Southern California Bight

2023 Regional Marine Monitoring Program

(Bight '23)

Estuary Wetland Assessment Workplan

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

EXECUTIVE SUMMARY

The condition of California's diverse coastal lagoons and estuaries can significantly influence water quality and ecosystem functioning in nearby coastal habitats. Estuarine condition is a focal point of multiple regulatory programs, and over the last decade, it has become clear that estuaries are one of the most degraded and contaminated systems in the Southern California Bight. However, there is a general lack of coordinated estuarine monitoring across the state of California making it difficult to understand the relative health of critical estuarine habitats. The overall goal of the Estuary Wetland component of Bight '23 is to conduct a comprehensive and holistic assessment of the extent and health of estuaries and lagoons in the Southern California Bight and to understand the relative condition and resilience. The proposed element will use a targeted study design and a function-based assessment framework to answer five primary questions focused on the relative condition of Southern California estuaries. A key aspect of the study is a focus on ecological functions versus a single species approach, with the underlying principle that all estuaries should provide a variety of ecological functions at some ideal rate in the absence of anthropogenic disturbance and alteration. To evaluate function, a set of priority indicators was chosen, where each function can be evaluated by one or more indicators. This approach provides flexibility to use indicators appropriate for the specific estuary, while still allowing the standard set of functions to be evaluated. Three types of indicators were selected: abiotic, biotic, and landscape. Collecting measures of physical and landscape conditions with measurements of biological response at common sites allows investigators to identify and model associations between altered ecological conditions and environmental stresses. 22 estuaries have committed effort to assess all indicators in fall 2023, and 2 additional estuaries are under consideration. This Workplan provides a summary of the Estuary Wetland project design.

Introduction

The Southern California Bight (SCB) is an important and unique ecological resource. This open embayment along the coast stretches from Point Conception to Punta Colonet (south of Ensenada), Baja California. The SCB is a transitional area that is influenced by currents from cold, temperate ocean waters from the north and warm, tropical waters from the south. In addition, the SCB has a complex topography, with offshore islands, submarine canyons, ridges and basins, bays and estuaries. The Southern California Bight Regional Marine Monitoring (Bight) Program was born from the frustration of environmental managers' inability to answer simple, holistic questions about the SCB coastal environment. Initiated in 1994, the Bight Program has grown both in size and scope with each successive survey, which have been conducted about every five years (1998, 2003, 2008, 2013 and 2018). An initial focus on sediment monitoring has now grown to include physical oceanography, eutrophication, seafood contamination, overfishing, beach water quality, and plastic pollution (Schiff et al. 2016). Although many of these elements have been sampled in estuaries, there has not been a consistent, comprehensive, and holistic assessment of the condition and health of the estuaries and lagoons in the SCB.

Coastal resource managers have long recognized that the health of coastal estuaries is integrally linked to the health of adjacent marine habitat, both in terms of physiochemical processes and biological communities. Estuaries play a key role in improving the quality of land-based runoff prior to its discharge to the coastal ocean. Estuaries modulate sediment and nutrient delivery to the coastal ocean and can provide important water quality improvement functions. In California estuaries, certain species of invertebrates and fish often spawn and rear in estuaries using them as critical nursery habitat or refugia before migrating to the ocean. However, there is a general lack of coordinated estuarine monitoring across the state of California, which makes it difficult to understand the relative health of critical estuarine habitats.

Incorporating estuarine condition assessment into Bight '23 is critical for four main reasons.

1. Estuaries are contamination hotspots. Based on previous Bight reports[1], estuaries and embayments are the most contaminated strata or habitat type. To begin to understand the impacts of this contamination, we need comprehensive assessments of all abiotic and biological indicators (water quality, fish assemblage, vegetation community, etc.).
2. Estuarine condition is a focal point of multiple regional and state-wide regulatory programs (MS4, NPDES, CA Wetlands Mitigation, Biostimulatory, etc.). Estuarine assessments are key in informing these programs.

[1] https://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1289_Bight18BenthicInfauna.pdf

3. Healthy and intact wetlands are important for coastal resiliency to sea-level rise. Estuaries and wetlands are key transition and buffer habitats between the land-sea interface. Over the next three years, the state is allocating over 500 million USD towards coastal resiliency. Estuaries are a key habitat for building this resiliency, and condition assessments can help inform those allocations.
4. Questions of overall ecosystem health, response to stress, and resiliency require an integrated assessment approach. Currently, there is no consistent, integrated, regional assessment of estuaries. The Bight ’23 Estuary element will be the first regional assessment of estuarine condition in the SCB.

Over the last five years, many groups have begun to build the tools to both monitor estuarine habitats and assess estuarine health and condition. The overarching goal of the Bight ’23 Estuary Wetland element is to build on these tools to conduct an integrated, regional assessment of estuaries using a function-based approach. 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 flexibility of application within a highly heterogeneous state, like California. The species of plants and animals that are the components of and used as indicators for ecological functions may change between regions and estuarine functional types, but the focal estuarine functions should remain relatively consistent. Flexibility of the function-based approach will ultimately allow comparative assessment across estuary type, regional differences, anthropogenic impacts - ultimately permitting assessment of management actions and protected area designations.

The Bight ‘23 Program is organized into 7 technical components: 1) Sediment Quality (formerly Contaminant Impact Assessment/ Coastal Ecology); 2) Microbiology; 3) Water Quality; 4) Shellfish; 5) Trash; 6) Estuary Wetland; and 7) Submerged Aquatic Vegetation (SAV). The Estuary Wetland component focuses on estuary condition, the relative risk of estuarine condition to major stressors, and sea-level rise resilience. 30 organizations, including international and volunteer organizations, have agreed to participate (

Table 1). The inclusion of multiple participants, many of them new to regional monitoring, provides several benefits. Cooperative interactions among many organizations with different perspectives and interests, including a combination of regulators and dischargers, ensure that an appropriate set of regional-scale questions will be addressed by the study.

This Workplan summarizes the Estuary Wetland project design. The Workplan is supported by three companion documents including the Field Methods and Logistics Manual, Information Management Plan, and Quality Assurance Plan (QAP). Separate Workplans are also available for the other elements of Bight ‘23.

Table 1. Participating organizations in the Bight '23 Estuary element.

Participating Organization
California Coastal Commission (CCC)
California Department of Fish and Wildlife Service (CDFW)
California State Coastal Conservancy (SCC)
California State University, Long Beach
City of Oceanside
City of San Diego
Environmental Protection Agency (EPA)
Laguna Ocean Foundation
Los Angeles Regional Water Quality Control Board (LARWQCB)
National Estuarine Research Reserve (NERR)
National Oceanic and Atmospheric Administration (NOAA)
Nature Collective
Naval Base Ventura County
Ocean Protection Council (OPC)
Orange Country Coastkeeper
Orange County Public Works
Physis Environmental Laboratories, Inc.
Point Blue Conservation Science (Point Blue)
Resource Conservation District of the Santa Monica Mountains (RCDSMM)
San Diego Regional Water Quality Control Board (SDRWQCB)
San Diego State University
San Onofre Nuclear Generating Station (SONGS) Mitigation Monitoring Program (SONGS)
Santa Ana Regional Water Quality Control Board
Southern California Coastal Water Research Project (SCCWRP)
Southern California Society of Environmental Toxicology & Chemistry (SoCAL-SETAC)
State Water Resources Control Board
The Bay Foundation
Tidal Influence
U.S. Fish and Wildlife Service (USFWS)
U.S. Geological Survey (USGS)
University of California Los Angeles
University of California Reserve System
University of California Riverside
University of California Santa Barbara
University of San Diego
USC Seagrant
Weston Solutions, Inc.
WSP USA

STUDY DESIGN

Study Objectives

The overall goal of the Estuary component of Bight ‘23 is to assess the condition and resiliency of the estuarine environment in the SCB. To accomplish this goal, Bight ‘23 will focus on five primary questions:

1. What is the relative condition of Southern California estuaries based on a function-based assessment?

The central question to Bight ’23 is understanding the relative condition of Southern California estuaries. This question directly assesses the status of estuaries in the SCB. Condition means the status of physical, chemical, biological, and ecological indicators of the levels of services and beneficial uses of wetland systems (SCWRP 2018). Specifically, this question will be assessed using a function-based approach, where an estuary in good condition will support more ecosystem functions than poor condition estuaries. Each estuary’s condition will be evaluated relative to other estuarine conditions in the SCB.

2. What sensitive fish and bird species are observed in the Southern California estuary surveys? How does that compare to historic observations?

A key concern for many federal, state, regional, and local managers is the status of specific fauna. A number of sensitive and/or protected species will be identified to compare to historical observations and trends. This question will require close collaboration with the California Department of Fish and Wildlife, State Parks, and local non-profits to access historical data.

