small creek	Santa Barbara
46	Eagle Canyon Creek	34.435511	-119.929214	Small creek	Santa Barbara
47	Escondido Canyon	34.025552	-118.765831	Small creek	Santa Monica
48	French Lagoon (Canyon)	33.264134	-117.437594	Small lagoon	San Diego
49	Goleta Slough	34.419902	-119.834207	Large river valley estuary	Santa Barbara
50	Hollister Ranch Creek	34.470927	-120.294282	Small creek	Santa Barbara
51	Huntington Beach Wetlands	33.640841	-117.969365	Fragmented river valley estuary	San Pedro
52	Huntington Harbor	33.722549	-118.064585	Open bay/harbor	San Pedro
53	Las Flores Canyon	34.036604	-118.636478	Small creek	Santa Monica
54	Las Flores Creek	33.290470	-117.461802	Small creek	San Diego
55	Las Llagas Canyon Creek	34.458393	-120.001747	Small creek	Santa Barbara
56	Las Pulgas Canyon	33.292864	-117.465617	Small lagoon	San Diego
57	Loma Alta Slough	33.178173	-117.368161	Small creek	San Diego
58	Long Beach Harbor 1	33.750585	-118.226755	Open bay/harbor	San Pedro
59	Long Beach Harbor 2	33.744480	-118.203015	Open bay/harbor	San Pedro
60	Long Beach Harbor 3	33.737479	-118.187064	Open bay/harbor	San Pedro
61	Long Beach Marina	33.759762	-118.185774	Open bay/harbor	San Pedro
62	Los Angeles Harbor	33.750228	-118.256561	Open bay/harbor	San Pedro
63	Los Angeles River	33.767928	-118.199586	Fragmented river valley estuary	San Pedro
64	Los Cerritos Channel	33.772095	-118.104506	Fragmented river valley estuary	San Pedro
65	Los Cerritos Wetlands	33.757171	-118.101590	Fragmented river valley estuary	San Pedro
66	Los Penasquitos Lagoon	32.925751	-117.247499	Large river valley estuary	San Diego
67	Los Trancos Canyon	33.574049	-117.840253	Small creek	San Pedro
68	Malibu Lagoon	34.033812	-118.682321	Intermediate estuary	Santa Monica
69	Mandalay Power Station Outfall	34.206447	-119.252911	Small creek	Ventura
70	Marina del Rey	33.974919	-118.450723	Open bay/harbor	Santa Monica
71	McGrath Lake	34.217143	-119.254426	Fragmented river valley estuary	Ventura
72	Mission Bay	32.777947	-117.231619	Open bay/harbor	San Diego
73	Mission Creek Lagoon	34.412995	-119.686574	Small creek	Santa Barbara
74	Morro Canyon	33.560609	-117.821840	Small creek	San Pedro
75	Muddy Canyon	33.564239	-117.827878	Small creek	San Pedro
76	Mugu Lagoon	34.108620	-119.115011	Intermediate estuary	Santa Monica
77	Newport Harbor	33.607723	-117.903607	Open bay/harbor	San Pedro
78	North Mission Bay Wetlands	32.793039	-117.227479	Intermediate estuary	San Diego
79	Oceanside Harbor	33.211032	-117.399688	Open bay/harbor	San Diego
80	Ormond Beach	34.138620	-119.183565	Fragmented river valley estuary	Ventura

#	Name	Latitude	Longitude	Archetype	Subregion
81	Otay River Estuary	32.597980	-117.108091	Intermediate estuary	San Diego
82	Pendleton Outfall	33.257960	-117.437595	Small creek	San Diego
83	Prima Deshecha Cañada	33.440983	-117.645224	Small creek	San Diego
84	Ramirez Canyon	34.020313	-118.786672	Small creek	Santa Monica
85	Redondo Beach King Harbor	33.845833	-118.397356	Open bay/harbor	Santa Monica
86	Rincon Creek	34.373984	-119.476910	Small creek	Ventura
87	Salt Creek	33.481754	-117.725000	Small creek	San Pedro
88	San Diego Bay	32.673144	-117.157690	Open bay/harbor	San Diego
89	San Diego River Estuary	32.757726	-117.228957	Large river valley estuary	San Diego
90	San Dieguito Lagoon	32.971900	-117.249741	Large river valley estuary	San Diego
91	San Elijo Lagoon	33.010552	-117.263488	Large river valley estuary	San Diego
92	San Gabriel River Estuary	33.760346	-118.103583	Fragmented river valley estuary	San Pedro
93	San Jon Barranca	34.272897	-119.285046	Small lagoon	Ventura
94	San Juan Creek	33.463154	-117.683045	Intermediate estuary	San Diego
95	San Luis Rey Estuary	33.205763	-117.386097	Intermediate estuary	San Diego
96	San Mateo Lagoon	33.388193	-117.591997	Intermediate estuary	San Diego
97	San Onofre Creek	33.381688	-117.578288	Intermediate estuary	San Diego
98	Santa Ana River	33.646437	-117.952557	Fragmented river valley estuary	San Pedro
99	Santa Ana Wetlands	33.633776	-117.951994	Fragmented river valley estuary	San Pedro
100	Santa Barbara Harbor	34.405869	-119.690952	Open bay/harbor	Santa Barbara
101	Santa Clara River Estuary	34.233653	-119.257243	Fragmented river valley estuary	Ventura
102	Santa Margarita Estuary	33.231483	-117.407840	Large river valley estuary	San Diego
103	Santa Monica Canyon	34.027545	-118.519926	Small creek	Santa Monica
104	Solstice Canyon	34.033121	-118.742416	Small creek	Santa Monica
105	Sweetwater Marsh	32.635440	-117.106566	Intermediate estuary	San Diego
106	Sycamore Creek	34.416987	-119.666830	Small creek	Santa Barbara
107	Tajiguas Creek	34.464035	-120.101164	Small lagoon	Santa Barbara
108	Tecolate Canyon Creek	34.432143	-119.917616	Small creek	Santa Barbara
109	Tijuana River Estuary	32.555517	-117.119771	Large river valley estuary	San Diego
110	Topanga Creek	34.038689	-118.583098	Small creek	Santa Monica
111	Trancas Lagoon	34.029542	-118.841968	Small creek	Santa Monica
112	UCSB Lagoon	34.408766	-119.847288	Large lagoon	Santa Barbara
113	Upper Newport Bay	33.637709	-117.885868	Open bay/harbor	San Pedro
114	Ventura Marina	34.248332	-119.264761	Open bay/harbor	Ventura
115	Ventura River Estuary	34.277526	-119.309860	Intermediate estuary	Ventura
116	West Paradise Cove	34.017003	-118.790074	Small creek	Santa Monica
117	Wintersburg Channel	33.705323	-118.044980	Small creek	San Pedro
118	Zuma Lagoon	34.014570	-118.820610	Small creek	Santa Monica

Appendix C. Sentinel Sites

The SAP selected 14 Reference Sites, 9 Restoration Sites, and 14 Other Sites of Interest, for a total of 37 sites. Colors denote subregions within southern California.

Site	Archetype	Subregion	Reference	Restoration	Other Site of Interest
Sweetwater Marsh	Bay Estuary	San Diego	x		
Kendall-Frost Reserve	Bay Estuary	San Diego			x
Upper Newport Bay	Bay Estuary	San Pedro	X		
Santa Ana Wetlands	River Valley Estuary	San Pedro		x	
Los Cerritos Wetlands	River Valley Estuary	San Pedro			x
Ballona Wetlands	River Valley Estuary	Santa Monica			x
McGrath Lake	River Valley Estuary	Ventura			x
Ormond Beach	River Valley Estuary	Ventura			x
Canada del la Gaviota Creek	Intermediate Estuary	Santa Barbara	X		
Carpinteria Salt Marsh	Intermediate Estuary	Santa Barbara	X		
San Mateo Lagoon	Intermediate Estuary	San Diego	X		
Otay River Complex Estuary	Intermediate Estuary	San Diego		x	
Malibu Lagoon	Intermediate Estuary	Santa Monica		x	
Ventura River Estuary	Intermediate Estuary	Ventura			x
Mugu Lagoon	Intermediate Estuary	Ventura	X		
Devereux Lagoon	Large Lagoon	Santa Barbara		x	
Batiquitos Lagoon	Large Lagoon	San Diego		x	
Huntington Beach Wetlands Complex	Large Lagoon	San Pedro		x	
Bolsa Chica Fully Tidal	Large Lagoon	San Pedro		x	

Site	Archetype	Subregion	Reference	Restoration	Other Site of Interest
Seal Beach Wildlife Refuge	Large Lagoon	San Pedro	x		
Goleta Slough	River Valley Estuary	Santa Barbara			x
Santa Clara River	River Valley Estuary	Ventura			x
Santa Margarita Estuary	River Valley Estuary	San Diego	X		
Tijuana River Estuary - North	River Valley Estuary	San Diego			x
Tijuana River Estuary - South	River Valley Estuary	San Diego			x
Los Penasquitos Lagoon	River Valley Estuary	San Diego	X		
San Elijo Lagoon	River Valley Estuary	San Diego		x	
San Dieguito Lagoon	River Valley Estuary	San Diego		x	
Arroyo de las Aguas	Small Creek	Santa Barbara	X		
El Capitan	Small Creek	Santa Barbara	X		
Damsite Canyon	Small Creek	Santa Barbara	X		
Mission Creek Lagoon	Small Creek	Santa Barbara			x
Las Flores Creek	Small Creek	San Diego	X		
Aliso Canyon Creek	Small Creek	San Pedro			x
Big Sycamore Canyon	Small Creek	Santa Monica			x
Topanga Canyon Creek	Small Creek	Santa Monica			x
Cockleburr Canyon	Small Lagoon	San Diego	X		

Appendix D: Indicator Prioritization

The SAP established a ranking process to select the core (Appendix E: Core Indicators) and supplemental (Appendix F: Supplemental Indicators) indicators for inclusion in the monitoring plan. These are the indicators that should be monitored across all sites at an ideal rate (dependent on the indicator) to answer the guiding questions. We outline the process below, which resulted in a final list of core and supplemental indicators.

1. Comprehensive indicator and method list

The SAP first established a comprehensive list of common wetland indicator and method pairs that are typically used in monitoring plans and are reflective of common assessment methods to evaluate wetland condition and trends over time. Indicators and methods are listed in Table D- 1. Each indicator-method pair was then linked to the specific metrics that the pair could produce.

2. Estimate the effort, cost, and frequency

The SAP then estimated the amount of effort (high, medium, low), cost ($, $$, $$$), and monitoring frequency of each indicator-method pair. Methods were selected to be affordable and replicable across multiple spatial and temporal scales for ease in implementation across the region. The list was further refined based on the applicability and feasibility of implementing the method in the field.

3. Link indicators to monitoring questions

The SAP linked each indicator with three categories – condition, stress, and resilience – which linked back to the monitoring questions.

4. Score each indicator

Each SAP member individually scored and ranked each indicator-method pair based on their best professional judgement (BPJ):

- 0 = Not a priority
- 1 = Supplemental
- 2 = Either supplemental or core
- 3 = Core

5. Select final list

The SAP discussed the results of the prioritization and exercise and selected a final list of priority indicators for inclusion in the RMP. The SAP also generated a supplemental list of indicators that could be monitored providing supplemental and complimentary data if funding is available.

Table D- 1. The potential indicators, methods, and metrics ranked by the SAP.

Indicator	Method	Possible Metrics	Effort	Cost	Questions		
					Stressors	*Condition*	*Resilience*
Habitat	High resolution aerial imagery of habitat types	Extent of CARI habitats, habitat diversity, % migration space, % algae cover; With associated DEMS - UVVR of marsh, percent marsh below MHW or in bottom third	medium	$$$		x	x
	CRAM	CRAM	low	$	x	x	
Elevation	SETs	Elevation change at m2 scale with mm accuracy	medium	$$	x	x	x
	DEMs - LIDAR	Elevation change over entire estuary at cm scale	medium	$$	x	x	x
	DEMs - UAV imagery	Elevation change over entire estuary at cm scale - more precise	high	$$$	x	x	x
Sediment Dynamics	Dated core	Long term accretion rates	medium	$$$	x		x
	Feldspar horizon	Short term accretion rates	low	$			x
	Bank erosion monitoring	Selection of metrics (bank width to depth ratio; bank angle)	medium	$$	x		x
Hydrology	Imagery	Mouth dynamics (% open)	medium	$$	x	x	x
	Water level sensor	Short-term inter-annual variability in water levels; tidal range	low	$		x	x
WQ	Continuous sampling - Data sonde	Temperature, DO, salinity	medium	$$$	x	x	
	Discrete sampling	Temperature, DO (informs stratification), salinity	medium	$$	x	x	

Indicator	Method	Possible Metrics	Effort	Cost	Questions		
					Stressors	*Condition*	*Resilience*
Eutrophication	Sampling for parameters of interest or concern	Chlorophyll a, turbidity, pH, phosphate, nitrate	medium	$$$	x	x	
	Sediment grab	Nutrients (e.g., TOC, TN, nitrate, phosphate, ammonium)	low	$$	x	x	
	Transect survey	Macroalgae (% cover, species richness)	low	$	x	x	
Marsh Vegetation	Transect survey	% cover, % invasive/native, richness/diversity	medium	$	x	x	x
SAV	Transect survey	Canopy height, shoot density, P/A wasting disease	high	$$		x	x
	Mapping	SAV extent/area	high	$$$		x	
Birds	Surveys	Community: Diversity/richness/abundance	high	$$		x	
	Targeted surveys	Targeted species surveys for species of concern (e.g., ridgway rail, least tern, snowy plover)	medium	$$		x	
Fish	Fish seines	Community: Diversity/richness/abundance	high	$$		x	
	Targeted surveys (e.g., additional seines, eDNA/targeted probe)	Targeted species (e.g. tidewater goby, selected flatfish): abundance and size distribution	medium	$$		x	
	eDNA/metabarcoding	Community composition	low	$$		x	
	Baited Remote Underwater Videos (BRUVs)	Community composition	medium	$$		x	
	Traps	Community composition	low	$		x	

Indicator	Method	Possible Metrics	Effort	Cost	Questions		
					Stressors	*Condition*	*Resilience*
Invertebrates	Sediment cores (infauna)	Benthic infauna Community: Diversity/richness/abundance	high	$$$		x	
	Sediment cores (macrofauna)	Benthic infauna Community: Diversity/richness/abundance	low	$		x	
	Traps	Large macroinvertebrates community: Diversity/richness/abundance	low	$		x	
	Targeted surveys or samples (e.g., additional surveys, samples, or eDNA)	Targeted species (e.g. oysters, selected clams or crabs): abundance and size distribution	medium	$$		x	

Appendix E: Core Indicators

The WRP RMP includes eight core monitoring indicators that should be included in all three monitoring elements (core, permit, special studies) (Table E 1). A summary of each indicator can be found in Table E-2. The WRP RMP describes a monitoring plan for monitoring indicators within a single year every five-years. Indicators could be monitored more frequently (ideally annually) if resources were available.

For each indicator we provide the following information:

1. *Definition and description* – a description and justification of the indicator
2. *Method* - the recommended method with associated SOP
3. *Critical metrics* - a suggested list of numerical or qualitative summaries of the assessment data
4. *Product or output* - the intended output from the indicator

Table E-1. Final list of core and supplemental indicators for inclusion in the WRP RMP.

Core Indicators	Supplemental Indicators
Habitat and Elevation	Sediment dynamics
Marsh Vegetation	Mouth dynamics
Water Quality: Temp., DO, Salinity	Water Quality: Parameters of Concern
Hydrology	Submerged Aquatic Vegetation
Rapid Assessment	Birds
Fish: Minimum sampling	Fish: Extensive sampling
Invertebrates: Macrofauna (> 3 mm)	Invertebrates: Infauna (< 500 um)
Eutrophication: sediment nutrients	Eutrophication: algae

Habitat and Elevation

Description

The first part of core monitoring is updating the wetland maps and surface elevations utilizing established methods once every 5 years.

Surface elevation is a critical structural component of low-lying coastal areas, where slight changes in elevation can alter hydrology and define the difference between extensive wetland habitats or open water. These minor variations can significantly impact the distribution and extent of habitats, influencing the ecological balance and biodiversity of coastal regions. To effectively monitor and manage these sensitive environments, baseline elevation data must be collected to track changes over time. Therefore, maintaining elevation in relation to relative sea level is crucial for coastal wetlands.

Habitat and elevation mapping involves a comprehensive analysis or survey of an area's topography and biology, focusing on identifying unique habitats and understanding how variations in elevation across a marsh plain influence these habitats. Mapping habitats and measuring elevation are therefore intertwined and measuring elevation helps define the habitat types of interest and therefore in some instances could be conducted simultaneously for similar outputs.