3. What is the range of sea-level rise resiliency of estuaries in Southern California? What factors affect the relative resilience of estuaries in Southern California?

Robust assessments of ecosystem stability are critical to inform conservation and management decisions. Managers need to identify estuaries with the greatest chance of persistence under future sea-level rise conditions, so that they have high priority for conservation to protect and sustain their areal extent and the processes necessary for their persistence. A variety of monitoring and modeling approaches can determine which tidal marshes are likely to persist into the future (Raposa et al. 2016, Thorne et al. 2018, Wasson et al. 2019). Using a combination of remote-sensing information and field-based metrics, a resilience scoring criterion will be created to quantify the relative resilience of estuaries in the SCB. The factors that influence estuarine resilience to sea-level rise will be identified.

4. What is the relative risk of estuarine condition to major stressors?

The condition of estuaries may be impacted by a number of stressors, specifically climatic conditions, sediment contaminants, nutrients, mouth dynamics and freshwater inputs. This question helps to understand the response of estuaries to disturbances and stressors.

5. What is the relative condition of estuaries based on level of management? What management factors contribute to relative condition scores?

The final question examines how management actions or lack-there-of may impact condition. Specific comparisons will include – estuary class (embayment, riverine, lagoon), typology (perennially open, temporarily closed), restoration status, inlet status (maintained, natural), management entity, MPA status, type of protection (restricted, partially restricted, full), and sediment management.

Sampling Design

To assess the overall health and condition of estuaries in the Southern California Bight (SCB), we will adapt and refine the assessment framework for the California Estuary Marine Protected Area (EMPA) Monitoring Program (https://empa.sccwrp.org/). The program's 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 to assess all estuaries in California. A key aspect of the EMPA Program and this study is a focus on ecological functions versus a single type of flora or fauna (

Table 2). This focus on function allows the framework to accommodate different estuary types and assimilate data from diverse existing monitoring programs, while maintaining underlying comparability. The Bight ‘23 Estuary Element will use this program and refine the indicators to assess the estuaries in the SCB and answer the study objectives.

Table 2. Priority estuarine ecological functions with a brief definition of each function.

Function	Definition
Nekton Habitat	Support for a variety of resident and transitory fishes and crustacean by creating structure that serves as shelter from predation and provides benthic or water column food sources.
Primary Production	Production of organic material from carbon input to the system that supports development of diverse microbial, algal, and macrophyte (plant) communities.
Secondary Production	Transformation of allochthonous and autochthonous organic matter into meiofauna and macrofauna, which in turn are consumed by the resident nekton of the estuary or are exported out to the nearshore coastal zone.
Protected Species Support	Provision of the appropriate subtidal, intertidal, and marsh habitat to support one or more life stages of species that are protected by federal, state, or local regulations. Includes physical structure and water quality conditions (salinity, oxygen, pH, etc.) to support these organisms.
Nutrient Cycling	Processing of nitrogen, phosphorous, and carbon from their elemental or detrital forms to support primary production by algae and vascular plants. Nutrient cycling is often high in estuaries because of high inputs, density/tidally driven estuarine circulation patterns, or geomorphology.
Sea Level Rise Amelioration and Resiliency	Capacity to absorb and protect adjacent uplands from increasing sea level 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 habitat growth and transgression.
Bird Habitat	Provision of physical and biological structure for resident and migratory birds to support predator evasion or nesting (via their associated wetlands) and abundant food (via high secondary and tertiary (nekton) productivity).
Shellfish Support	Provision of habitat for establishment and growth of shellfish. Estuaries are obligate habitats for a variety of societally, economically, and ecologically important shellfish species that rely on the basin morphology, mesohaline/oligohaline salinities, and large amounts of primary production only available in estuaries.
Nursery Habitat	Provision of habitat for spawning and nursery support for marine or anadromous species based on the structural complexity and high primary / secondary productivity found in estuaries.
Support of Vascular Plant Communities	Support of a diversity of fresh and salt tolerant plant species distributed throughout the system based on the complex geographic and temporal variability in water depth, sediment composition and elevation, salinity gradient and submergent condition.
Wildlife Support	Support for different life stages and access to movement corridors for a variety of marine- and land-based fauna that rely on estuaries to fulfil a portion of their life history need.

A targeted sampling design will be used to assess the study objectives. Sites were specifically chosen by the committee to ensure an equal representation of all estuarine archetypes (a group of wetlands that are similar in terms of form, function, and processes [small creek, lagoon, intermediate estuary, large river valley, fragmented river valley, bay]; SCWRP 2018) across the SCB, as well as to incorporate different estuaries with varying levels of management (question 5). 22 sites were chosen based on the level of committed effort and our ability to assess a representative sample of the SCB; 2 additional sites are under consideration (

Table 3, Figure 1, Appendix A. Sampling Maps). To answer all five questions, the bulk of sampling will occur in fall 2023 and either spring or fall 2024. Fall 2023 was chosen for the study because it represents the end of the growing season for most vascular plants, as well as the end of the critical breeding season for protected species. After fall sampling, indicators will be evaluated and a subset will be reassessed in 2024, allowing for adaptive refinement of the assessment framework (more schedule information below; Schedule).

A key component of this study is to conduct a holistic assessment of estuarine health at as many estuaries as possible within the SCB. To accomplish this effort, multiple indicators need to be assessed at multiple locations within each estuary. Within each estuary, a minimum of three sampling stations will be established. Differences in annual precipitation, watershed and coastal geology, and land use drive tremendous variability in estuarine conditions and functions. To capture seasonal and interannual variation among and within estuaries, sampling protocols will concentrate multiple measurements around sampling stations. Users will establish a number of permanent sampling zones within their sites to concentrate multiple sampling methods (i.e., cluster sampling) in a given area and have the ability to return to the area. This approach is favored over distributing measures more diffusely across the site, as concentrating multiple measures will enhance our ability to interpret data.

Table 3. List of estuarine sites for Bight '23. 22 sites with committed field effort and 2 potential sites (highlighted in red). * Indicates sites with partial field effort.

Sites	Field effort
Tijuana River estuary	TRNERR
San Diego Bay: South salt ponds	TRNERR
San Diego Bay: Sweetwater	TRNERR
Mission Bay: Kendall-Frost Reserve	USD/SDSU*
Los Penasquitos Lagoon	TRNERR
San Dieguito Lagoon	SONGS
San Elijo Lagoon	Nature Collective
Batiquitos Lagoon	EMPA
Agua Hedionda	Nature Collective*
Santa Margarita Estuary	
Aliso Creek	Laguna Ocean Foundation
Newport Bay	EMPA
Huntington Beach Wetlands	HBWC
Bolsa Chica	SCCWRP
Seal Beach	TBD*
Topanga Canyon	SCCWRP/CSULB
Malibu Lagoon	EMPA
Zuma Canyon	SCCWRP/CSULB
Point Mugu	SONGS/Naval Base Ventura County
Santa Clara River Estuary	TBD*
Ventura River	EMPA
Carpinteria Estuary	SONGS
Goleta Slough	EMPA
Devereux Slough	UCSB