The data obtained from habitat and elevation mapping serves multiple purposes. Land managers can use this information to make informed decisions regarding land use planning and conservation management. For instance, they can identify areas most vulnerable to sea level rise and prioritize them for conservation efforts. Additionally, the data can enhance public awareness by illustrating the intricate relationship between elevation and habitat distribution, fostering a deeper understanding and appreciation of coastal ecosystems.

Moreover, habitat and elevation mapping are instrumental in habitat restoration and creation projects. By understanding the specific elevation requirements of different wetland species, restoration efforts can be tailored to create suitable conditions for these species to thrive. This targeted approach increases the likelihood of successful habitat restoration and contributes to the overall resilience of coastal ecosystems.

In summary, habitat and elevation mapping is a vital tool for preserving the delicate balance of coastal wetlands. Through data collection and analysis, it provides the necessary insights for effective land management, conservation planning, public education, and habitat restoration, ensuring the long-term sustainability of these valuable ecosystems.

Methods

There are a variety of methods that could be used to produce the desired outputs. Mapping processes typically employ advanced technologies such as LiDAR (Light Detection and Ranging), remote sensing, and GIS (Geographic Information Systems) to create detailed topographical maps and habitat distribution models. The WRP RMP recommends following guidance outlined in the OPC Report: Tracking Habitat Change Over Time (SFEI and SCCWRP 2025). Changes in habitat extent are part of the complex product of a variety of natural and anthropogenic processes. Fluctuations in extent will vary in magnitude and will likely differ (i.e., gains and losses) in different areas of the coastline. Some types of change may be detected from more coarse mapping of habitat where others may only be detected through more detailed and higher resolution data/mapping. Each mapping approach provided in the OPC summary provides a different level of accuracy and detail.

In addition to mapping, for most smaller/supratidal estuary systems, ground-based survey methods utilizing RTK GPS equipment and/or a differential GPS with post-correction equipment can be suitable to characterize estuarine topography and determining elevation in vegetated areas.

SOP

- San Francisco Estuary Institute (SFEI) and Southern California Coastal Water Research Project (SCCWRP). 2025. Tracking Coastal Habitat Change Over Time: Combined Habitats Whitepaper. SFEI Publication No. 1246. SCCWRP Publication No. 1438. Richmond, CA. April 2025, pp. 69.
- EMPA Topographic Surveys

Critical Metrics

This indicator helps assess the extent of wetland systems. Critical qualitative assessments could include

- Extent (ha) of different wetland habitat types and corresponding elevation ranges
- Percent of marsh that is in the bottom third of inundation tolerance
- Extent of marsh migration space relative to existing marsh

Outputs

The appropriate output for this indicator is a classified habitat map for the entire wetland and upland buffer area (minimum upland area of 3m vertical of king tide). The coastal wetland map should map all tidally influenced wetlands as well as cover areas where tidally influenced wetland could occur if levees or other unnatural barriers were removed. Approaches should produce high resolution mapping of habitat classification systems that provide accurate acreage measurements as well as information on habitat functionality and health, including tracking of smaller features such as tidal ponds/pannes and channels. Accurate DEMS should be produced once every five years if expected change is primarily due to sea level rise.

Marsh Vegetation

Description

Long-term monitoring of vegetation is essential for evaluating the health and functioning of wetland systems (Zedler et al. 2001). Changes in the composition of native and non-native plant species can impact associated wildlife and serve as indicators of physical characteristics, human impacts, and changes in plant community composition.

Evaluating shifts in dominant vegetation communities can be achieved at various landscape levels. Broad evaluations typically use airborne or satellite remote sensing tools and imagery for extensive spatial coverage and high potential temporal frequency analysis. Ground surveys, provide detailed assessments of community composition and change at the community and species-level that aerial surveys cannot achieve.

The integration of remote sensing and ground surveys creates a robust vegetation monitoring schema. Remote sensing offers a broad overview and efficient large-area monitoring, while ground surveys provide detailed site-specific community- or species-level information. This combined approach allows for comprehensive monitoring and assessment, enabling informed decisions for managing and conserving estuarine ecosystems. By systematically collecting and analyzing both types of data, land managers can detect changes, assess impacts, and guide restoration and conservation efforts to maintain healthy, resilient wetlands.

Methods

There are a variety of methods that could be used to produce the desired outputs. The WRP RMP recommends a combination of methods to allow for comprehensive monitoring and assessment of estuarine vegetation. Remote sensing provides broad spatial coverage and temporal analysis capabilities, while ground surveys offer detailed, site-specific data. UAVs (Unmanned Aerial Vehicles) can add

flexibility and high-resolution data collection, while GIS can integrate these various data sources for in-depth spatial analysis.
At a minimum, transect surveys should be conducted to complement aerial imagery, quantify vegetation composition and community, and conduct invasive species tracking. We provide an SOP for the transect surveys.

SOP

- EMPA Vegetation

Critical Metrics

Critical qualitative assessments could include

- Extent (ha) of different wetland plant communities and/or species
- Ratio of native to non-native percent cover
- Absolute cover of target species or problematic invasive species
- Percent native to invasive total relative cover
- Plant species richness and diversity

Outputs

The appropriate output for this indicator is a plant community map for the entire wetland and upland buffer area if combing habitat mapping with remote sensing and UAVs. The WRP RMP recommends ground transect surveys at a minimum to produce a database with percent cover and maximum height of plant species.

The desired outputs differ between the Habitat and Elevation indicator and Vegetation indicator due to the distinction between a habitat map vs a plant community map. Habitats can be defined more generally as salt marsh, brackish wetland, salt pan, upland scrub, etc., while plant communities are specific to the vegetation types/communities combined with elevation, such as low marsh, mid-marsh, and high marsh.

Water Quality: Temp, DO, Salinity

Description

Estuarine wetlands are hydrologically dynamic habitats with constantly changing abiotic conditions due to interactions between freshwater inflows, tidal cycles, and meteorological events. Hydrology and water quality are fundamental drivers of estuarine extent, condition, and functions, especially in California which experiences tremendous intra- and inter-annual variability in rainfall, runoff, and temperatures. This is among the many reasons why the WRP RMP monitoring framework emphasizes time series collection of water quality data.

Methods

Continuous water quality monitoring in these areas typically involves using multi-parameter sondes or sensors, which collect data on parameters such as pH, temperature, salinity, chlorophyll, dissolved oxygen, and turbidity at user-defined intervals. These probes are deployed at strategic monitoring stations to capture detailed temporal records over multiple tidal cycles and freshwater input events, providing a cost-effective method to track changes in water chemistry. Objectives include quantifying specific water parameters and assessing long-term trends related to climate change, such as acidification, temperature warming, and sea-level rise, and management actions within the watershed, such as beach nourishment, inlet maintenance, and dam releases. The integration of these methods offers high-resolution data that captures rapid changes during events and identifies long-term trends.

To fully capture the status, trends, and inherent dynamism of these systems, and identify management interventions that can support long-term estuarine health and resilience, significant investment is needed to deploy water quality loggers. Effective and high-quality data collection requires, at a minimum, monthly download, intercalibration, and maintenance of data loggers. Efficient data storage requires the infrastructure for large data management and query, as well as personnel hours for comprehensive quality assurance/quality control. At a minimum, the WRP RMP recommends deployed data loggers during the summer for one month to track summer hypoxia or the typical season for hypoxia in a given system. Ideal deployments would be continuous over the year with collection intervals every 15-30 min. Based on project needs, alternatives may include temporary or fixed deployment of Hobo or other multi-parameter sensors for specific water quality assessments.

SOP

- EMPA Water Quality
- NERR

Critical Metrics

Critical qualitative assessments could include:

- Percent of deployment that is hypoxic (<3 ppm)
- Temperature and salinity trends over time
- Percent of time parameters are over species physiological limits (e.g., temperature > 25C)

Outputs

The appropriate output for this indicator is a database with water quality measurements (at a minimum temperature, salinity, and conductivity) and/or summary tables or figures identifying hypoxic or other conditions.

Hydrology

Description

Estuaries are inherently dynamic systems. Conditions vary due to tidal, day-night, weather-related (including waves and river flow), seasonal, interannual, and decadal cycles. This high degree of variability among estuaries makes it difficult to discern patterns driven by anthropogenic disturbance from patterns driven by natural system variability. Specifically, in intermittently closed estuaries, conditions can be dramatically different between wet and dry years - exceeding and obfuscating human impacts. Because estuaries integrate environmental stress from watersheds and the ocean, it can be difficult to identify primary stressors and document clear stress response relationships. Given this variability, monitoring over many years is essential to identify and assess human-induced trends. A key factor in understanding underlying patterns and stressors is the monitoring and tracking of the mouth dynamics.

Mouth state and closure duration are key considerations for management of estuaries of all types. 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.

Methods

Placement of low-cost pressure sensors within estuaries should be a standard practice in most systems. Sensors should be placed in a location that receives the full range of water elevations and is not dry when the water is at its lowest point. In addition, automated cameras can be placed at the mouth of key estuaries to track mouth migration, mouth state, wave overtopping, and breach events. For systems that dry periodically, careful sensor management and calibration will have to be considered. Additional sensors could be deployed to understand specific dynamics, such as tidal muting.

SOP

- EMPA Water Quality

Critical Metrics

Critical qualitative assessments could include:

- Depth and inundation frequency
- Mouth or inlet status
- Short- and long-term changes in water surface elevation

Outputs

The appropriate output for this indicator is a database with water level measurements (depth) and/or a summary table or figure identifying mouth closure events.

Rapid Assessment

Description

Rapid Assessment methods assess the existing condition of a wetland relative to its broadest suite of suitable functions, services, and beneficial uses, such as flood control, groundwater recharge, pollution control, and wildlife support, based on the consensus of best professional judgment. In this regard, a rapid assessment represents the overall functional capacity of a wetland. To be valid, rapid assessments must be strongly correlated to measures of actual functions or services. Once validated, rapid assessments can be used where intensive data are lacking or too expensive to collect. Rapid assessments can thus lessen the amount and kinds of data needed to monitor wetlands across large areas over long periods.

Methods

The WRP RMP recommended method is the use of the California Rapid Assessment Method for Wetlands (CRAM), which is a rapid wetland habitat condition assessment tool and is the most completely developed and tested rapid method for California at this time. 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.

CRAM 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 in approximately three hours to assess a representative wetland Assessment Area. Monitoring practitioners should refer to the CRAM Technical Bulletin for guidance on the placement of assessment areas. In general, CRAM assessment areas should be co-located with the sampling stations that are designated as part of the regional monitoring effort.

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 an average of four Attribute scores. The Attribute scores are the result of a combination of metrics scores based upon visual and easily measured indicators of ecological and physical conditions in the field. 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.

SOP

- CRAM

Critical Metrics

Critical qualitative assessments could include:

- CRAM Index score
- CRAM Attribute scores

Outputs

The appropriate output for this indicator is completed and uploaded CRAM survey to the EcoAtlas databases.

Fish: Minimum Sampling

Description

The composition of native fish communities are critical indicators to an estuary supporting nekton habitat, serving as nursery for commercially valuable seafood, and providing food chain and trophic support. Understanding estuarine fish communities requires measures of fish density and species richness. Due to the highly mobile nature and varying sizes of fish, defining the complete fish assemblage in a wetland can be challenging.

Methods

Understanding estuarine fish communities relies on quantification of density and/or species richness of fish. Seines are one of the most widely used gear types for sampling estuarine fishes (e.g., Allen 1982; Allen et al. 1992) because they capture a wide variety of species and are relatively easy to use. However, seines themselves are biased towards smaller, mid-water and sometimes slower fish than other methods such as beam trawls or hook and line fishing. As explored thoroughly in Steele et al. 2006a and 2006b, various factors about seines including mesh size, length, skill of fishers, and block netting can influence the density and species richness estimates. The choice of seine may vary with the project goals and should be carefully considered by the practitioner.

Due to the diversity of fishing methods commonly used across southern California, the main parameter of focus and goal of the WRP RMP is to generate a species list. Due to different seine types, methods, and replication, data **cannot** be used to compare species abundance or diversity of fish at this time, and species richness data should be interpreted with caution. Over time, as more sites are added with similar methods and replication, species abundance can be compared.

If users are interested in specific fish species (species of protection or priority, e.g., tidewater goby, California halibut, etc.), we recommend targeted surveys (Appendix F: Supplemental Indicators).

The WRP RMP recommends using the EMPA SOP, which provides a standard approach using beach seines to quantitatively assess the distribution, relative abundances, species richness, and diversity of fish. If estuarine sites do not have a methodology in place for consistent sampling, we recommend beach seining. This provides a fast and efficient way to assess the relative abundance of fish throughout an estuary.

Within a single monitoring year, the WRP RMP recommends sampling in the spring and fall. However, an ideal monitoring would occur across all seasons to capture seasonal and event-based changes in species composition. Permission and accessibility may limit the ability to fish seasonally. For example, many reserve managers do not allow access onto reserves during the bird breeding season (April-August).

If practitioners are interested in crustacean communities, the EMPA Monitoring Framework includes an SOP utilizing minnow traps and shrimp pots which can be incorporated into a monitoring program.

SOP

- EMPA Fish

Critical Metrics

Critical qualitative assessments could include:

- Species list to track composition through time
- Comparisons of species composition to expected populations
- Presence of obligate species
- Percent of native to non-native species

Outputs

The appropriate output for this indicator is a database with fish species abundance and sizes. Clearly defined metadata should accompany fish data to ensure regional assessments use comparable data.

Invertebrates: Macrofauna (>3 mm)

Description

Monitoring macrofauna (> 3 mm) in estuaries is crucial for understanding and maintaining the health of these dynamic ecosystems. Benthic invertebrate taxa, which include both infauna (organisms that burrow into and live in bottom sediments) and epifauna (organisms that live on the surface of bottom sediments), are valuable ecological indicators. They reflect the state of the environment, especially at the critical transition zones between water and land. The presence or absence of specific infauna species within tidal channels can indicate water quality, levels of anthropogenic stress, and the estuary's capacity to support other trophic levels. These benthic communities provide essential ecosystem services, such as nutrient cycling, sediment stabilization, and food for higher trophic levels, thereby supporting overall biodiversity.

Long-term monitoring of benthic infauna involves assessing the invertebrate community at higher taxonomic levels or evaluating the community as a whole. By examining changes in these communities over time, researchers can detect shifts in environmental quality and biodiversity. Regular sampling and analysis of benthic infauna helps identify trends in pollution, habitat degradation, and the effects of restoration efforts, providing critical data to inform conservation and management strategies.

Methods

The WRP RMP recommends using the EMPA SOP, which assesses large benthic infauna using deeper (~30 cm) sediment cores and sieved on a 3mm mesh screen. In addition to assessing large benthic infauna, the WRP RMP recommends keeping a species list of targeted species, such as oysters (e.g., *Ostrea lurida*), crabs (e.g., *Pachygrapsus crassipes*), and snails (*Cerithidea californica*).

If projects are specifically interested in oysters, then alternative methods should be followed, as outlined by the Native Olympia Oyster Collaborative.

SOP

- EMPA Invertebrates

Critical Metrics

Critical qualitative assessments could include:

- Species list to track composition through time
- Comparisons of species composition to expected populations
- Presence of obligate species
- Presence of native/invasive oysters
- Presence of targeted species

Outputs

The appropriate output for this indicator is a database with macrofauna species abundance and sizes, as well as the presence of targeted species.

Eutrophication: Sediment Nutrients

Description

Eutrophication of estuaries and coastal waters is a global environmental issue, with demonstrated links between anthropogenic changes in watersheds, increased nutrient loading to coastal waters, harmful algal blooms, hypoxia, and impacts on aquatic food webs (Valiela et al. 1992, Kamer and Stein 2003). These ecological impacts of eutrophication of coastal areas can have far-reaching consequences, including fish-kills and lowered fishery production (Glasgow and Burkholder, 2000), loss or degradation of seagrass and kelp beds (Twilley 1985, Burkholder et al. 1992, McGlathery 2001), smothering of bivalves and other benthic organisms (Rabalais and Harper 1992), nuisance odors, and impacts on human and marine mammal health from increased frequency and extent of harmful algal blooms and poor water quality (Bates et al. 1989, Bates et al. 1991, Trainer et al. 2002). These modifications have significant economic and social costs, some of which can be readily identified and valued, while others are more difficult to assess (Turner et al. 1998). According to EPA, eutrophication is one of the top three leading causes of impairments of the nation's waters (US EPA 2001).

Total organic carbon (TOC) and total nitrogen (TN) are crucial components of sediments and soils in estuarine environments, serving as key indicators for assessing eutrophication. These metrics can distinguish between marine and terrestrial sources of organic matter, offering insights into environmental depositional conditions and pollution levels. By measuring TOC and TN, researchers can evaluate the overall health and productivity of estuarine ecosystems.