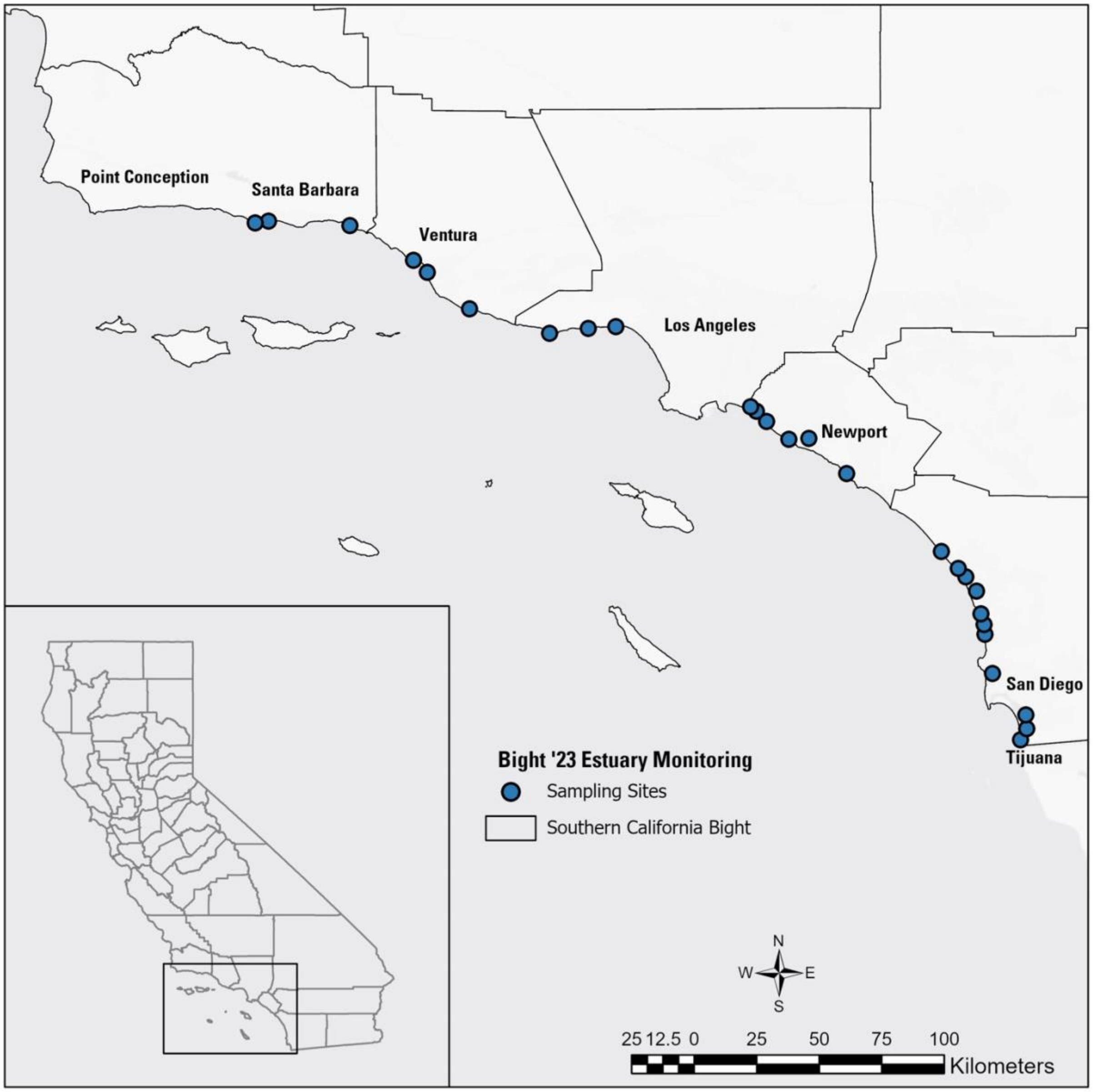

Figure 1. The 26 estuaries under consideration for Bight ’23 estuarine monitoring.

Indicators

The health and condition of biological communities in estuaries and coastal lagoons can be assessed using a combination of biotic and abiotic measures. Biotic measures of health include measurements of abundance, diversity, and richness for producers, such as plant communities and submerged aquatic vegetation (SAV), and consumers, such as benthic macroinvertebrates and fish. Abiotic factors, such as salinity, dissolved oxygen, and temperature, are important condition indicators because they can affect biological communities in a variety of ways. Organisms that rely on estuaries can be directly affected by water quality conditions or indirectly affected via changes in vegetation communities. Given the inherent variability and complexity of estuaries, ongoing monitoring of key indicators is essential for improving our understanding of the relationship between abiotic parameters and species and for detecting changes that may signal the need for management intervention.

Given the ecological and hydrological complexity of estuaries, there are a vast number of potential indicators one could use to evaluate the health and condition of estuaries. Eleven priority ecological functions of estuaries were identified by the EMPA Program. The underlying principle is that all estuaries should provide a variety of ecosystem functions in the absence of anthropogenic disturbance and alteration. Priority functions are a mix of true ecological functions (processes with limited direct society value) as well as ecosystem services (processes with direct, often commodifiable, society value;

Table 2). Each function can be evaluated by one or more indicators providing flexibility to use indicators appropriate for the specific estuary, while still allowing the standard set of functions to be evaluated. Using the EMPA indicators as a starting point, each indicator was considered and then linked to each study objective to ensure that each objective will be appropriately measured and answered (

Table 4).

Indicators were organized into three categories: abiotic, biotic, and landscape. Collecting measures of physical and landscape conditions with measurements of biological response at common sites allows investigators to identify and model associations between altered ecological conditions and environmental stresses. A description of each indicator is provided below.

Table 4. Indicators chosen to answer the five study questions.

Category	Indicators	Question				
		1. What is the relative condition of S. CA estuaries based on function-based assessment?	2. What sensitive fish and bird species are observed in the S. CA estuaries sampling?	3. What is the range of sea-level rise resiliency of estuaries in S. CA?	4. What is the relative risk of estuary condition to major stressors?	5. What is the relative condition of estuaries based on level of management ?
Abiotic	Water quality: climatic conditions	x	x		x	x
Abiotic	Water quality: turbidity and TSS	x		x	x	x
Abiotic	Water level	x		x	x	x
Abiotic	Sediment quality: contaminants	x	x		x	x
Abiotic	Sediment quality: sediment nutrients	x			x	x
Abiotic	Sediment quality: sediment grain size	x	x	x	x	x
Abiotic	Mouth and freshwater dynamics	x	x	x	x	x
Abiotic	Trash/ microplastics	x			x	x
Biotic	Benthic infauna	x	x			x
Biotic	Fish: general fish surveys	x	x			x
Biotic	Fish: targeted fish community	x	x		x (invasives)	x
Biotic	Vegetation	x	x	x	x (invasives)	x
Biotic	Macroalgae	x	x		x (invasives)	x
Biotic	Bird: general bird surveys	x	x			x
Biotic	Bird: targeted bird surveys	x	x			x

Category	Indicators	Question				
		1. What is the relative condition of S. CA estuaries based on function-based assessment?	2. What sensitive fish and bird species are observed in the S. CA estuaries sampling?	3. What is the range of sea-level rise resiliency of estuaries in S. CA?	4. What is the relative risk of estuary condition to major stressors?	5. What is the relative condition of estuaries based on level of management ?
Biotic	Invertebrates/ epifauna	x	x			x
Biotic	General community composition (eDNA)	x	x			x
Landscape	Sediment accretion	x		x		x
Landscape	Surface elevation	x		x		x
Landscape	Relative habitat composition/ Habitat type	x	X	x		x
Landscape	Physical disturbance	x	X	x	x	x
Landscape	CRAM	x		x	x	x

Abiotic Indicators

Abiotic indicators assess the physical characteristics and processes of the estuary.

Water quality

Climatic conditions

A series of loggers will be deployed at each estuary to identify the general water quality conditions. The archetype and mouth state of the estuary can influence abiotic conditions within the estuary; therefore, a multi-array of instruments will be used to capture conductivity (salinity), temperature, and dissolved oxygen. Depending on the availability of sensors, a subset of estuaries will capture pH, turbidity, and chlorophyll using specialized sensors. The number of sensors deployed within each estuary will depend on the size and the vertical gradient (stratification) of the estuary. The following criteria should be used to select the location for deployment of the instruments: logistics of instrument deployment; maintenance, safety and vandalism/theft; existing site where historical continuous data exist; area that characterizes the variability in water characteristics; and maximum depth to ensure that the instruments remain under water at low water levels. Priority consideration of site selection should be given to site with prior Bight '08 logger deployment[2]. By re-deploying loggers in Bight '08 locations, more in-depth trend analysis could be conducted. Sensor arrays should be deployed a minimum of 1 year to track seasonal and inlet changes across a full year.

Turbidity and Total Suspended Solids

Elevated turbidity can prevent the penetration of light into the water column, suppressing oxygen production by phytoplankton, altering trophic interactions, and hindering submerged aquatic vegetation (SAV) productivity. Turbidity can also act as a proxy for Total Suspended Solids (TSS). Due to the complexity and cost associated with acquiring accurate turbidity readings, there will be several options for assessing turbidity. Users can take a minimalist approach and use a Secchi disk to take point measurements of turbidity. Alternatively, more involved and expensive approaches can be used, such as using a turbidity collection field kit or calibrated sensors. At a subset of sites, samples will be collected for analysis of TSS. TSS and Secchi disk readings will be regressed to understand relationships between sediment load and turbidity. Method evaluation and comparison will allow us to make recommendations on methods for future long-term monitoring.

Water level

A key component to understanding how resilient an estuary will be to changing sea level is characterizing changes in local water level in conjunction with sediment dynamics (accretion, erosion) and marsh inundation. A Rugged Troll pressure transducer or a

[2] http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/711_B08EE.pdf

similar sensor (e.g., HOBO water level logger) will be deployed at a permanent location and elevation to track long term water elevation variability and periods of marsh inundation. The number of sensors deployed within each estuary will depend on the size of the estuary. Sensors should be deployed a minimum of 1 year to track seasonal, inlet, and elevational changes over time.

Sediment quality

Chemical analysis of sediment samples provides an assessment of contaminant exposure for bottom dwelling animals at each estuarine sampling location, as well as the potential for bioaccumulative pollutants to be present at multiple trophic levels in the overall estuarine ecosystem. The distribution of biota is also affected by other physical factors, such as grain size and the amount of organic matter present. These habitat indicators will be measured to distinguish the relative effects of natural and anthropogenic factors on biotic distribution. The protocols and methods used to assess sediment chemistry within estuaries will follow the methods in the Bight ’23 Sediment Quality Workplan, as feasible. Sample replication and analytes may differ between workplans. All sediment samples will be collected adjacent to one another.

Two types of sediment samples will be collected for sediment contaminants and sediment nutrients. The Bight ’23 Sediment Quality group will collect a subset of subtidal samples in estuaries. The Estuary Element will collect additional samples where necessary for analysis as funding allows. For each estuary, a target total of three subtidal and three intertidal sampling locations will be selected for sediment collection. Sufficient volumes of sediment will be collected at each location for potential analysis of sediment contaminants, toxicity, grainsize and nutrients.

Sediment contaminant and nutrient samples will be analyzed consistent with the Bight ’23 Sediment Quality Workplan. The chemical analyte list will include both inorganics and organics (

Table 5). The sediment nutrient analyte list includes Total Organic Carbon (TOC), Total Nitrogen (TN), ammonia, nitrate, and phosphate. Toxicity analysis tests will be selected to be consistent with the Bight ’23 Sediment Quality Workplan. Grainsize will also be measured.

Table 5. Chemical analyte list for analysis.

Constituent	Analytes
Trace Metals	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Lead Mercury Nickel Selenium Silver Zinc
PCB Congeners	PCB 8 PCB 18 PCB 28 PCB 37 PCB 44 PCB 49 PCB 52 PCB 66 PCB 70 PCB 74 PCB 77 PCB 81 PCB 87 PCB 99 PCB 101 PCB 105 PCB 110 PCB 114 PCB 118 PCB 119 PCB 123 PCB 126 PCB 128 PCB 138 PCB 149 PCB 151 PCB 153 PCB 156 PCB 157 PCB 158 PCB 167 PCB 168 PCB 169 PCB 170 PCB 177

Constituent	Analytes
	PCB 180 PCB 183 PCB 187 PCB 189 PCB 194 PCB 195 PCB 201 PCB 206
Chlorinated Hydrocarbons	4,4'-DDT 2,4'-DDT 4,4'-DDD 2,4'-DDD 4,4'-DDE 2,4'-DDE 4,4'-DDMU alpha-Chlordane gamma-Chlordane cis-nonachlor trans-nonachlor oxychlordane
Polycyclic Aromatic Hydrocarbons	1,6,7-Trimethylnaphthalene 1-Methylnapthalene 1-Methylphenanthrene 2,6-Dimethylnaphthalene 2-Methylnapthalene Acenaphthene Acenaphthylene Anthracene Benz[a]anthracene Benzo[a]pyrene Benzo[b]fluoranthene Benzo[e]pyrene Benzo[g,h,i]perylene Benzo[k]fluoranthene Biphenyl Chrysene Dibenz[a,h]anthracene Fluoranthene Fluorene Indeno[1,2,3-c,d]pyrene Naphthalene Perylene Phenanthrene Pyrene
PolyBrominated Diphenyl Ethers	BDE 17 BDE 28 BDE 47 BDE 49 BDE 66 BDE 85 BDE 99 BDE 100 BDE 138

Constituent	Analytes
	BDE 153 BDE 154 BDE 183 BDE 190
Pyrethroids	Bifenthrin Cyfluthrin (total) Cypermethrin (total) lambda-Cyhalothrin (total) cis-Permethrin Trans-Permethrin Deltamethrin Esfenvalerate
Neonicotinoids	acetamiprid clothianidin imidacloprid thiacloprid thiamethoxam
Tire Wear	6PPD-quinone
Per- and Polyfluorinated Substances (PFAS)	PFOS PFOA
Other	Total Organic Carbon Total Nitrogen Grain Size

Mouth and freshwater dynamics

Estuary types are typically defined by the duration and frequency of mouth condition (whether or not the estuary mouth is open to the ocean). The dynamic nature of an estuary's mouth can influence water quality, sediment transport, trophic interactions, nutrient cycling, and fish assemblages. The dynamic nature of the mouth should be evaluated across large temporal and spatial scales. To effectively document mouth closure events, a series of techniques will be used – in situ camera stations, in situ data loggers, and a combination of satellite and models (inlet tracker). Based on available effort, a variety of tasks will be implemented.

Mouth dynamics depend on oceanic conditions, as well as freshwater input. To fully understand the complex hydrodynamics in the estuaries, HOBO loggers or similar sensors will be installed at the main freshwater input in each estuary without existing freshwater gauges. Sensors should be deployed a minimum of 1 year to track seasonal and mouth changes over time.

Trash and microplastics

The amount of plastic, metal, and other debris in the estuary is a measure of human impact. Debris will be classified by type (e.g., plant material, plastic, and cans, etc.) and scored according to relative abundance within vegetation transect surveys across the marsh plain. Additionally, microplastic samples will be collected in conjunction with sediment and benthic infauna samples. For more detail on the marine debris assessment, please refer to the Bight '23 Trash Workplan.

Biotic Indicators

Biotic indicators assess and quantify the biological communities within the estuary. For all biotic indicators, historic survey data will be combined with Bight '23 data collection to begin to compile more in-depth temporal community assemblage information.

Benthic infauna

Benthic infauna (animals that live in the sediment) are an important part of the ocean food web. Because infauna generally reside in one location for most of their lives and can be chronically exposed to sediment contaminants, they are an excellent indicator of environmental quality. Both small and large benthic infauna will be quantified.

Samples for small benthic infaunal analysis will be collected following similar methods as the Bight '23 Sediment Quality Workplan. The Bight '23 Sediment Quality group will be collecting a subset of subtidal samples in estuaries. The Estuary Element will add additional samples where necessary. For each estuary, a total of three subtidal and three intertidal samples will be collected for small benthic infauna analysis.

Large benthic infauna will be assessed in the field using deeper (~30 in) sediment cores and sieved on a 3mm mesh screen. Animals will be identified and counted for each sample. Three cores will be taken in the intertidal and subtidal at each sampling zone within the estuary (18 samples per estuary).

Fish

The community assemblage of fish is a key indicator of ecological condition in estuaries. Understanding estuarine fish communities requires measures of fish density and species richness. Two types of fish surveys will be conducted: general and targeted fish surveys. General surveys will be conducted by seining at each sampling station within the estuary. Each fish will be identified to the lowest taxonomic unit, counted, and measured across its standard length. At a subset of sites, targeted surveys will be conducted for protection or priority (e.g., tidewater goby, California halibut, etc.). Targeted surveys will consist of more intensive seining, using block nets and enclosure traps to seine until completion. Ongoing efforts will be leveraged to complete targeted surveys, such as efforts conducted by CDFW and RCDSMM.

Vegetation

A key component to estuary health is the support of vascular plant communities. Vegetation surveys will be conducted using a standard approach to evaluate three important plant community parameters in tidal marshes: 1) plant species diversity, 2) community physical structure, and 3) the invasion of non-native species. The surveys will focus on estuarine wetland habitats including the backshore (i.e., upland transition zone), marsh plains, channel margins, tidal pannes and ponds, and foreshore (i.e., channel-ward transition zones from the marsh plain to open tidal mud flats). Transect survey methods will quantify percent cover and plant height within 1m^2 quadrats. To understand where plants exist in the tidal frame, the elevation of the start and end of each transect will be collected using a Real-time kinematic positioning (RTK) unit or similar.

At a subset of sites where *Spartina foliosa* (Pacific cordgrass) exists, transect surveys will be conducted within the cordgrass zone to quantify average cordgrass density and height. Cordgrass is an important habitat for the endangered bird species, Ridgeway’s rail (*Rallus obsoletus*). By quantifying cordgrass density, the relative condition of cordgrass habitat can be evaluated across estuaries.

Macroalgae

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 result in extensive blooms that can cover large expanses of intertidal and shallow subtidal habitat. Two macroalgae surveys will be conducted in two major habitat types: 1) intertidal (mud or sand) flats and 2) subtidal surface habitat. Intertidal flats are the unvegetated band of habitat found in the lower intertidal zone. In the intertidal, transect surveys will be conducted in conjunction with the vegetation transects to quantify the percent cover of macroalgae species within $1m^2$ quadrats. Methods will be similar to Bight '08 Eutrophication macroalgae transect methods[3]. When possible, transects will be placed in similar locations to Bight '08 Eutrophication surveys.

The subtidal surface habitat represents the algae in areas where algae is prolific on the surface of the water. The free-floating algae cover will be estimated in the subtidal by calculating the percent cover of algae within a specified zone. This method will provide a general estimate of the percent of the subtidal covered in algae.