TOC represents the amount of carbon found in organic compounds within sediments. High TOC levels typically indicate an abundance of organic matter, which can originate from various sources such as decaying plant material, phytoplankton, and anthropogenic inputs. In estuaries, elevated TOC levels may signal increased nutrient input, often a result of agricultural runoff, sewage discharge, or other human activities contributing to eutrophication. This process leads to excessive plant and algal growth, depleting oxygen levels and harming aquatic life.

Similarly, TN measures the total concentration of nitrogen within sediments. Nitrogen is a vital nutrient for plant growth, but excessive amounts can lead to detrimental effects in aquatic systems. Elevated TN levels often point to nutrient pollution, which, like high TOC, can result from agricultural practices, urban runoff, and wastewater discharge. The balance between carbon and nitrogen in sediments is essential for understanding the nutrient dynamics and potential for eutrophication in estuarine environments.

By regularly monitoring TOC and TN in estuarine sediments, researchers can track changes in organic matter sources, identify areas affected by pollution, and assess the effectiveness of management practices aimed at reducing nutrient inputs. This information is critical for developing strategies to mitigate eutrophication, enhance water quality, and preserve the ecological integrity of estuarine ecosystems.

Additional soil indicators can be added which meet the monitoring needs of a particular project. These may include soil organic matter, carbon: nitrogen ratio, porosity/compaction, and salinity.

Methods

The WRP RMP recommends using the EMPA SOP, which assesses TOC and TN concentrations with sediment grab samples. Grab samples should also be analyzed for grain size, which can help interpret nutrient concentrations.

SOP

- EMPA Sediment

Critical Metrics

Critical qualitative assessments could include:

- TOC concentration
- TN concertation
- Grain size

Outputs

The appropriate output for this indicator is a database with TOC, TN, and grainsize concentrations.

Table E-2. The core indicators for the WRP RMP monitoring year to be repeated on a five-year cycle. For each indicator, the recommended method is listed with the associated SOP, as well as the expected critical metrics and outputs. Within the sampled year, the minimum and ideal temporal frequency or season is listed. This is the frequency within one year of sampling. The minimum frequency is the time of year and sampling period at which the indicator should be monitored, while the ideal frequency lists the complete time of year and sampling period that could be monitored if resources allow. The table also provides the recommended spatial scale and replication, temporal monitoring questions one could answer, and which monitoring question categories the indicator could help answer.

Indicator	Method	Selected Critical Metrics	Product / output	Within the sampled year		Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
				Min. Temporal Freq. or season	Ideal Temporal Freq. or season			Extent	Condition	Resilience	
The core monitoring indicator	*The recommended method with suggested SOP in column L*	*A suggested list of numerical or qualitative summaries of the assessment data*	*The intended output from the indicator*	*The minimum sampling frequency within a given monitoring year*	*The ideal sampling frequency within a given monitoring year*	*The recommended spatial scale for monitoring a given indicator*	*Example temporal monitoring questions one could answer through time when monitoring a given indicator*	*The indicators that could help answer the monitoring questions within each category*			*The recommended SOP for each monitoring method*
Habitat & Elevation	Menu of options: High resolution aerial imagery of habitat types	Extent (ha) of different wetland habitat types and elevations; what percent of marsh is in bottom 1/3 of inundation tolerance; how large is migration space relative to existing marsh?	Classified habitat map for entire wetland and upland buffer area; DEM	Once any time of year	Once in Fall at same time as vegetation sampling	Coastal wetland map of all tidally influenced wetlands as well as cover areas where tidally influenced wetland could occur	Is there loss or gain of wetland habitat extent? Is the proportion of marsh in bottom 1/3 of inundation tolerance increasing or decreasing?	x	x	x	OPC Mapping EMPA Topography

Indicator	Method	Selected Critical Metrics	Product / output	Within the sampled year		Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
				Min. Temporal Freq. or season	Ideal Temporal Freq. or season			Extent	Condition	Resilience	
Marsh Vegetation	Transect surveys to complement aerial imagery, vegetation composition, invasive species tracking	% cover of target species or problematic invasive species; percent native to invasive total cover; species richness	Database with cover and max height of plant species	Fall	Spring and Fall	3-15 transects per wetland (depending on size) extending from foreshore to backshore	Is percent cover of particular desired or undesired plant species changing over time?	x	x	x	EMPA Vegetation
WQ	WQ measurements (data sondes or loggers)	% of summer deployment that is hypoxic; temperature and salinity over time; % over physiological limits	Database with temp, salinity, DO	Continuous over 1 month during the summer or fall, every 15-30 min	Continuous over the year; every 15-30 min	1-3 sondes per wetland depending on size and variability	Is hypoxia increasing or decreasing over time?		x		EMPA WQ NERR
Hydrology	Water level measurements (data sonde or logger)	Depth and inundation frequency; inlet status	Database of water level readings	Continuous over the year; every 15-30 min		1 sensor per wetland (unless hydrology is very different among regions)	How does the change in water level within the wetland compare to offshore SLR?		x	x	EMPA WQ
Rapid Assessment	CRAM	CRAM index and attribute scores	Completed and uploaded CRAM survey to EcoAtlas	Once		# of Assessment Areas (AAs) dependent on size of estuary	Is CRAM score increasing or decreasing?		x	x	CRAM Manual

Indicator	Method	Selected Critical Metrics	Product / output	Within the sampled year		Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
				Min. Temporal Freq. or season	Ideal Temporal Freq. or season			Extent	Condition	Resilience	
Fish	Beach seines	Species list; species composition similar to the expected; presence of obligate species; percent of native to invasive species	Database with fish species abundance and sizes	Fall	Seasonally	3-5 stations depending on size and variability	Are communities changing through time? Are species of concern decreasing over time?		x		EMPA Fish
Invertebrates - macrofauna	Sediment cores (large macrofauna)	Species list; species composition similar to the expected; presence of obligate species	Database with invert species abundance and sizes	Fall	Seasonally	3-5 stations depending on size and variability	Are communities changing through time? Are species of concern decreasing over time?		x		EMPA Invertebrates
	Targeted checklist of key species	Presence of native/invasive oysters; presence of targeted species	Database with presence/absence of target species at stations	Fall	Seasonally	3-5 stations depending on size and variability	Is number of sites with native/non-native targeted species (e.g., oysters) increasing or decreasing?		x		EMPA Invertebrates
Eutrophication	Sediment grab	TOC/TN concentration	Database with TOC and TN at stations	Fall	Spring and Fall	3-5 stations depending on size and variability	Is TOC/TN increasing or decreasing?		x		EMPA Sediment

Appendix F: Supplemental Indicators

An additional eight supplemental indicators were selected for monitoring of the WRP RMP (Table F-4). A summary of each indicator can be found in Table F-1. For each indicator we provide the following information:

1. *Definition and description* – a description and justification of the indicator
2. *Method* - the recommended method with associated SOP
3. *Critical metrics* - a suggested list of numerical or qualitative summaries of the assessment data
4. *Product or output* - the intended output from the indicator

Table F-4. Final list of core and supplemental indicators for inclusion in the WRP RMP.

Core Indicators	Supplemental Indicators
Habitat and Elevation	Sediment dynamics
Marsh Vegetation	Mouth dynamics
Water Quality: Temp., DO, Salinity	Water Quality: Parameters of Concern
Hydrology	Submerged Aquatic Vegetation
Rapid Assessment	Birds
Fish: Minimum sampling	Fish: Extensive sampling
Invertebrates: Macrofauna (> 3 mm)	Invertebrates: Infauna (< 500 um)
Eutrophication: sediment nutrients	Eutrophication: algae

Sediment Dynamics

Description

A resilient estuary has the capacity to absorb and protect adjacent uplands from rising sea levels based on the geomorphology and habitat associated with the marine-freshwater-terrestrial interfaces. Intact estuaries provide resiliency to sea-level rise by dissipating energy, accreting sediment, and providing space for landward migration.

Methods

There are many techniques for measuring sediment accretion. At a minimum, feldspar plots can be installed to establish an effort to quantify sediment accretion through time. Surface elevation tables (SET) can be used to acquire more in-depth measurements of sediment accretion.