Bird

An estuary in good condition should provide physical and biological structure for both resident and migratory birds to support predator evasion or nesting (via their associated wetlands) and abundant food (via high secondary and tertiary (nekton) productivity). To quantify the bird community, two types of bird surveys will be conducted: general and targeted bird surveys. General surveys will consist of the identification of bird species and overall bird counts within distinct habitat areas (e.g., mudflat, marshplain, shellfish reef, etc.). To complete these surveys, existing local efforts will be leveraged, such as local Audubon groups, iNaturalist, and community science efforts.

Targeted surveys will be conducted for the Ridgway's rail, California Least Tern, and Belding's Savannah Sparrow. Annual surveys for species are required by CDFW, and these efforts will be included in Bight 2023 efforts, specifically working in conjunction with CDFW, Point Blue, and Dick Zembal. Sites with existing Least Tern monitoring include Tijuana River Estuary, San Diego Bay, San Dieguito Lagoon, San Elijo Lagoon, Batiquitos Lagoon, Santa Margarita Estuary, Newport Bay, Huntington Beach Wetlands, Bolsa Chica, Seal Beach National Wildlife Refuge, Malibu Lagoon, Point Mugu, Santa Clara River Estuary, and Devereux Slough.

Invertebrates and epifauna

A healthy estuary should support a variety of invertebrate species. Several techniques will be used to assess the invertebrate community within the estuaries: benthic infauna samples (described above), trapping, and transect surveys. At each sampling station, multiple trapping methods will be used to assess the distribution, relative abundances, species richness, and diversity of crab, crustaceans, and small fish species. At every estuary, baited minnow traps will be deployed. If estuaries are deep enough, then shrimp pots will also be deployed. In conjunction with the vegetation transects, epifauna species will be identified and counted. Epifauna species are defined as the bottom-dwelling and mud-dwelling species, such as snails and crabs. This effort will not include terrestrial insects (bees, leafhoppers, scales). In each vegetation and macroalgae

[3] http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/711_B08EE.pdf

quadrat (surveys in both the marshplain and mudflat), the total abundance of each epifauna species will be recorded, as well as the number of crab burrows.

General community composition (eDNA)

Molecular methods are becoming increasingly popular in environmental monitoring and bioassessment applications. Environmental DNA (eDNA) metabarcoding can be used to estimate species richness within communities, similar to traditional methods. In conjunction with the other biotic indicators, water samples will be collected to better understand general community composition. Following similar methods as outlined in the Bight '23 Water Quality element, water column eDNA will be sampled by collecting ~950mL bottles of water at each estuary. If there is enough effort, specific samples can also be collected for targeted species eDNA metabarcoding.

Landscape Indicators

Landscape indicators evaluate the overall estuarine habitat. One major threat to marsh stability and function is the projected acceleration in the rate of sea-level rise. Indicators that can help assess overall marsh resilience to sea-level rise are important for informing coastal management strategies. A series of indicators will be included that can help understand tidal marsh trajectories, as laid out in Raposa et al. (2016) and Wasson et al. (2019). When data is available, the MARS (M**a**rsh Resilience to Sea-level **R**ise) indices will be used to address the relative risk of southern California estuaries to sea-level rise (question 3).

Sediment accretion

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. There are many techniques for measuring sediment accretion. At a minimum, feldspar plots will be installed to establish an effort of quantifying sediment accretion through time. At a subset of estuaries, existing surface elevation tables (SET) will be used to acquire more in-depth measurements of sediment accretion. If effort is available, installing SET stations at more Southern California estuaries should be a priority.

Surface elevation

Surface elevation is a critical structural component of low-lying coastal areas, where slight changes in elevation can mean the difference between extensive wetland habitats and open water. Therefore, maintaining elevation with relative sea level is critical to coastal wetland persistence. To track changes in surface elevation, baseline elevation data must be collected. Topographic surveys will be conducted at each estuary using RTK GPS units. If possible, surveys can be paired with and bolstered by existing SET data and digital elevation models (DEM).

Habitat composition and type

With changing oceanic conditions and sea-level rise, estuaries are expected to see shifts in habitat types and in the mosaic of the estuary. Using existing aerial imagery, maps of habitat composition and types will be constructed to understand how the landscape has changed through time. A key metric to understand when assessing resilience is the percent of the marsh that is in the lowest third of plant distribution. The higher the percent, the more at risk the marsh to sea-level rise (Raposa et al. 2016). Additionally, the relative area of vegetated marsh and unvegetated areas (UVVR) will be calculated from aerial imagery. A stable tidal marsh, with intact marsh plains and little deterioration tends to a UVVR ~ 0.1 (Ganju et al. 2017).

Physical disturbances

Estuaries are the receiving waters for the greater headwaters. This land-sea interface subjects estuaries to many physical disturbances. Using existing spatial data, such as percent urbanization and agriculture, the relative disturbance of each estuary will be quantified.

CRAM

The California Rapid Assessment Method (CRAM) is a tool for assessing the condition of wetlands and streams at scales ranging from individual projects to watersheds, regions, and statewide. CRAM, alone or with other assessment methods, can be used to assess current conditions, understand potential factors impacting wetland/stream condition, evaluate alternative project sites and designs, and assess project performance. At each estuary, CRAM surveys will be conducted at each sampling station. If CRAM surveys have been conducted within the last two years and there has been limited impact to the estuary, then CRAM surveys will not be repeated.

SCHEDULE

The bulk of sampling will occur in fall 2023. Some indicators are important to assess over a longer time period, e.g., climatic conditions, mouth dynamics. After fall 2023 sampling, biotic indicators and methods will be evaluated to determine which indicators should be repeated in fall 2024. A preliminary schedule is provided in

Table 6.

Table 6. Preliminary schedule for field effort for each indicator. All indicators will be evaluated in Fall 2023.

Category	Indicators	Summer 2023	Fall 2023	Winter 2024	Spring 2024	Summer 2024	Fall 2024	Desktop	Notes
Abiotic	Water quality: climatic conditions		x	x	x	x	x		Sensors
Abiotic	Water quality: turbidity and TSS		x	x	x	x	x		Seasonal sampling
Abiotic	Water level		x	x	x	x	x		Sensors
Abiotic	Sediment quality: contaminants	x	x						Bight ’23 Sediment Quality
Abiotic	Sediment quality: Sediment nutrients	x	x						Bight ’23 Sediment Quality
Abiotic	Sediment quality: Sediment grain size	x	x						Bight ’23 Sediment Quality
Abiotic	Mouth and freshwater dynamics		x	x	x	x	x		Seasonal sampling
Abiotic	Trash/microplastics		x						Bight ’23 Trash
Biotic	Benthic infauna	x	x						Bight ’23 Sediment Quality
Biotic	Fish: General fish surveys		x				TBD		
Biotic	Fish: Targeted fish community		x				TBD		
Biotic	Vegetation composition/biomass/cover		x				TBD		
Biotic	Macroalgae		x				TBD		
Biotic	Bird: General bird surveys		x				TBD		
Biotic	Bird: Targeted bird surveys	x	x		x	x	TBD		
Biotic	Invertebrates/ epifauna		x				TBD		
Biotic	General community composition (eDNA)		x				TBD		
Landscape	Sediment accretion		x	x	x	x	x		
Landscape	Surface elevation		x				x		
Landscape	Relative habitat composition/ Habitat type							x	
Landscape	Physical disturbance							x	
Landscape	CRAM		x				x	x	CRAM when possible

Effort Inventory

Committed Effort

The specified indicators are the ideal indicators for the assessment of all five study objectives. Based on the commitment of effort, some sites may not be evaluated for all indicators. The current effort inventory is listed in Table 7. The unfunded effort is listed in Appendix B. Unfunded Effort.

Table 7. The current field and analysis effort and funding for each indicator.

Indicator	Funded Field (by site)	Funded Analysis (by sample)
Water quality: climatic conditions	22/24	
Water quality: turbidity	22/24	0/288
Water quality: TSS	22/24	0/288
Water level	22/24	
Sediment quality: contaminants	22/24	22/124
Sediment: grainsize	22/24	0/124
Sediment quality: toxicity	22/24	50/124
Sediment quality: nutrients	22/24	18/124
Mouth dynamics	22/24	
Trash	22/24	
Microplastics	22/24	23/23
Benthic infauna	22/24	59/124
Fish: General fish surveys	22/24	
Fish: Targeted fish community	22/24	
Vegetation composition/biomass/cover	22/24	
Macroalgae	22/24	
Bird: General bird surveys	22/24	
Bird: Targeted bird surveys	22/24	
Invertebrates/epifauna	22/24	
General community composition (eDNA)	22/24	61/209
Sediment accretion	22/24	
Surface elevation	22/24	
Relative habitat composition/ Habitat type	22/24	
Physical disturbance	22/24	
CRAM	22/24	

Leveraged Effort

To help complete this work, several ongoing and upcoming efforts will be leveraged.

OPC EMPA 2023 Surveys

The California Estuarine Marine Protected Area (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. The Program includes the compilation and analysis of select, currently available data sets, a focused field data collection effort to fill data gaps through implementation of standard protocols (abiotic, biotic, habitat, and stressor parameters), quantification of the current benefits of MPA status, and the development of long-term monitoring and management recommendations to expand the benefits of EMPA designation and document changes through time. Through ongoing commitment to statewide monitoring, partners will be able to answer key questions about the efficacy of the estuarine MPA program (relative to non MPA sites), stressor management, and resilience to climate change. The EMPA website and data portal provides extensive details - https://empa.sccwrp.org/.

The EMPA Program will continue monitoring and refining the EMPA assessment framework in 2023. OPC has funded the Program to sample 15 estuaries in spring and fall of 2023. Five of the estuaries are within the SCB – Goleta Slough, Ventura River, Malibu Lagoon, Newport Bay, and Batiquitos Lagoon. Sampling efforts will overlap with the Bight '23 Estuary sites. All field efforts and sampling analysis will be covered by the EMPA Program.

Prop 50 Santa Monica Bay 2023-2024 Surveys

Santa Monica Bay (SMB) is a network of estuaries that provide a suite of functions and key aquatic habitats. The 2018 Comprehensive Conservation and Management Plan represents a framework to assess the extent, condition, vulnerability, and stress of these systems. To date, only large systems like Malibu Lagoon and Ballona Estuary have been evaluated. Little information is available for the smaller, intermittently open systems in SMB. A project led by California State University Long Beach and SCCWRP and funded by Prop 50 funds will fill this critical data gap and support wetland assessment under the CMP by evaluating habitat extent, condition/function and stress at several small estuaries in SMB using an assessment framework and protocols developed for the state's estuarine MPA program. SCCWRP and California State University, Long Beach will monitor and assess five estuaries within the SMB watershed using the EMPA assessment framework in spring and fall of 2023. Three of these sites will be Bight ’23 Estuary sites – Topanga Canyon, Malibu Lagoon, and Zuma Canyon.

Baja California 2023 Surveys

Coastal lagoons in the SCB have been highly altered from their historical state. In the past four years they have been threatened with an increase in flooding at high tide associated with sea-level rise and flooding events are expected to continue. The resulting changes in vegetation including the reduction of native cordgrass (*Spartina foliosa*) have contributed to the precipitous decline of the federally and State endangered light-footed Ridgway’s rail (rail), which relies heavily on tall emergent vegetation. However, there are two large coastal lagoons in Ensenada and San Quintín, Baja California, Mexico that have not been highly altered and remain relatively intact with little human modification and have shared species with the SCB. Due to resource constraints, large data gaps exist concerning the habitats of these two lagoons and their associated species and have not been assessed as intensively as those within the SCB. Filling these gaps will not only aid in the recovery of these and other species, but it will also provide invaluable information regarding protection and management of this habitat type for other regions.

A key goal of this project is to understand the relative condition of Baja California estuaries to Southern California estuaries. This comparison is important for three key reasons:

1) Connectivity – Even though coastal lagoons and estuaries are discrete ecosystems, they are connected. Ensenada and San Quintín are part of the Southern California Bight.
2) Spectrum of disturbance – Baja California lagoons have been less impacted and affected by anthropogenic disturbance, such as urbanization. Therefore, these estuaries have a greater area of pristine or intact habitat. We hypothesize that healthier and better condition lagoons may have more Ridgeway Rails.
3) Tropicalization – Since Baja California is further south than the Southern California lagoons, these estuaries will see and feel the effects of tropicalization (lower latitude species moving north) before Southern California. Therefore, these Baja California estuaries may act as the ‘canary in the coal mine’- a warning for what southern California may soon face.

Although these efforts are outside of the scope of the Bight ’23 Estuary workplan, the efforts being conducted in Baja California can be incorporated into final data analysis to further answer questions regarding relative condition.

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APPENDIX A. SAMPLING MAPS

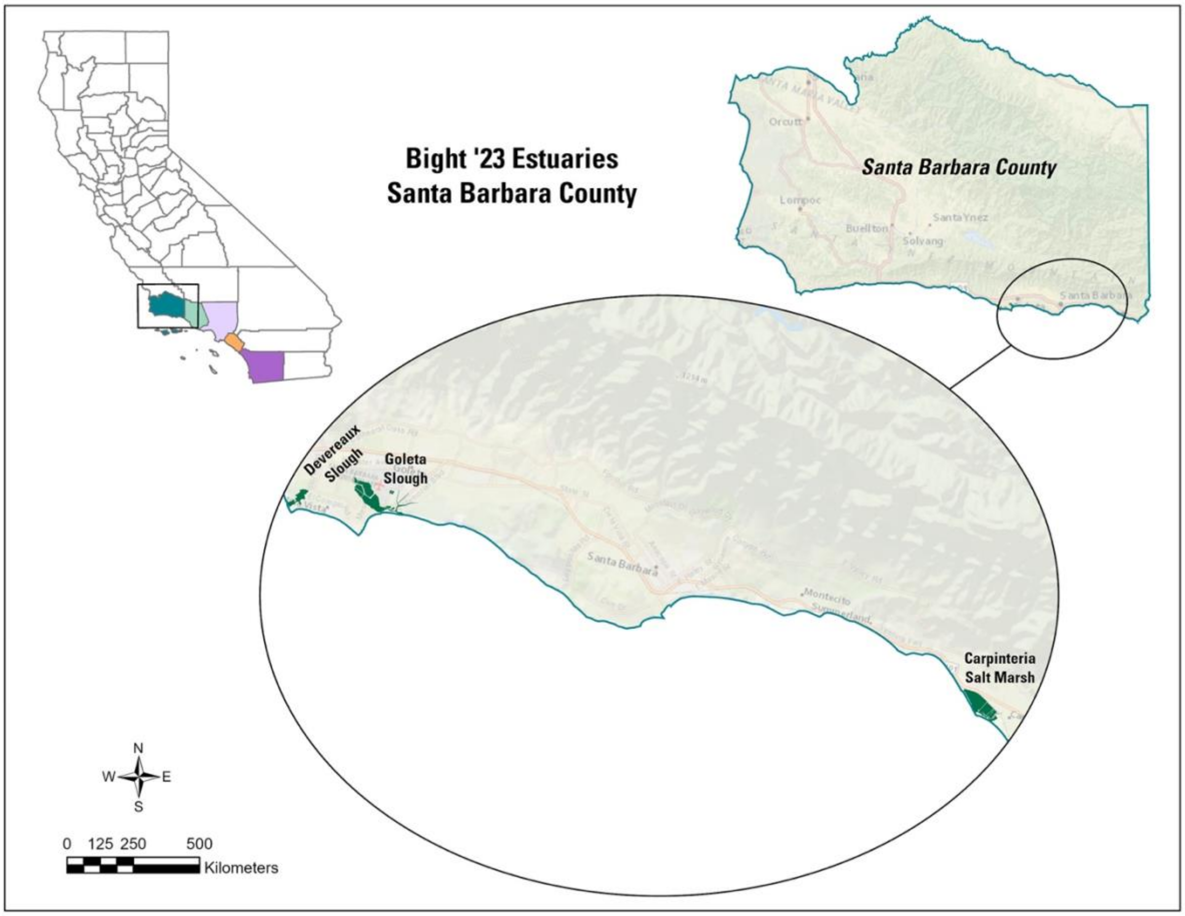

Figure A 1. Sampling sites in Santa Barbara County.