The Surface Elevation Table (SET) consists of a portable mechanical leveling device in conjunction with a permanent base pounded to refusal used for measuring the relative elevation change of wetland sediments. We recommend following the USGS standard operating procedure (SOP), which presents information on the purpose, design, and use of the SET. Precise measures of sediment elevation in wetlands are necessary to determine rates of elevation change, particularly relative to sea level rise, and to gain an understanding of the processes responsible for elevation change. The SET provides a nondestructive method for making highly accurate and precise measurements of sediment elevation of intertidal and subtidal wetlands over long periods of time relative to a fixed subsurface datum. This technique overcomes many of the limitations of methods currently used to estimate elevation such as sedimentation pins, and precision surveying (Lynch et al. 2015).

Marker or feldspar horizons are commonly used in conjunction with the SET. This is critical because installing feldspar horizons next to the SET stations is the only way to understand the mechanisms behind patterns observed in the SET data. For example, if your SET shows marsh elevation is not tracking with sea level rise, then the feldspar plots can help you understand why (e.g., accretion vs. subsidence). Marker horizons measure vertical accretion which predominantly incorporates surface processes. Numerous materials such as sand, feldspar, brick dust and glitter, can be used as marker horizons.

SOP

- USGS
- EMPA Feldspar

Critical Metrics

Critical qualitative assessments could include:

- Marsh accretion rates
- Sediment supply

Outputs

The appropriate output for this indicator is a database with SET or feldspar measurements. Clearly defined metadata should accompany accretion data to ensure regional assessments use comparable data.

Mouth Dynamics

Description

Estuaries are inherently dynamic systems. Conditions vary due to tidal, day-night, weather-related (including waves and river flow), seasonal, interannual, and decadal cycles. This high degree of variability among estuaries makes it difficult to discern patterns driven by anthropogenic disturbance from patterns driven by natural system variability. Specifically in intermittently closed estuaries, conditions can be dramatically different between wet and dry years - exceeding and obfuscating human impacts. Because estuaries integrate environmental stress from watersheds and the ocean, it can be difficult to identify primary stressors and document clear stress response relationships. Given this variability, monitoring over many years is essential to identify and assess human-induced trends. A key factor in understanding underlying patterns and stressors is the monitoring and tracking of the mouth dynamics.

Methods

There are a variety of methods that could be used to help track mouth dynamics. 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 sites should be a standard practice in all managed systems. In addition, automated cameras can be placed at the mouth of key sites to track mouth migration, mouth state, wave overtopping and breach events. In systems with additional monitoring capacity, regular tidal prism surveys are encouraged.

Imagery Options

Cameras: One or more fixed photo-station(s) can be established at each estuary. At these camera locations, GPS coordinates, including height, and the direction(s) of the photo station should be documented. These stations can be used to document temporal changes in berm/mouth condition, inundation, and berm topography. If possible, semi-automated camera stations (e.g., GoPro or Reconyx cameras) can also be deployed in order to capture morphological changes to the lagoon over the course of a few months. If a fixed photo station cannot be installed, digital photos should be taken at several locations around the beach berm and surrounding nearshore area to capture any migration to the entrance channel as soon as possible and safe following storm events.

Remote Sensing: Remote sensing approaches that utilize satellite data may be especially helpful in monitoring the enormous geography of the California coast. In 2021, the EMPA team collaborated with NASA-JPL to build a Google Earth Engine-based tool which can be used to assess and classify estuaries along the California coast (Payne et al. 2025). This interactive, cost effective, user-friendly tool uses maps and time series satellite data to quantify various water quality metrics including temperature, chlorophyll concentrations, and mouth condition (degree of opening/closure) over time. Unfortunately, this tool is still not available to the public due to prolonged NASA review, but alternative satellite-based approach (Inlet Tracker, Heimhumber et al. 2021) may be equally suitable for tracking mouth dynamics.

Drones: Drone-based assessment techniques can allow for temporal flexibility and cost-effective repeat photogrammetry, affording a significant advancement in other remote sensing approaches for coastal mapping, habitat monitoring, and environmental management. Drone surveys provide on-demand remote sensing at low cost and with reduced human risk.

Instrument Options

Tidal prism surveys: Inlet status affects tidal prism which is the amount of water that flows into and out of a wetland with the tide. A reduction in tidal prism can lead to tidal muting where inundation regimes are altered and habitats convert (e.g., high marsh to upland transition or mudflat to low marsh) and is often used as a management trigger for inlet maintenance or dredging. Whereas, an increase in tidal prism can lead to localized scour, erosion, and sediment redistribution or export. Maintaining the desired or expected tidal prism of a wetland can prevent the degradation of water quality and biological communities that may be especially sensitive to a reduction in tidal flushing or prism (e.g., fish). Tidal prism is calculated using instrumentation (e.g., SonTek River Surveyor) that integrates measures of tidal flow and the cross-sectional area of a channel to compute discharge in acre-feet (Page et al. 2022). Surveys should be conducted on numerous incoming tides throughout the year that capture the range of neap and spring high tides. Data can be analyzed multiple ways, including calculating the cumulative discharge (acre-feet) and plotting the data against the high tide (maximum water surface elevation, ft) for each survey. There are other more sophisticated and sensitive analyses that can be pursued to produce a time series of the mean wetland acres filled or the wetland acres filled for a given water surface elevation—such approaches as these should be pursued if detecting subtle changes in prism or identifying where in the tidal frame inundation frequency is changing are of management interest (SONGS Wetland Monitoring Plan, *in prep;* Kathryn Beheshti, *pers. comm.*). Typically, tidal prism surveys are labor and cost-intensive and require specialized skills to both operate the instrument and analyze its data.

Water depth monitoring: Water level loggers offer a more affordable alternative to tidal prism surveys but require more routine instrument maintenance and are less powerful of a measure to identify changes in tidal flushing. Yet, water level loggers (e.g., HOBOs) can provide some insight on inlet status by producing a time series of water depth that tracks tidal cycles. In the event of an inlet closure or sill formation, the water level data would show either little to no tidal signature or a substantial lag in the filling of the wetland or evidence of poor drainage. All water level loggers should be installed using RTK GPS to ensure the elevation of the sensor is known. Most water level loggers measure water pressure, meaning a companion pressure sensor on land that is never immersed is needed to correct the water pressure measures with ambient pressure measures at the site. Sensors should be maintained and data offloaded every 2-4 weeks to ensure limited biofouling data drift. Prior to each deployment, instrument position should be measured using an RTK GPS. Water level loggers are required in the core monitoring (see more details above in Appendix E).

SOP

- SONGS

Critical Metrics

Critical qualitative assessments could include:

- Percent of time mouth is open
- Tidal prism (acre-feet)
- Number of wetland acres filled for a given water surface elevation
- Water surface elevation time series

Outputs

The appropriate output for this indicator is a database with opening and closing mouth events.

Water Quality: Parameters of Concern

Description

Estuarine wetlands are dynamic habitats with constantly changing abiotic conditions due to interactions between freshwater inflows, tidal cycles, and meteorological events. Hydrology and water quality are fundamental drivers of estuarine extent, condition, and functions, especially in California which experiences tremendous intra- and inter-annual variability in rainfall, runoff, and temperatures. This is among the many reasons why the WRP RMP monitoring framework emphasizes time series collection of water level and water quality data.

The WRP RMP recommends consistent collection of temperature, salinity, dissolved oxygen, and depth. However, to further understand the dynamics of these systems and better identify stressors, other water quality parameters could be added on either via additional water quality sensors or water column grabs. These parameters could include: chlorophyll a, turbidity, pH, phosphate, or nitrate.

Methods

To fully capture the status, trends, and inherent dynamism of these systems, and identify management interventions that can support long-term estuarine health and resilience, significant investment is needed to deploy water quality loggers. Effective and high-quality data collection requires, at a minimum, monthly download, intercalibration, and maintenance of data loggers. If additional parameters are added, such as chlorophyll, turbidity, or pH, then more frequent maintenance is necessary.

Additional water quality parameters could also be collected via water column grab samples. Depending on the parameter, additional preservation techniques may need to be implemented to effectively sample such parameters.

SOP

- EMPA Water Quality Samples
- EMPA Water Quality
- NERR

Critical Metrics

Critical qualitative assessments could include:

- Percent of summer deployment that is acidic
- Percent of time parameters are over species physiological limits

Outputs

The appropriate output for this indicator is a database with water quality measurements

Submerged Aquatic Vegetation (SAV)

Description

Submerged Aquatic Vegetation (SAV) provides an important role in the ecology of coastal systems, as it provides unique structure and enhancement of biogeochemical processes. SAV, such as eelgrass (Zostera sp.), can form expansive beds or meadows in the shallow, soft sediments that serve as temporary refuge from predators, enhance carbon and nitrogen cycling, and serve as a productivity hot spot for commercially and societally important fauna, as well as protected species like sea turtles. Due to the diversity of estuaries along the coast of California, some systems are expected to consist of expansive eelgrass beds, while other systems may have more ephemeral eelgrass or widgeon grass (*Ruppia sp.*) beds. However, the extent and distribution of these SAV beds is not well known or mapped across the coast.