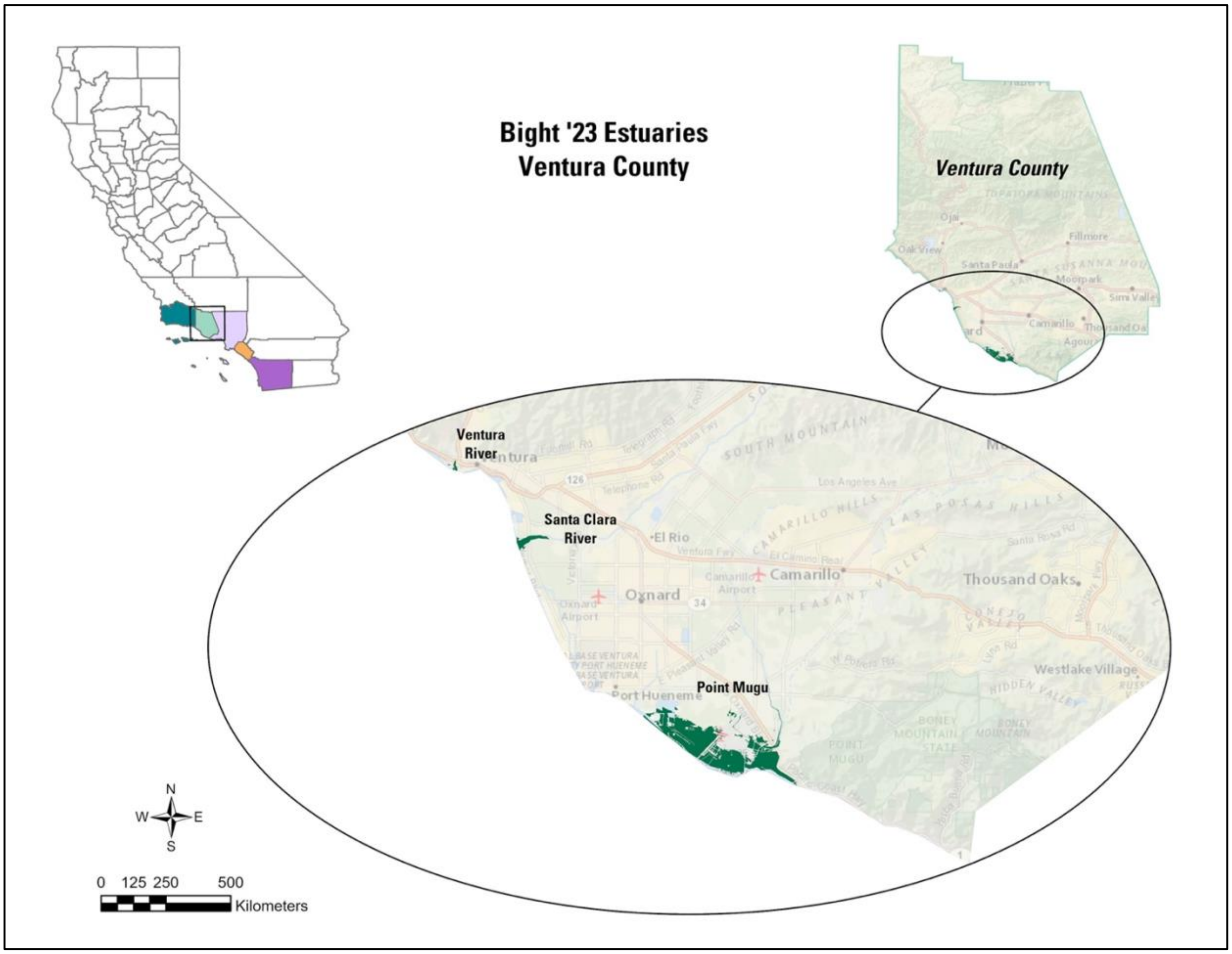

Figure A 2. Sampling sites in Ventura County.

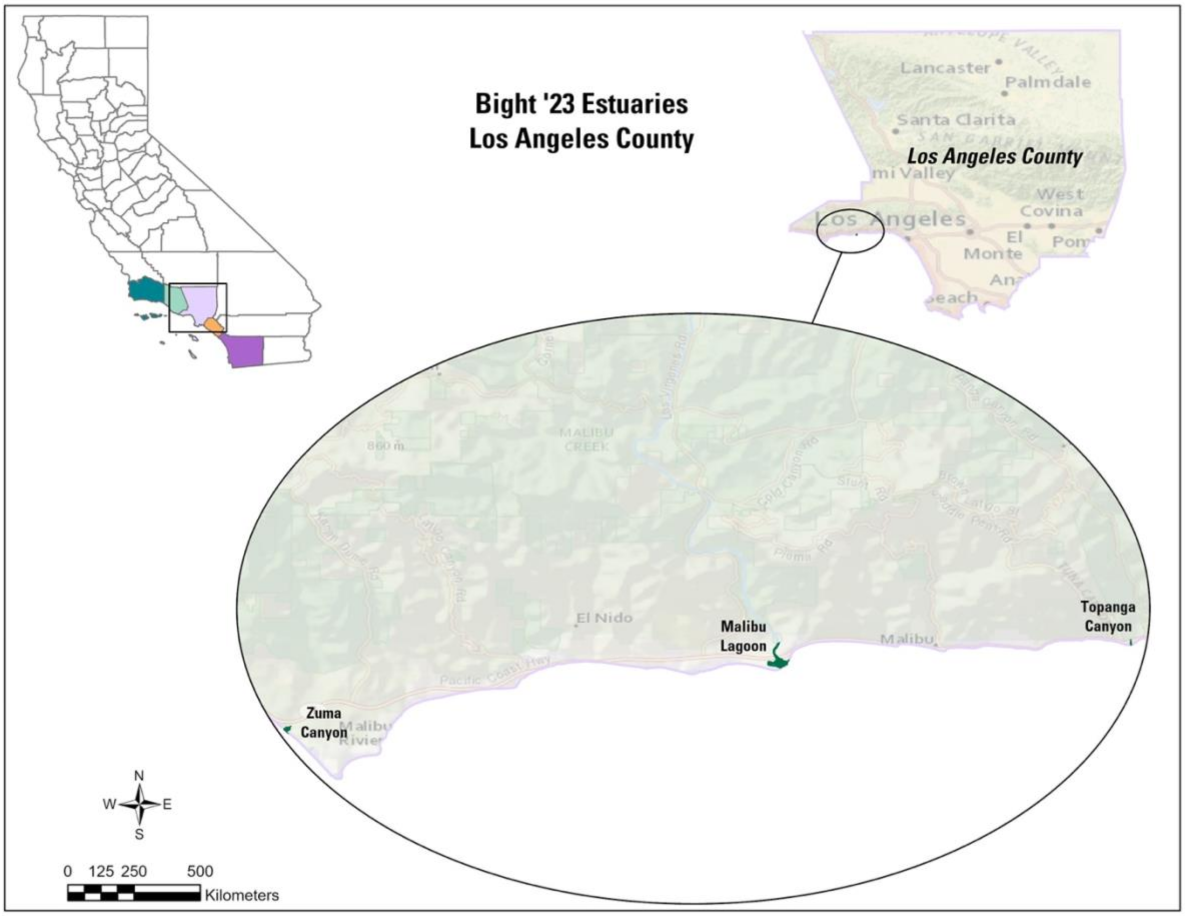

Figure A 3. Sampling sites in Los Angeles County.