Extensive resources are needed to implement complete monitoring of SAV within a site. There are regional efforts that could be leveraged to connect site data with SAV monitoring data, such as the Southern California Bight Regional Monitoring Program. The Bight program monitors on a five-year cycle, where eelgrass monitoring began in 2023. Additionally, mapping efforts by the OPC could help fill in gaps on extent (SFEI & SCCWRP 2025).

Methods

To fully capture the extent and condition of SAV beds, both mapping efforts and field-based monitoring efforts are needed.

Mapping: There are a variety of methods that could be used to produce the desired outputs. The RMP recommends following guidance outlined in the OPC Report: Tracking Habitat Change Over Time (SFEI & SCCWRP 2025). Changes in habitat extent is the complex product of a variety of natural and anthropogenic processes. Fluctuations in extent will vary in magnitude and will likely differ (i.e., gains and losses) in different parts across the length of the coastline. Some types of change may be detected from more coarse mapping of habitat where others may only be detected through more detailed and higher resolution data/mapping. Each mapping approach provided in the OPC summary provides a different level of accuracy and detail.

Structure Metrics: The WRP RMP recommends following the Bight Regional Monitoring Program SOP for collecting eelgrass measurements and samples from the field and processing samples to produce data that can be used in assessing the overall condition of a given bed. The general assessment framework was designed to be applicable to all species of SAV, with a common approach (i.e., transect surveys to collect combinations of structural metrics that can be used to infer functional capacity) applied across species and habitats to maximize comparability of results. However, given the morphological differences in individual plants and beds/meadows due to the species-to-species differences in autecology (e.g., *Zostera marina* vs. *Zostera pacifica*), as well as the influence of the habitat where the SAV is growing (e.g., embayments vs. open coastline), the Bight program goal is to produce a suite of field and laboratory methods for distinct species-habitat combinations.

SOP

- Bight Program SAV: Gillet et al. XX. Field and Lab Methods for Assessing the Function-Based Condition (Tier III) of Eelgrass (*Zostera marina*) Beds and Meadows in Southern California Estuaries and Embayments
- San Francisco Estuary Institute (SFEI) and Southern California Coastal Water Research Project (SCCWRP). 2025. Tracking Coastal Habitat Change Over Time: Combined Habitats Whitepaper. SFEI Publication No. 1246. SCCWRP Publication No. 1438. Richmond, CA. April 2025, pp. 69.

Critical Metrics

Critical qualitative assessments could include:

- SAV structure metrics (canopy height, shoot density, presence of wasting disease)
- Extent (ha) of eelgrass beds

Outputs

The appropriate output for this indicator is both a map of eelgrass beds (and other SAV if possible) and a database with SAV measurements.

Birds

Description

Birds (resident and migratory) are indicators of habitat quality in estuaries because they depend on these habitats for reproductive success, sufficient foraging opportunities, and protection from predators. Proper management of estuarine habitat is especially important for special-status species, whose low numbers may be most impacted by poor foraging and reproductive opportunities. Program partners such as CDFW, USFWS, Joint Ventures, and NGOs often have specific targets for the recovery of these species, and dedicate considerable resources to recovery efforts. The general public also broadly perceives the presence or absence of these species to reflect the overall health of an estuary; opportunities to view these species frequently drive public interest in estuarine conservation and stewardship. Numerous estuaries within the RMP monitoring network are known for their bird and wildlife populations.

Despite the importance of birds as indicators of estuarine health, there are several challenges to integrating monitoring of these species into the WRP RMP framework. Different bird species and guilds often require different monitoring SOPs (e.g. point counts, transects, playback, etc.) during different seasons (breeding, nonbreeding) to accurately capture status and trends of bird abundance and community composition over time. Estuaries that are frequented by humans (boaters, hunters, recreators, etc.) may alter how and when birds and other wildlife use estuarine habitats, which can complicate detections. It can be challenging to draw conclusions from site-specific data about the status and trends of species that utilize a broad spectrum of habitats throughout their life cycle, such as migratory shorebirds/waterfowl.

Method

Counts of birds seen, heard, or captured are commonly used to answer many research questions including describing avian-habitat relationships, investigating responses of avian populations to management or to environmental stressors, estimating spatial distribution of species, and monitoring population trends. The point-count method, in which an observer records all birds detected within either a fixed or an unlimited distance from a point during a specified time period (e.g., Ferry and Frochot 1970, Hutto et al. 1986), is the most widely used counting method in bird population studies (Ralph et al. 1995, Rosenstock et al. 2002). Point counts rely on the assumption that numbers of individuals detected (e.g., seen, heard, or captured) represent a constant proportion of actual numbers present across space and time. Point-count surveys should be used to estimate population numbers as well as to generate a species list of birds present at time of sampling.

Concurrently or in addition to point counts, bird assemblage can also be assessed auditorily with wildlife recording equipment (Wildlife Acoustics Song Meter Micro bird and wildlife audio recorder). The recording device should be mounted on to an upright object (e.g., fence post or sign) out of the direct path of the wind to avoid background noise and away from the observers at each sampling zone.

Besides following the outlined method, we also recommend that sites could consider leveraging partnerships with local groups to incorporate ongoing surveys and databases like eBird. In many cases, local observers have detailed knowledge of their environment and bird populations and are at sites more frequently than the monitoring teams, which can enhance the quality and accuracy of the data collected. Additionally, by involving a wide variety of participants, data can be cross-checked and verified, increasing its reliability. One of the most well-known examples of participatory science in bird monitoring is the Christmas Bird Count by the National Audubon Society. Every year, thousands of volunteers participate in this event, contributing valuable data on bird populations, which helps track the health of bird species over time. These participatory science surveys can play key roles in monitoring birds, especially in large-scale and long-term studies that would otherwise be difficult to achieve with limited professional resources. Overall, monitoring bird populations in estuaries allows us to better understand environmental health and to implement effective conservation and management strategies.

SOP

- SONGS

Critical Metrics

Critical qualitative assessments could include:

- Species list
- Presence of targeted species

Outputs

The appropriate output for this indicator is a database with the presence of targeted bird species across the estuary.

Fish: Extensive Sampling

Description

As a supplementary indicator, if users are interested in specific fish species (species of protection or priority, e.g., tidewater goby, California halibut, etc.), we recommend targeted surveys.

Method

Targeted surveys should consist of more intensive seining, using block nets and enclosure traps to seine until completion. Ongoing efforts can be leveraged to complete targeted surveys, such as efforts conducted by agencies, such as the California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA), and Resource Conservation District of the Santa Monica Mountains (RCDSMM) as well as ongoing long-term monitoring programs including the San Onofre Nuclear Generating Station (SONGS) Mitigation Monitoring Program, the Tijuana River Estuary National Estuarine Research Reserve and The Nature Collective’s San Elijo Restoration Project.

To conduct more extensive sampling, we recommend a mix of targeted surveys (e.g., increased sampling, including replication and frequency), as well as the use of eDNA (e.g., metabarcoding and targeted probes).

Although beach seines provide a good general indicator of a wetland's fish assemblage, studies done by the SONGS Mitigation Monitoring Program have demonstrated that beach seines greatly undersample gobies, which are typically the most abundant fish in southern California tidal wetlands. In addition to seines, the SONGS monitoring program uses enclosure traps, which is an effective method to capturing gobies and other small benthic fish.

Additionally, the use of molecular methods (e.g., eDNA based assessments) can be used in addition to traditional measures. Environmental DNA (eDNA) methods provide an opportunity to survey multiple taxa at one time from an environmental sample, including microbes, fish, and mammals. eDNA assessments can also be used to target specific species of interest.

SOP

- EMPA eDNA
- SONGS

Critical Metrics

Critical qualitative assessments could include:

- Presence of targeted species
- Abundance of gobies and other small benthic fish

Outputs

The appropriate output for this indicator is a database with the presence of targeted fish species or abundance of gobies and other small benthic fish across the estuary.