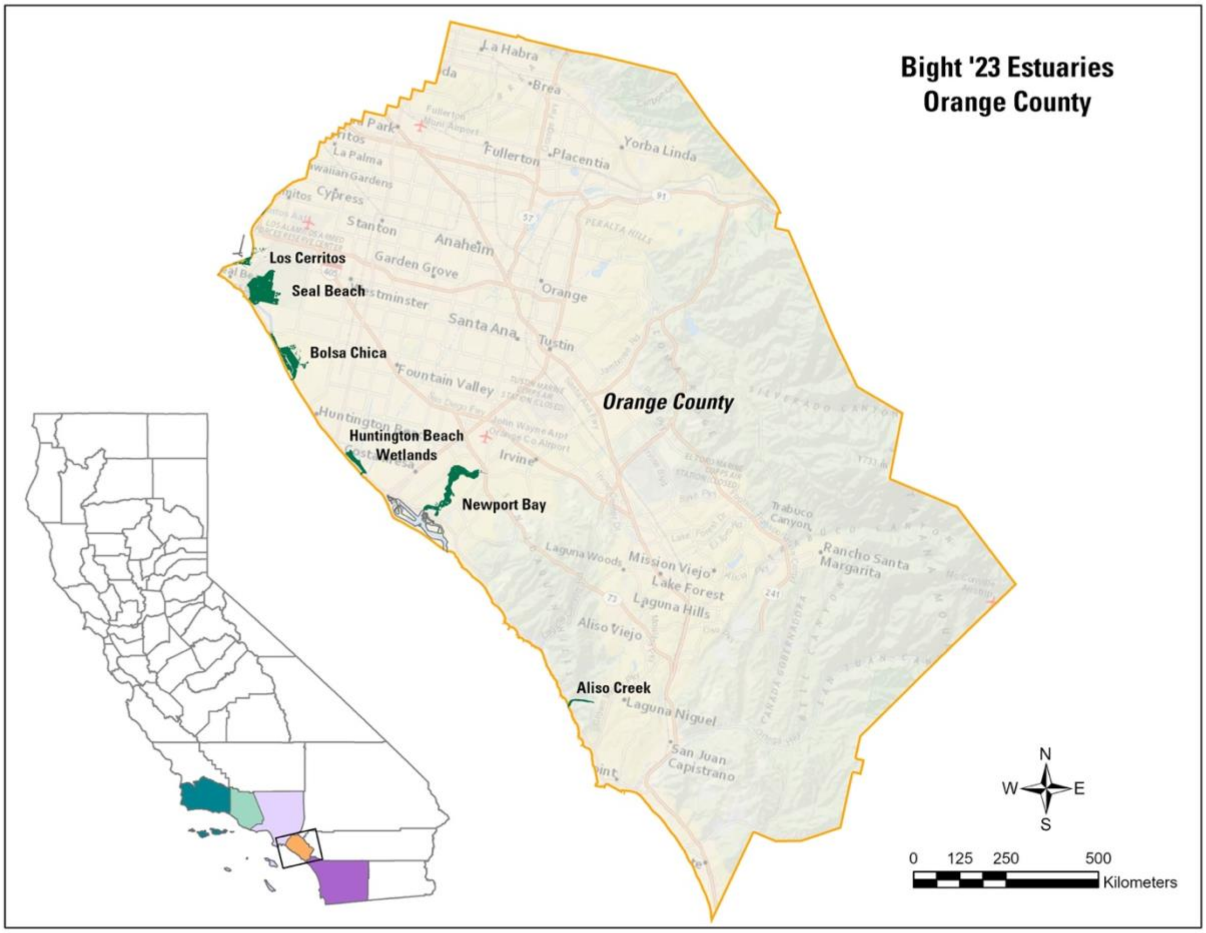

Figure A 4. Sampling sites in Orange County.

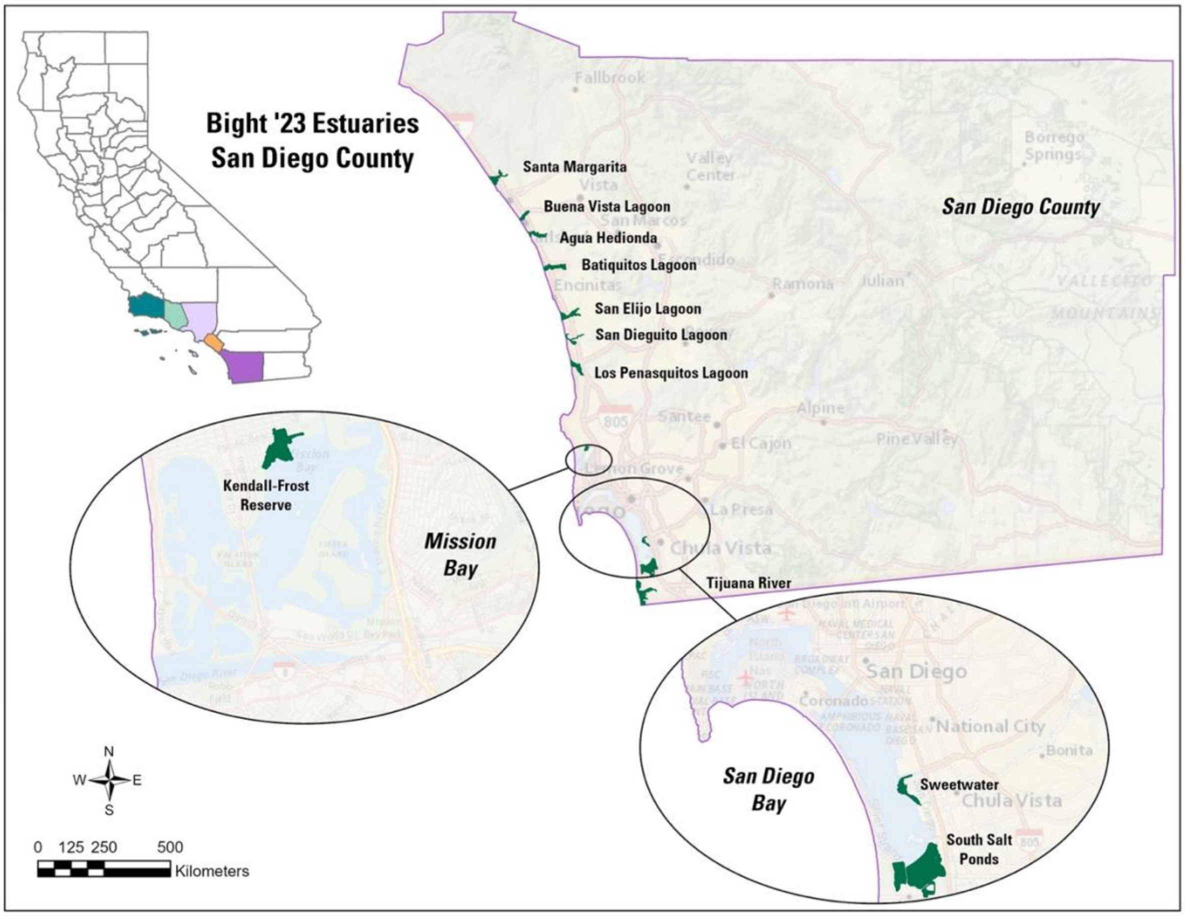

Figure A 5. Sampling sites in San Diego County.

Appendix B. Unfunded Effort

Below we outline the priority funding needs. There is no outstanding field effort needed for the Fall 2023 surveys. We have partial funding for laboratory analysis across different metrics. The Estuary Wetlands Planning Committee has prioritized funding for intertidal lab* samples over subtidal samples. We list the preference of metrics and the total number of samples unfunded below. Prices can be found in Table B 1.

1. **Sediment nutrients** - Chemical analysis of sediment samples provides an assessment of contaminant exposure for bottom dwelling animals at each estuarine sampling location, as well as the potential for bioaccumulative pollutants to be present at multiple trophic levels in the overall estuarine ecosystem. Sufficient volumes of sediment will be collected at each location for potential analysis of sediment contaminants, toxicity, grainsize and nutrients. The sediment nutrient analyte list includes Total Organic Carbon (TOC), Total Nitrogen (TN), ammonia, nitrate, and phosphate.
    a. *Intertidal – 44 samples unfunded
    b. Subtidal – 62 samples unfunded
2. **Sediment grainsize** – Since most estuaries will not have chemical analysis completed, separate grainsize analyses should be prioritized for each estuary
    a. *Intertidal – 62 samples unfunded
3. **Benthic infauna** - Because infauna generally reside in one location for most of their lives and can be chronically exposed to sediment contaminants, they are an excellent indicator of environmental quality. Benthic sediment cores will be collected.
    a. *Intertidal – 47 samples unfunded
    b. Subtidal – 18 samples unfunded
4. **eDNA samples** – Environmental DNA (eDNA) metabarcoding can be used to estimate species richness within communities, similar to traditional methods. In conjunction with the other biotic indicators, water samples will be collected to better understand general community composition of fish and macroinvertebrates.
    a. *148 samples unfunded
5. **Sediment contaminants -** The chemical analyte list will include both inorganics and organics, and will be selected to be consistent with the Bight ’23 Sediment Quality Workplan.
    a. *Intertidal – 62 samples unfunded
    b. Subtidal – 30 samples unfunded
6. **Sediment toxicity** - Toxicity analysis tests will be selected to be consistent with the Bight ’23 Sediment Quality Workplan.
    a. *Intertidal – 34 samples unfunded
    b. Subtidal – 30 samples unfunded
7. **Total suspended solids -** Elevated turbidity can prevent the penetration of light into the water column, suppressing oxygen production by phytoplankton, altering trophic interactions, and hindering submerged aquatic vegetation (SAV) productivity. Seasonal samples will be taken to assess TSS.

a. 288 unfunded samples

Table B 1 The price per sample for each analysis listed above.

Item	Medium	Price per sample
Nutrient chemistry	Sediment	$45 (per analyte)
General chemistry	Sediment	$175
Trace metal chemistry	Sediment	$214
CHC & PCB chemistry	Sediment	$204
PAH chemistry	Sediment	$204
Pyrethroid chemistry	Sediment	$204
PBDE chemistry	Sediment	$204
Benthic infauna analysis	Sediment	$875
eDNA – DNA extraction	Water	$50
eDNA – fish (12S sequencing)	Water	$150
eDNA – macrofauna (CO1 sequencing)	Water	$150
eDNA – targeted species (qPCR)	Water	$250
Toxicity - Eohaustorius	Sediment	$946
Toxicity - Mytilus	Sediment	$850
Toxicity - Ceriodaphnia	Sediment	$550
TOC/TON	Sediment	$63
TSS	Water	$145

Appendix C. Leveraged Studies

The Bight effort provides a template and a base for a wealth of sampling and monitoring. Some studies might choose to solicit additional funding to conduct complimentary studies during the Bight ’23 efforts. As the effort continues, leveraged studies will be added.