Invertebrates: Benthic Infauna (< 500 um)

Description

Long-term monitoring of benthic infauna involves assessing the invertebrate community at higher taxonomic levels or evaluating the community as a whole. By examining changes in these communities over time, researchers can detect shifts in environmental quality and biodiversity. Regular sampling and analysis of benthic infauna help identify trends in pollution, habitat degradation, and the effects of restoration efforts, providing critical data to inform conservation and management strategies.

Methods

For the supplemental indicator, we recommend monitoring benthic infauna smaller than 500 um. The WRP RMP recommends using the EMPA SOP, which assesses benthic infauna (< 500um) using sediment cores.

The EMPA protocol provides a sampling method for collecting and assessing the density and composition of benthic infauna. However, the method provides the minimum sampling when assessing the benthic community. Because the minimum sampling method only extracts two cores per sampling zone (six cores per estuary), the data won't allow surveyors to characterize individual estuaries, rather they will only be able to make gross comparisons among estuaries.

If users want to assess estuarine condition within an estuary, we recommend adjusting the following parameters to meet your needs:

1. Sample replication – Users should increase replication (greater than 3 replicates per estuary) to include samples along the channel from the mouth to the head of the estuary. Additionally, users should sample a diversity of habitats: SAV beds, the marsh plain, the subtidal channel, and the intertidal channel. Within a channel, users could increase replication along an elevation gradient from the channel edge to the bottom of the channel (i.e., thalweg).
2. Depth – Core depth can influence invertebrate richness and biomass and can have less of an impact on abundance (Valenca and Lo Santos 2013). Therefore, the top layer of sediment to 2 cm must be included to capture a majority of infaunal invertebrates (0-2 cm – Levin et al. 1998). Without at least 2 cm of sediment, the core would not be representative of any sediment invertebrate community, and it would be recommended to ignore those cores for data comparison.
3. Area of core – The core diameter or grab size (and thus area) should be chosen carefully as gear size targets particular size classes of organisms. For example, smaller core sizes will target smaller macrofauna (e.g., 1- 2 mm) and are likely to exclude megafauna, such as large clams or crabs (e.g., 20 mm). Core size chosen should be consistent with existing studies or published literature on macrobenthos from the site and/or nearby marshes (common core sizes: 3.5 cm diameter x 6 cm depth; 4 cm x 10 cm; 10 cm x 10 cm).
4. Sampling frequency - The reproductive biology, abundances, and feeding habits for many estuarine species vary seasonally and are associated with environmental factors such as temperature and salinity. In some cases, a species may be classified as carnivorous during the winter, herbivorous during the spring, and omnivorous during the summer and fall (Light's manual 4th edition). Therefore, users should consider sampling in all seasons. At a minimum, all users should sample in the Fall to remove any confounding effects of seasonality on invertebrate metrics and allow for comparison across lagoons.

SOP

- EMPA Invertebrates

Critical Metrics

Critical qualitative assessments could include:

- Species list to track composition through time
- Comparisons of species composition to expected populations
- Presence of obligate species

Outputs

The appropriate output for this indicator is a database with infauna species abundance and biomass.

Eutrophication: Algae

Description

In addition to measuring total organic carbon (TOC) and total nitrogen (TN) as indicators of eutrophication, the assessment of macroalgae is another important indicator of eutrophication.

Macroalgae are an important component of estuarine habitats. In intertidal and shallow subtidal estuaries macroalgae provide food and refuge for invertebrates, juvenile fish, crabs and other species. However, when the estuary is subject to nutrient pollution or other stresses, such as hydromodification, some species of macroalgae can outcompete other primary producers (e.g., benthic microalgae, seagrass) and may create extensive blooms that can cover large expanses of intertidal and shallow subtidal habitat.

Methods

To further assess eutrophication, we recommend a mix of macroalgae surveys and seasonal measurements of chlorophyll-a concentrations. Other optional monitoring could occur, such as Harmful Algae Bloom (HAB) monitoring.

At the minimum, macroalgae surveys can help identify areas that might be indicative of impairment to aquatic life. We recommend conducting transect surveys in the intertidal to estimate the percent cover of macroalgae. Alternatively, aerial imagery could also be used to assess the cover of algae. Although this will estimate the overall cover of the site better than transect surveys, macroalgae is extremely seasonal. Therefore, drone flights would need to be conducted more frequently.

SOP

- EMPA Macroalgae

Critical Metrics

Critical qualitative assessments could include:

- Percent cover of intertidal macroalgae above critical thresholds
- Concentration of water column chlorophyll-a

Outputs

The appropriate output for this indicator is a database with macroalgae percent cover estimates, as well as other parameters of concern for eutrophication (e.g., chlorophyll-a)

Table F-1. The supplemental indicators for the WRP RMP monitoring year to be repeated on a five-year cycle. For each indicator, the recommended method is listed with the associated SOP, as well as the expected critical metrics and outputs. Within the sampled year, the ideal temporal frequency or season is listed. This is the frequency within one year of sampling. The ideal frequency lists the complete time of year and sampling period that should be monitored if resources allow. The table also provides the recommended spatial scale and replication, temporal monitoring questions one could answer, and which monitoring question categories the indicator could help answer.

Indicator	Method	Critical metrics	Product / output	Within the sampled year, ideal temp. freq. or season	Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
							Extent	*Condition*	*Resilience*	
The core monitoring indicator	*The recommended method with suggested SOP in column K*	*A suggested list of numerical or qualitative summaries of the assessment data*	*The intended output from the indicator*	*The ideal sampling frequency within a given monitoring year*	*The recommended spatial scale for monitoring a given indicator*	*Example temporal monitoring questions one could answer through time when monitoring a given indicator*	*The indicators that could help answer the monitoring questions within each category*			*The recommended SOP for each monitoring method*
Sediment Dynamics	SETs, dated cores, feldspar horizon, bank erosion	marsh accretion rates	Database with SET measurements	Once	1-3 SETs per wetland depending on size and variability	Are marshes accreting sediment at rates sufficient for SLR?		x	x	USGS EMPA Feldspar
Eutrophication	Transect survey	% cover of intertidal macroalgae above critical threshold	Database with macroalgae	Seasonally	3-5 stations depending on size and variability	Is macroalgae cover increasing over time?		x		EMPA Macroalgae
	Water grab	Concentration of parameters of concern (chlorophyll)	Database with chlorophyll concentrations	Seasonally		Are POCs increasing or decreasing?		x		EMPA Water and Sediment

Indicator	Method	Critical metrics	Product / output	Within the sampled year, ideal temp. freq. or season	Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
							Extent	*Condition*	*Resilience*	
WQ	Sampling for parameters of interest or concern	% of 24 hour deployment in summer that is acidic	Database with POCs (Chlorophyll a, turbidity, pH, phosphate, nitrate)	Seasonally	1-3 sondes per wetland depending on size and variability	Are POCs increasing or decreasing?		x		EMPA WQ EMPA WQ Samples NERR
SAV	Transect survey	SAV structure metrics (Canopy height, shoot density, P/A wasting disease)	Database with SAV measurements	Fall	5-15 beds depending on size and variability	Is the condition of eelgrass beds changing over time?		x	x	Bight Eelgrass SOP
	Mapping	Extent (ha) of eelgrass beds	Habitat map of eelgrass beds	Fall	Estuary extent	Is there loss or gain of SAV extent?		x		OPC mapping
Birds	Surveys	Species list; Presence of targeted species	Database with presence/absence of target species at stations	Seasonally	3-5 stations depending on size and variability	Are communities changing through time? Are species of concern decreasing over time?		x		SONGS
	Targeted surveys			Seasonally				x		
Fish	Targeted surveys (e.g., additional seines, enclosure traps)	Presence of targeted species	Database with presence/absence of target species at stations	Seasonally	3-5 stations depending on size and variability	Are communities changing through time? Are species of concern decreasing over time?		x		EMPA Fish SONGS
	eDNA/metabarcoding			Seasonally				x		EMPA eDNA

Indicator	Method	Critical metrics	Product / output	Within the sampled year, ideal temp. freq. or season	Spatial scale/ Replication	Temporal trends in wetland health	Questions			SOP
							Extent	*Condition*	*Resilience*	
Invertebrates	Sediment cores (infauna)	Species list	Database with presence/absence of target species at stations	Seasonally	3-5 stations depending on size and variability	Are communities changing through time? Are species of concern decreasing over time?		x		EMPA Invertebrates
Mouth Dynamics	Imagery; sondes	% opening of mouth	Database with opening and closing events	Continuous throughout the year with sensors; Satellite imagery	1 estuary mouth	Are the dynamics of the mouth changing through time?		x	x	